WORLD SMALL HYDROPOWER DEVELOPMENT REPORT 2013

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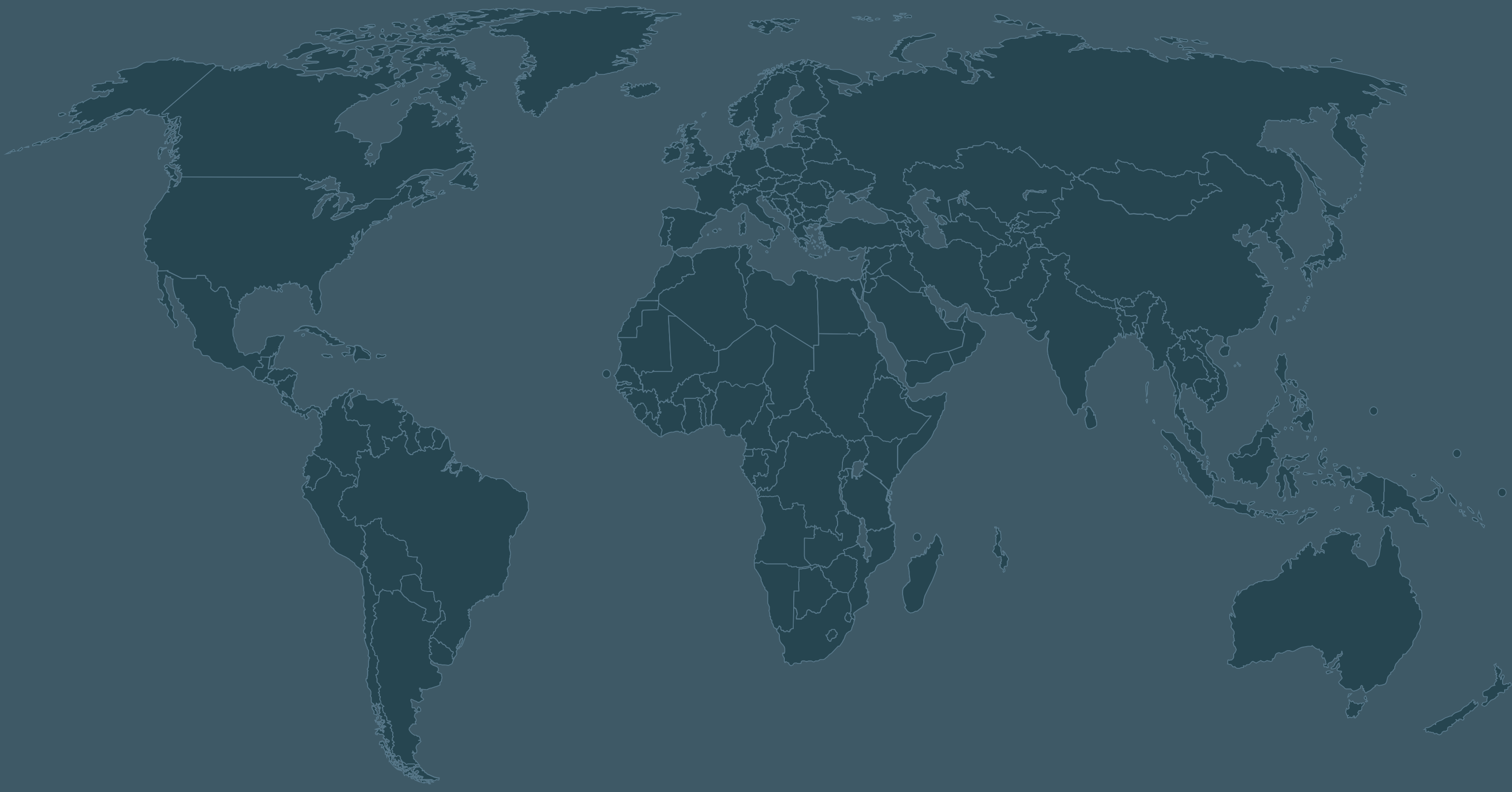

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World Small Hydropower Development Report 2013

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Foreword

CHEN Lei
Minister of Water Resources, People's Republic of China and Honorary Chairman, INSHP

Hydropower, as the largest clean and renewable energy source, has played an essential role in the global energy mix. Against the backdrop of rapid social-economic development and global warming, the development of renewable energy has gained increased attention among the global community. The manifold benefits of small hydropower - the relatively low investment capital, small engineering work, simplistic maintenance and operation, minimal environmental impacts, suitability for scattered development in rural and remote areas - have attracted special attention from the global community. Small hydropower has seen rapid development in many countries, making important contribution to meeting daily electricity demand, reducing poverty and advancing socio-economic improvement.

The Chinese Government attaches top priority to the development and utilization of hydropower as well as other renewable energy sources. After many years of efforts, China has an installed hydropower capacity of 249 GW, ranked first in the world. Among which, small hydropower is significant, with 45,000 stations nationwide and 65 GW installed capacity and an annual output of, accounting for 27 per cent and 25 per cent of the nation's hydropower installed capacity and electricity output respectively. In particular, several national programmes have been implemented in recent years, such as the Small Hydropower Replacing Fuel Wood Program, New Rural Hydropower Electrification Program and the Capacity Expansion and Efficiency Improvement of Rural Hydropower Program. As a result, electricity has been provided to those people who have no access to electricity, the wellbeing of the rural residents has been improved, the local environment has been protected and rural economic progress has been promoted. Significant contribution has been made to energy saving, emission reduction and energy security. Half of the world's small hydropower installed capacities are located in China. The country has accumulated abundant experiences in small hydropower equipment manufacturing, planning and design, technology development, operation and management as well as enabling policy framework. China's successful approaches in small hydropower development have been applauded by international organizations such as the United Nations, and attracted the attention from the international community, all of which paved the way for the establishment of the first China-based international organization – the International Network on Small Hydro Power (INSHP).

In different parts of the world, the availability of water resources, socio-economic conditions, small hydropower technology sophistication and management standard vary greatly from country to country. Developed countries boast of advanced small hydropower technologies and up-to-date equipment as well as managerial expertise, accumulating rich experiences in constructing environment- friendly hydropower projects, which are of great reference value to developing countries. In the process of socio-economic development, developing countries have urgent need for energy and electricity. Blessed with huge hydro potentials yet hindered by low level of development, developing countries still face a huge gap in terms of hydropower technology and equipment manufacturing. Therefore, it is important and imperative to regularly publish reliable official information on small hydropower development worldwide and promote modern concepts, updated technologies and latest approaches and experiences about small hydropower, in order to create opportunities for bilateral and multilateral cooperation, while highlighting it as a green and clean renewable energy to serve world development.

As the hosting country of INSHP, the Chinese Government actively supports initiatives by the INSHP and International Center on Small Hydro Power (ICSHP) to work closely with other international organizations, including United Nations Industrial Development Organization (UNIDO), and independent experts and scholars, with a view of promoting the worldwide development of small hydropower. After a three-year effort, under the auspices of INSHP and UNIDO, the compilation of the world's baseline data on small hydropower from 152 countries, territories and regions has finally been completed and contained in the *World Small Hydropower Development Report 2013 (WSHPDR 2013)*, with contributions from over 60 experts worldwide. The *WSHPDR 2013* began with a global vision of small hydropower development, providing regional and international institutions as well as countries concerned with baseline information and strategic outlook on renewable energy planning and integrated water resources management. With the *WSHPDR 2013*, the experiences and lessons of small hydropower development could be shared among countries and more opportunities provided for the technical innovation, technology transfer and expertise services in those untapped small hydropower markets.

The Chinese Government welcomes the in-depth exchange and practical cooperation in small hydropower development with the rest of the world. Meanwhile, I sincerely hope that the publishing of *WSHPDR 2013* serves to build a global knowledge platform on small hydropower; one that will play an active role in expanding cooperation and exchange among countries around the world in the development, management, technology, marketing, investment and finance of small hydropower; one that will expedite the sound development of small hydropower and contribute to the creation of a beautiful life for humankind.

CHEN Lei
Minister of Water Resources
People's Republic of China
Honorary Chairman
International Network on Small Hydro Power

Foreword

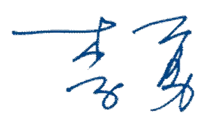
LI Yong
Director General, UNIDO

Since the industrial revolution and the introduction of steam power, energy has been at the forefront of boosting industrialization and economic growth. The availability of fossil fuels led to increased production, employment and technological innovation, which improved living standards around the world. Environmental challenges, energy security, and volatile fuel prices associated with conventional fossil fuels, have shifted the focus to renewable energies as a basis for low-carbon and sustainable development. Access to reliable low-cost energy based on locally available renewable resources for productive use is a pre-condition for industrial competitiveness, increased productivity, job creation, and income generation, which provide opportunities for social incluđion. Renewable energies are also key success factors in reducing the environmental footprint (e.g. CO2-emissions per unit of output) of industrial production.

Small hydropower is one of the most suitable renewable energy solutions for productive use and rural electrification. Small hydropower is a mature technology that can be easily constructed, operated and maintained locally. A great share of the small hydropower value chain benefits local economies. It has the lowest electricity generation prices of all off-grid technologies, and has the flexibility to be adapted to various geographical and infrastructural circumstances. Increased small hydropower development will showcase the use of renewable energy in industries, and small and micro enterprises, being an ideal technology option to mainstream renewable energy use to improve productivity, boost industrialization and reduce geographic inequality in industrial production.

As a leading United Nation agency in the provision of renewable energy solutions for inclusive sustainable development, UNIDO is collaborating with the International Center on Small Hydro Power (ICSHP), based in China, to develop a small hydropower knowledge platform www.smallhydroworld.org and to publish the *World Small Hydropower Development Report 2013*. This flagship initiative of UNIDO is a world-first compilation of global small hydropower data, and will be a crucial policy and investment guide for renewable energy provision through small hydropower. It aims at identifying the world's small hydropower development status and its potential in different countries and regions by engaging with stakeholders to share information. The initiative reinforces UNIDO's continuous commitment to accelerating sustainable development and enhancing productive capacities.

To date, much of the world's small hydropower potential remains untapped. The first step to promote small hydropower is through dissemination of reliable data for policy development and energy planning, as well as though guiding investors in entering renewable energy markets. UNIDO and ICSHP are proud to facilitate this collective effort based on the contribution of more than 60 different authors and organizations from all over the world. We would like to thank all contributing authors and organizations for their work. We are proud to jointly promote small hydropower development for productive use and sustainable industrialization further, and invite interested organizations and experts to participate. UNIDO will continue to play a special role in promoting a system of international dialogue and engaging small hydropower stakeholders from across the world to make this initiative a hub for all small hydropower related information.



LI Yong
Director General
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The *World Small Hydropower Development Report 2013 (WSHPDR 2013)* benefited from the support of many organizations, international experts and individuals, especially Arun Kumar and Wim Jonker Klunne. This publication wouldnot have been possible without their support and contribution from around the world.

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Technical notes and abbreviations

Within the *World Small Hydropower Development Report 2013 (WSHPDR 2013)* small hydropower is defined as plants with a capacity of up to 10 MW per plant. This definition is also used for summary statistics at the regional level. On country level, the national definitions apply while, where possible, capacities and potentials up to 10 MW are also given. The term 'small hydropower' in this Report has a different meaning from country to country.

The information on small hydropower potential presented has been derived from various sources, often it was not clear from sources if gross, technical or economical potential was considered. Furthermore, not all of the countries have identified their small hydropower potential, in the case where data on small hydropower potential were not available, planned small hydropower potential was reported instead.

The *WSHPDR 2013* adheres to the geographical region and composition defined by the United Nations Statistics Division. Melanesia, Micronesia and Polynesia do not contain many countries or territories that use small hydropower, therefore were combined under the regional heading of 'Pacific Island Countries and Territories (PICTs)'. This report was compiled for both 'countries' and 'territories'. Overseas territories have been included in the continent where they are geographically located in following the online M49 list of the United Nations Statistic Division. Countries that are not part of the United Nations were not considered in this report. For more details and a full list of countries or territories according to the UN regions, see http://unstats.un.org/unsd/methods/m49/m49regin.htm.

The graphs on electricity in each report provide the percentage of electricity generated by its source or type. As detailed information from each country varies, the terminology was adapted from the respective source and the most recent available information was used.

Not all countries that possess potential or installed small hydropower enacted legislation on small hydropower. In cases where no legislation or no information were provided by the author, the section on Legislation on Small Hydropower was omitted intentionally.

The information on small hydropower potential presented has been derived from various sources, often it was not clear from sources if gross, technical or economical potential was considered. Furthermore, not all of the countries have identified their small hydropower potential, in the case where data on small hydropower potential were not available, planned small hydropower potential was reported instead.

References to dollars ($) are to US dollars, unless otherwise indicated. Where other currencies were used, an approximate US dollar value was provided.

The *WSHPDR 2013* includes information on small hydropower of 152 countries/territories, however detailed reports are available for only 149 countries.

Please note that information presented was true up to end of December 2012, if not otherwise indicated.

ADB	Asian Development Bank
AfDB	African Development Bank
CER	Certified Emission Reduction
CDM	Clean Development Mechanism
CSP	Concentrated solar power
EBRD	European Bank for Reconstruction and Development
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
ESHA	European Small Hydropower Association
FIT	Feed-in tariff
GEF	Global Environment Facility
GIZ	Gesellschaft für Internationale Zusammenarbeit
GTZ	German Technical Cooperation Agency
IEA	International Energy Agency
IRENA	International Renewable Energy Agency

JICA	Japan International Cooperation Agency
NEP	National Energy Policy
NREAP	National Renewable Energy Action Plan
OLADE	Latin American Energy Organization (Organización Latinoamericana de Energía)
PICTS	Pacific Island Countries and Territories
PPA	Power Purchase Agreement
PPP	Public Private Partnership
RE	Renewable energy
RET	Renewable energy technology
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax
WFD	Water Framework Directive

Technical abbreviations

Hz	Hertz
kW	Kilowatt
kWh	Kilowatt hour
GWh	Gigawatt hour
l/s	liter/second
MVA	Mega Volt Ampere
MW	Megawatt
Rpm	Rate per minute
m^3/s	Cubic meter per second
kWp	Kilowatt peak
CO_2	Carbon dioxide

Contributing organizations

(inter alia, non-exhaustive list)

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Executive Summary

Comprehensive information regarding global small hydropower potential and development has not been available so far. For many years, information on small hydropower has had to be sourced at the local or regional level, with a great variety in depth, availability and reliability of data, even lacking a universal small hydropower definition. A comprehensive reference publication for decision makers, stakeholders and potential investors is clearly needed to more effectively promote small hydropower as a renewable and rural energy source for sustainable development and to overcome the existing development barriers. This, the first *World Small Hydropower Development Report 2013 (WSHPDR 2013)* aims to identify the development status and resource potential of different countries, territories and regions in the world by engaging with experts and those working at the ground level to compile and share existing information, experiences and challenges in one comprehensive report.

Energy is one of the most critical economic, environmental and sustainable development issues concerning people worldwide. According to the *World Energy Outlook 2012*, 1.3 billion people still lack the access to electricity while 2.7 billion must rely solely on traditional biomass to meet their energy needs. The United Nations estimated that among those with access to electricity, 1 billion people have poor quality electricity or can only obtain it intermittently from unreliable grid networks. Electrification is an important prerequisite of development, yet the fact remains that hundreds of millions remain trapped in a cycle of energy poverty. Albeit inefficient, many resort to traditional sources of energy, while their production and utilization have been shown to be detrimental to health and the environment.

Small hydropower is a well-developed small-scale renewable energy technology, which can contribute to the improvement of electricity access in rural areas and be part of the solution for socially inclusive sustainable industrial development as per the mandate of the United Nations Industrial Development Organization (UNIDO). One of the main challenges of implementing hydropower is capital cost. However, this disadvantage is weighed against the long term as small hydropower is a locally available renewable energy resource that can be used for electrification both on- and off-grid in a clean, efficient and secure manner. It has a high tariff payback ratio while serving to mobilize financial resources locally. Such economic benefits may contribute to the long term socio-economic development of populations that are small in group, dispersed and geographically isolated, combating their vulnerable status with autonomous electricity generation and a resilient micro grid network.

Many countries including several small island states rely on diesel for electricity generation. Soon they will be impacted by increasing petroleum prices and growing trade deficits. The switch to renewable energy, including small hydropower, may provide greater energy independence and economic stability, as well as contributing to climate change mitigation. Even in countries that are fully electrified, small hydropower may contribute to achieve renewable energy targets, energy diversification and energy independence.

Overview of small hydropower worldwide

Currently, small hydropower plants with a capacity of 10 MW, exist in 148 countries or territories worldwide. Four other countries have been identified with resource potential.

The findings of *WSHPDR 2013* show that small hydropower potential globally is approximated at almost 173 GW. The figure is arrived by totalling data from a wide range of sources with potential compromise of data integrity to varying degrees. For example, research data on economically feasible potential were more readily available in developed countries than those in the least developed or developing countries. More than half of the world's known hydropower potential is located in Asia, around one third can be found in Europe and the Americas. It is possible in the future that more small hydropower potential might be identified both on the African and American continents. The installed small hydropower capacity (up to 10 MW) is estimated to be 75 GW in 2011/2012.

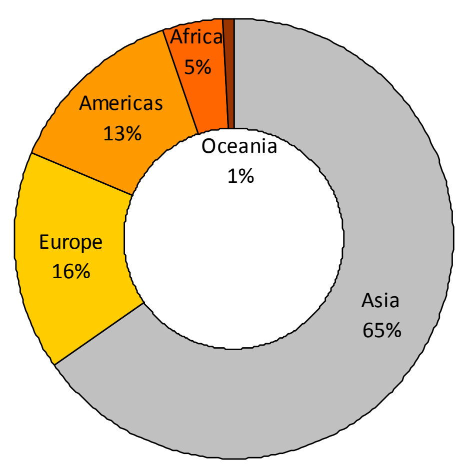

Figure 1 **Global distribution of small hydropower resource potential up to a capacity of 10 MW**

Africa

Box 1
Countries and territories with small hydropower in Africa

Eastern Africa	Northern Africa
Burundi	Algeria
Ethiopia	Egypt
Kenya	Morocco
Madagascar	Sudan
Malawi	Tunisia
Mauritius	
Mozambique	**Western Africa**
Réunion	Benin
Rwanda	Burkina Faso
South Sudan*	Côte d'Ivoire
Uganda	Ghana*
United Republic of Tanzania	Guinea
Zambia	Liberia
Zimbabwe	Mali
	Niger*
Middle Africa	Nigeria
Angola	Sierra Leone
Cameroon	Togo
Central African Republic	
Democratic Republic of the Congo	**Southern Africa**
São Tomé and Príncipe	Lesotho
	Namibia
*** potential only**	South Africa
	Swaziland

Eastern Africa

Thirteen of the twenty countries in Eastern Africa use small hydropower to supplement their existing electrification efforts. Eastern Africa has an estimated small hydropower potential of 6,262 MW (up to 10 MW), of which 209 MW has been developed. Among these, countries with the highest potential are Kenya (3,000 MW), Ethiopia (1,500 MW) and Mozambique (1,000 MW). Most of the other countries do not have an official small hydropower definition, and Mozambique defines it as up to 15 MW.

Most of the countries in Eastern Africa have national energy policies (e.g. Malawi, Rwanda) or rural electrification policies (e.g. Madagascar, Tanzania) in place to support the use of renewable energy. In Uganda, the renewable energy policy has a target that includes mini- and micro-hydropower and value-added tax exemption for hydropower investors. Micro hydropower and isolated mini-grids are explicitly mentioned in the national energy policy of Rwanda. Kenya possesses a revised feed-in tariff (FIT) policy for small hydropower. Several countries such as Madagascar, Mauritius, Rwanda and Réunion already use FITs. Rwanda also uses other forms of incentives such as tax exemption and direct subsidies. Both Ethiopia and Zambia are preparing to introduce renewable energy FITs.

Barriers to small hydropower development are manifold, ranging from lack of hydrological data in Burundi, Réunion and Tanzania, to inadequate awareness of small hydropower in Tanzania. Some data need to be updated, such as Burundi's small hydropower master plan and Malawi's resource potential due to environmental degradation. Difficult site access due to lacking road infrastructure in remote areas pose barriers in Mauritius, Madagascar and Zambia, as these barriers mean higher transport costs while energy consumers either live far away from the power generation sites or have low income (e.g. Rwanda). Another barrier is the lack of investment from foreign investors, private companies. Banks in particular, are reluctant to lend the start-up capital upfront. In addition, human resource capacity, especially technical know-how, needs to be improved in view of the poor maintenance and management of small hydropower plants i.e. in Kenyan communities. South Sudan's meteorological and hydrological data collection network were destroyed post-conflict, water resources management also does not receive priority, on top of that there is a lack of technical capacity.

Water is a very scarce resource in both Ethiopia and Mauritius. Effects of climate change, deforestation and degradation of water in catchment areas were reported for in Kenya and Malawi. Seasonal fluctuation of water flow in Mauritius and climatic variations in Réunion pose challenges and concerns to small hydropower development.

Middle Africa

Five out of nine countries in Middle Africa use small hydropower to some degree or have the potential to do so. Middle Africa has an estimated small hydropower potential of about 328 MW (for plants up to 10 MW), of which 76 MW has been developed. It should be noted that none of the countries have had their full small hydropower resources assessed and the estimated potential is based on individual, probably non-comprehensive country lists of sites that may be inaccurate or out of date at the time of this writing.

No specific renewable energy policy exists in any of the Middle African countries mentioned. Legislation for renewable energy sector in Angola is underway and small hydropower endorsement can be found in poverty reduction and rural electrification strategies. In Cameroon, the development objectives up till 2035 include renewable energy for economic development. The energy policy of the Central African Republic favours renewable energy and energy diversification. It aims to reduce poverty based on expanded rural electrification, building micro-hydropower plants and electrifying villages using photovoltaic systems and biomass energy.

Financial and administrative barriers as well as difficulty of access to technology were reported in Cameroon. However, a comprehensive barrier analysis is needed for the whole region.

Northern Africa

Five out of seven countries in Northern Africa use small hydropower as part of their electrification grid. Northern Africa has an estimated small hydropower potential of about 184 MW (for plants up to 10 MW), of which 155 MW has been developed. There has been little interest in assessing and harnessing small hydropower as energy source due to the region's characteristics such as its arid climate, desert landscape, very high solar reception and a high electrification rate of up to 99 per cent. Drought in Morocco and water scarcity and over-exploitation of groundwater resources in Tunisia are issues of concern.

Energy subsidies and the lack of suitable hydro sites further hinder small hydropower development in Egypt. Public awareness on the benefits of small hydropower is low in Sudan. Furthermore, a clear policy is lacking and institutional capacity is low.

Southern Africa

Four out of the five countries in Southern Africa use small hydropower. Southern Africa has an estimated small hydropower potential of about 383.5 MW (for plants up to 10 MW), of which 43 MW has been developed. In South Africa, a governmental programme supports only hydropower up to a capacity of 10 MW. Lesotho defines small hydropower with a capacity of up to 15 MW. The other two countries, Namibia and Swaziland, do not have their own official definition of small hydropower.

South Africa has a renewable energy policy. In Lesotho, rural electrification is used to increase electricity access while renewable energy is used to replace fossil fuel use. Namibia, South Africa and Swaziland have programmes and action plans in place to support renewable energy.

Known barriers, range from difficulty in accessing sites to the lack of equipment spare parts (e.g. Lesotho) and the lack of knowledge on plants that need refurbishment (e.g. Swaziland). Namibia's desert climate is not suitable for hydropower development. A comprehensive barrier analysis is still needed for the region.

Western Africa

Nine out of the seventeen countries in Western Africa use small hydropower. Western Africa has an estimated small hydropower potential of about 742.5 MW (for plants up to 10 MW), of which 82 MW has been developed. The countries with the highest known potential are Togo (144 MW) and Burkina Faso (139 MW). It should be noted that not all countries have small hydropower potential due to unsuitable climate and topography.

Until recently, most of the countries in Western Africa did not have renewable energy policy. Electricity access is still a major issue, thus Ghana, Nigeria and Liberia are all in the process of establishing rural electrification agencies. Ghana has a renewable energy law and is about to announce its FIT for small hydropower. Nigeria has a renewable energy master plan (at the time of writing it is in its final draft) and a trust fund to support renewable technologies including small hydropower. Mali has a national renewable energy strategy and takes part in the Scaling-Up Renewable Energy Program in Low Income Countries (SREP) by the African Development Bank. It has an investment plan which integrates the main principles of the Growth and Poverty Reduction Strategy and the National Climate Change Strategy. The establishments of the UNIDO-Regional Center for Small Hydropower in Nigeria and the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in Cape Verde are key steps to support the up-scaling of small hydropower and renewable energy in the region through technical trainings, information exchange and identifying financing mechanisms.

Lack of hydrological data in the countries mentioned makes it difficult to give a comprehensive and updated summary. To date, inventories established decades ago have not been updated. Resource assessments in the 1970s to 1990s were conducted by foreign consultants; therefore, regional expertise in hydro resource assessments is relatively poor. Financial barriers include little or no incentives to attract investors to small hydropower projects and inadequate financing of civil engineering works. To varying degrees, there is limited technical expertise for equipment manufacturing, construction, operation and maintenance. There is need to improve institutional, regulatory and legal frameworks for the development and use of renewable energy sources including small hydropower. Some climatic factors also limit the suitability of small hydropower development, such as irregular or seasonal rainfall, low flow and drying up of rivers and in some countries a highly variable and arid climate.

Americas

Box 2
Countries and territories with small hydropower in the Americas

Caribbean	South America
Cuba	Argentina
Dominican Republic	Bolivia (Plurinational State of)
Guadeloupe	Brazil
Haiti	Chile
Jamaica	Colombia
Puerto Rico	Ecuador
Dominica	French Guiana
Saint Lucia	Peru
Grenada*	Uruguay
Saint Vincent and the Grenadines	
	Northern America
Central America	Canada
Belize	Greenland
Costa Rica	United States of America
El Salvador	
Guatemala	
Honduras	
Mexico	
Nicaragua	* potential only
Panama	

Latin America and the Caribbean

Caribbean

Nine out of the twenty-eight countries or territories, use small hydropower. The Caribbean has an estimated small hydropower potential of about 252 MW (for plants up to 10 MW), of which 124 MW has been developed. The countries with the highest known potential are Jamaica (63 MW), Cuba (62 MW), followed by Guadeloupe (46 MW) and Puerto Rico (45 MW).

The topic of renewable energy is discussed at a political level because one of the region's priorities is securing energy supply and becoming increasingly independent from fuel imports. Several countries have individually passed energy policies with mixed outcomes. The renewable energy policy draft of Jamaica includes a premium for renewable plants while the Dominican Republic grants an exemption on all import taxes of equipment and machinery necessary for renewable energy production. At a regional level, there are several initiatives that promote the use of renewable energy, especially the Caribbean Renewable Energy Development Programme (CREDP), which is an initiative of the Caribbean Community (CARICOM).

The hydropower potential of Cuba needs to be re-assessed. In Jamaica, easier access to information on potential sites is needed, as well as a corresponding institutional framework and regulatory platform that facilitates and attracts private investment. Private sector financing of renewable projects is non-existent in Haiti, as recurring natural disasters have diverted the attention of international community to emergency issues such as food security. A comprehensive barrier analysis is needed for the Caribbean region.

Central America

All eight countries, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama, in Central America use small hydropower. Central America has an estimated small hydropower potential of about 4,116 MW (for plants up to 10 MW), of which 599 MW has been developed. The country with the highest potential is Mexico (with a gross estimate of 3,250 MW). All countries need nationwide studies on their small hydropower potential.

Many of the countries in Central America have legislation that promotes renewable energy generation and many offer tax-based incentives such as exemption from income and on imported equipment and machinery. Preferential measures for mini- and small-hydropower plants in Panama include direct sales contracts with the electricity distribution company, with exemption from distribution and transmission costs for the first 10-year of commercial operation.

In many countries, domestic financing for small hydropower projects is difficult to obtain and/or the terms of commercial credit are not favourable. Major investments into interconnections are required in Mexico due to the lack of grid coverage and capacity in areas with high small hydropower potential. Incentives for the purchase of power generated from small hydropower plants are still missing on a wider-scale. Technical barriers include the lack of detailed and reliable national small hydropower potential inventory in natural and artificial streams (e.g. Mexico) or out-of date nationwide data (e.g. El Salvador). This is linked to a lack of adequate and/or affordable hydrological data in these countries. Social and community concerns about large and small hydropower projects in general prevail in Mexico, and land-issues and concerns about private sector involvement in natural resource management exist in Guatemala. Both institutional and administrative barriers to small hydropower development can be found in Costa Rica and El Salvador.

South America

Nine out of the fourteen countries in South America use small hydropower. The region has an estimated small hydropower potential of about 9,465 MW (for plants up to 10 MW), of which 1,735 MW has been developed. The country with the highest estimated potential is Chile (7,000 MW). Some countries define small hydropower as below 10 MW, however Argentina has an upper limit of 15 MW, Chile of 20 MW and Brazil of 30 MW. There have been difficulties in data compilation because not all countries have separate data available for capacity up to 10 MW. For example, the small hydropower potential in Brazil is 22,500 MW (for plants up to 30 MW) and Chile is 17,000 (for plants up to 20 MW).

Not all countries have renewable energy policies in place at the moment, especially where electricity access poses a challenge. Bolivia, Chile and Peru have decrees, laws or programmes to support rural electrification. Uruguay has a high electrification rate and sees small hydropower as an opportunity to promote rural development and to achieve 100 per cent electrification rate. Argentina has a FIT to guarantee power purchase agreements while Peru uses a premium price for electricity from renewable energy sources including small hydropower. Most countries use tax-based incentives. In Brazil, small hydropower producers sell their energy directly to the consumers via the grid at half price for grid use. Small hydropower action plans in Argentina and Colombia have yet to determine their national potential. Bolivia has a hydropower programme that has successfully built small hydropower plants.

All countries report financial barriers due to a range of reasons: a weak micro-financing sector, access to appropriate loans from banks, lack of incentives for private investors, inadequate metering of energy sold, over-reliance on governmental support and financial disadvantage in comparison to other types of renewable technologies, in particular wind (e.g. Brazil). Other barriers include governmental predisposition in Bolivia to support projects that can be connected to the central electricity grid, in the case Ecuador, preference was given to large power projects. The topography of Colombia, Uruguay as well as French Guiana makes them suitable only for low head installations which are technically and economically more challenging to build. In Chile, it is difficult and costly for small hydropower plants to be connected to the secondary grids because of the lack of transportation capacity on existing lines.

Northern America

Three out of five countries use small hydropower. Their potential of small hydropower (for plants up to 10 MW) is not fully known. It is estimated that about 7,843 MW has been developed. Greenland has only introduced hydropower in 1993. The small hydropower potential in Canada is 15,000 MW (for plants up to 50 MW) which does not include a high refurbishment potential (1,000 MW).

The United States established the Renewable Portfolio Standard in many of its states, and the governmental programmes focus on different aspects of small hydropower, such as low-impact, adding capacity to non-powered dams and increasing efficiency. In Canada, incentives to develop clean, renewable or green power take one or more of the following forms: tax incentives, special requests for proposal, standard offer programmes, net-metering and/or FITs.

In Canada and the United States, the investment of time and money necessary to obtain a licence for small hydro plants has become a significant burden. Concerns about environmental impacts caused by small hydropower projects are common.

Asia

Box 3
Countries and territories with small hydropower in Asia

Central Asia	**South-Eastern Asia**
Kazakhstan	Cambodia
Kyrgyzstan	Indonesia
Tajikistan	Lao PDR
Turkmenistan	Malaysia
Uzbekistan	Myanmar
	Philippines
Eastern Asia	Thailand
China	Timor-Leste
Japan	Vietnam
DPR Korea	
Republic of Korea	**Western Asia**
Mongolia	Armenia
	Azerbaijan
Southern Asia	Cyprus
Afghanistan	Georgia
Bangladesh	Iraq
Bhutan	Jordan
India	Lebanon
Islamic Republic of Iran	Turkey
Nepal	
Pakistan	
Sri Lanka	

Central Asia

All five countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan) in Central Asia use small hydropower. Central Asia has an estimated small hydropower potential of about 4,880 MW (for plants up to 10 MW), of which 183.5 MW has been developed so far. The countries with the highest potential are Kazakhstan (2,707 MW) and Uzbekistan (1,760 MW).

Legislations on renewable energy exist in Kazakhstan, Kyrgyzstan and Tajikistan, while Turkmenistan's Renewable Energy Development Strategy includes plans to develop renewable energy frameworks. Only Kyrgyzstan has a special FIT for small hydropower. However, accompanying by-laws and regulations are yet to be developed or adopted. The region has a large reservoir of small hydropower sites, but its potential is hampered by in-country disadvantages. Both Turkmenistan and Uzbekistan do not have a related policy in place to promote renewable energy. Even where such legislations exist, the uncertainty in the legal and regulatory framework for private sector participation is high (e.g. Kyrgyzstan and Tajikistan).

The local technical capacity for construction, maintenance and equipment or spare parts required for small hydropower projects need to be improved in Kyrgyzstan or built up in the case of Tajikistan. There is a need in Tajikistan to attract financing and managing resources from donors or state-funded support for decentralized renewable development. In Kyrgyzstan, private investors face unfavourable economic conditions, also low stream flow reduces operation hours during winter time, when power and heat are greatest in demand and the central grids are unable to compensate. Additionally, most communities are grid-connected, thus during summer the demand for additional off-grid power is low.

Eastern Asia

Five out of seven countries/regions in Eastern Asia use small hydropower. Eastern Asia has the largest estimated small hydropower potential worldwide. The potential is estimated at 75,312 MW (for plants up to 10 MW), of which 40,485 MW has been developed. The country with the highest potential is China (63,492 MW) followed by Japan (7,062 MW). China is the only country in the region with a small hydropower definition of up to 50 MW. China's small hydropower potential (for plants up to 50 MW) is 128,000 MW, of which 65,680 MW has been developed.

The importance of renewable energy is widely acknowledged throughout the region. The Republic of Korea has legislation on alternative energy with the aim of reaching a renewable energy supply share of 6.1 per cent by 2030. China plans to achieve a 30-per cent non-fossil capacity in its national installed capacity by 2030. The local governments in China are encouraged to develop small hydropower; value-added tax (VAT) for small hydropower is subsidized. In Japan, a FIT system was established in 2012 under an Act that promotes renewable energy usage. Some laws in Japan simplify the process for renewable energy producers to sell electricity to the electric utility. The policy orientation of Democratic People's Republic of Korea inclines towards non-fossil fuel options, solving the issues of ageing infrastructure and of the transmission and distribution networks. Its policy is favourable to the development of small hydropower. However, small hydropower information about this country is scarce. Mongolia has a renewable energy programme that aims to achieve a renewable energy share of 25 per cent in its electricity system by 2020.

The main barrier to small hydropower development is of a financial nature, such as the access to funding and generation equipment in the Democratic People's Republic of Korea. In the Republic of Korea, topographical conditions are not suitable for small hydropower, thus the economic feasibility of small hydropower projects is limited. In Japan the potential is being reassessed to include less conventional sites from existing infrastructure facilities, such as dams, weirs, irrigation channels, water supply and sewerage systems, in order to avoid environmental impacts.

Southern Asia

Eight out of the nine countries in Southern Asia use small hydropower. The region has the second largest small hydropower potential estimated at 18,077 MW (for plants up to 10 MW), of which 3,563 MW has been developed. Afghanistan has a known potential of (1,200 MW). The small hydropower potential in India for plants up to 10 MW is not known, and it is 15,000 MW for plants up to 25 MW. Some countries define small hydropower as below 10 MW, however Bangladesh has an upper limit of 15 MW. Bhutan and India apply a threshold of 25 MW and Pakistan of 50 MW.

Most countries have renewable energy policy (e.g. Bangladesh, Bhutan, Pakistan) and a renewable energy target, or a hydropower policy (e.g. Bhutan, India, Nepal). Afghanistan has a Rural Renewable Energy Strategy Action Plan up to 2014. Renewable energy is seen as an opportunity to boost rural electrification (e.g. India, Afghanistan) and an option to be less dependent on imported fossil fuels (e.g. Pakistan). In India, subsidies for the development of small hydropower through the private sector are in place, but it varies from state to state and may include power wheeling, power banking, buy-back of power and/or facilities for third party sales. Some states also provide concessions such as leasing of land, exemption from electricity duty and entry tax on power generation equipment. The Iranian Government purchases electricity produced by private sector renewable energy plants at a tariff three times higher than those paid by the consumers. In Nepal, there are several incentives available, such as VAT exemption, custom duty reductions for imported small hydropower related machinery or equipment and income tax exemptions for the first 10 years from the date of plant commissioning, thereafter 50 per cent for the next five years.

A range of barriers exist in Southern Asia, such as the remote location of potential sites and the need for road access and long-distance transmission lines (e.g. Bangladesh, Pakistan). Related to this is the uncertainty of grid extension, as it may not be economically feasible in rural areas where power demand is low (e.g. Nepal, Bhutan). Financial barriers include economic feasibility due to terrain and topographical conditions (e.g. Bhutan) and the lack of understanding by the local banks on financing needs of project developers (e.g. Bangladesh). In short, the lack of/low interest from the private sector to develop small hydropower plants is because there is no proper tariff structure and/or electricity market system (e.g. Pakistan, Bhutan) in place. Administrative complexity and long waiting times delay small hydropower development in Bangladesh, India and Nepal. The seasonality of rain, with low output during the dry season poses a barrier for Bangladesh and Bhutan, and in countries like Bhutan it is a big concern due to the country-specific conservative environmental laws. Other specific barriers reported for each country were with regards to human resources capacity, technical knowledge and institutional capacity.

South-Eastern Asia

Nine out of eleven countries in South-Eastern Asia use small hydropower. The region has an estimated small hydropower potential of about 6,682.5 MW (for plants up to 10 MW), of which 1,252 MW has been developed. The country with the highest known potential is Viet Nam (2,205 MW), followed by the Philippines (1,876 MW) and Indonesia (1,267 MW). The upper limit of small hydropower varies. In Malaysia and Indonesia it is 10 MW, in Lao People's Democratic Republic (PDR) and Thailand it is 15 MW and in Viet Nam 30 MW. In the Philippines and Cambodia the upper limit of mini-hydropower is 10 MW, while no definition is available for Myanmar and Timor-Leste.

Most South-Eastern Asian countries have a national renewable energy action plan that sets renewable energy target in the national power generation mix. Lao PDR has a draft Renewable Energy Development Strategy that promotes small hydropower of up to 15 MW. Thailand also has a small hydropower target of 0.04 per cent of the total generation mix by 2015. Viet Nam has an avoided cost tariff specifically for small hydropower, and the Philippines has mini-hydropower projects auctions as well as a FIT. In Indonesia, the electricity is bought by the State at an agreed fixed price. In general the FIT system is not well developed in the region. Renewable energy policy limitations have been reported in Timor-Leste, Malaysia, Indonesia and the Philippines. For example there was a delay in the implementation of the Renewable Energy Act of the Philippines.

The lack of field expertise and technical skills is the largest barrier impeding the development of small hydropower and this has been reported in many countries. The second important barrier is of a financial nature, ranging from the lack of financial sources in Cambodia; to financial institutions that are unfamiliar with assessing risks for small hydropower projects in Malaysia and Thailand. High costs for the development of small hydropower are reported in Cambodia, Malaysia and Timor-Leste. More subsidies are available in Thailand for importing electricity to rural areas than for building small hydropower plants. In Lao PDR, only large hydropower projects attract foreign investors. Environmental or climatic barriers are reported as well, such as vulnerability to drought in Malaysia and Timor-Leste, and a reduction of maximum water flow from rivers that can be used for electricity generation in the Philippines have been reported.

Western Asia

Eight out of eighteen countries in Western Asia use small hydropower. Western Asia has an estimated small hydropower potential of about 7,754 MW (for plants up to 10 MW), of which 489 MW has been developed. The country with the highest known potential is Turkey (more than 6,500 MW). Not all countries in the region are suitable for small hydropower development due to climatic conditions, some even suffer from water stress.

Most countries consider renewable energy as an important resource. Armenia and Turkey have renewable energy laws, while other countries such as Azerbaijan, Georgia and Armenia have national renewable energy programmes. Armenia has a strategic hydropower development programme that includes small hydropower and international finance mechanisms to support its development. Azerbaijan does not have any customized laws for renewable energies, but producers of small hydropower plants with a capacity from 50 kW to 10 MW do receive subsidy that guarantees the unlimited purchase of their electricity based on a combination of applicable laws. In Georgia, the programme regulates and supports the construction of new renewable energy projects with a capacity up to 100 MW. It offers long-term purchasing agreements and favourable FITs and license-free electricity generation for power plants up to 10 MW.

Some countries such as Iraq, Jordan and Lebanon, do not have any policy for renewable energy, as renewable energy in general is not prevalent. Lebanon needs to evaluate the various demands on its water resources. Turkey's renewable energy law does not differentiate between small- and large-hydropower, thus the private sector's interest has moved towards large hydropower systems due to potentially higher profits. Many regulatory, legal and technical barriers need to be overcome in Armenia to fully develop the small hydropower potential, including its low FIT.

Europe

Box 4
Countries and territories with small hydropower in Europe

Eastern Europe	Southern Europe
Belarus	Albania
Bulgaria	Bosnia and Herzegovina
Czech Republic	Croatia
Hungary	Greece
Republic of Moldova	Italy
Poland	the former Yugoslav Republic of Macedonia
Romania	Montenegro
Russian Federation	Portugal
Slovakia	Serbia
Ukraine	Slovenia
	Spain
Northern Europe	
Denmark	**Western Europe**
Estonia	Austria
Finland	Belgium
Iceland	France
Ireland	Germany
Latvia	Luxembourg
Lithuania	Netherlands
Norway	Switzerland
Sweden	
United Kingdom of Great Britain and Northern Ireland	

Eastern Europe
All ten countries, Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia (EU Member States) and Belarus, Republic of Moldova, the Russian Federation, and Ukraine in Eastern Europe use small hydropower. Eastern Europe has an estimated small hydropower potential of about 3,495 MW (for plants up to 10 MW), of which 2,735 MW has been developed. The countries with the highest potential are the Russian Federation (1,300 MW) and Romania (730 MW). Apart from the Russian Federation which has a definition of up to 30 MW, small hydropower is mostly defined as up to 10 MW in the region.

Most of these countries have policies for renewable energy as well as targets. A Renewable Energy Directive has been implemented within the European Union (EU). Thus all the Member States currently have a renewable energy policy and a target share from renewable sources in gross final consumption of energy by 2020. Tariffs for electricity from renewable energy sources including small hydropower exist in Belarus, Bulgaria, Czech Republic and Ukraine. Slovakia supports small hydropower through additional payment for electricity supplied from these plants for the first 15 years.

In both Belarus and the Czech Republic, the flat topography of the country seems to limit the small hydropower development to low head sites. However this is also seen as a change to apply small hydropower to waterworks in combination with other uses such as water regulation, supply and transport. The lack of involvement of private companies in small hydropower projects is mentioned as a barrier in Moldova and Belarus; the former is due to lack of funds available for private companies, the latter has an incomplete legal framework for independent power producers. Residual flow regulations exist in Czech Republic, Poland and Romania. Similar legislation is planned in Bulgaria, where an increased residual flow means an increase in operating costs.

Northern Europe
Ten out of eighteen countries or territories use small hydropower. Northern Europe has an estimated small hydropower potential of about 3,841 MW (for plants up to 10 MW), of which 3,643 MW has been developed. The upper limit of small hydropower is generally 10 MW. However, some have lower limits such as 5 MW in the United Kingdom, 1.5 MW in Sweden and 1 MW in Denmark and Iceland.

A Renewable Energy Directive has been implemented within the European Union (EU). Thus all the Member States now have a renewable energy policy and a target share from renewable sources in gross final consumption of energy by 2020. All countries except Iceland, have support systems for small hydropower. Seven countries have FITs applicable to small hydropower, while Finland discontinued its fixed production support but supports small hydropower developers with tax incentives. Norway uses a quota system and Sweden uses electricity certificates as a market-based support system for renewable electricity including small hydro. Residual flow is regulated in most countries except Iceland and Sweden. The EU Water Framework Directive applies to most countries, however, its full impact has yet to be determined. In the case of Estonia, this has led to a decrease in small hydropower potential.

Southern Europe
Eleven of the sixteen countries or territories use small hydropower. Southern Europe has a small hydropower potential estimated at 14,169 MW (for plants up to 10 MW), of which 5,640 MW has been developed. The countries with the highest potential are Italy (7,066 MW) and Spain (2,185 MW). Most countries use the 10 MW definition. However, in Italy, the upper limit of small hydropower is 3 MW, in Bosnia and Herzegovina 5 MW and in Greece 15 MW.

The Renewable Energy Directive has been implemented in the EU, five countries are not Member States (Albania, Bosnia and Herzegovina, Macedonia and Montenegro). Most countries in Southern Europe have a national renewable energy action plan. Apart from Albania, Macedonia and Bosnia and Herzegovina, all countries have a renewable energy target for 2020 or 2025, ranging from 17 per cent in Italy and Greece, to 60 per cent in Portugal. Albania is preparing a new power sector law and a new renewable energy law. The FIT system is used in eight of the eleven countries and is sometimes compiled with a market price and premium, as in the case of Spain.

The main barrier to the development of small hydropower is related to administrative procedures. Authorization of procedures and network connections are long and often complex, such as the case in Serbia, Italy, Slovenia or Spain. There is a lack of methodology for concession, licensing and permit delivery in Bosnia and Herzegovina and Portugal. Protection of culture or landscape and mountainous areas are noted barriers to small hydropower development in Croatia and Greece. The implementation of the EU Water Framework Directive decreases the potential of small hydropower as mitigation costs have risen in Greece and Italy.

Western Europe

Seven out of nine countries or territories in Western Europe use small hydropower. Western Europe has an economic small hydropower potential estimated at 6,644 MW (for plants up to 10 MW), of which 5,809 MW has been developed. The countries with the highest potential are France (2,615) and Germany (1,830 MW). The limit of small scale of hydropower is 10 MW in most of the countries. However, in the Netherlands, the limit is 15 MW, 6 MW in Luxembourg, and Germany has several definitions: the limit differs from 1-5 MW.

The Renewable Energy Directive has been implemented in the EU. All countries, except Switzerland are part of the EU. All of its Member States have a renewable energy policy and a target share from renewable sources in gross final consumption of energy by 2020. The FIT system exists in five countries, whereas Belgium uses Green Certificates and the Netherlands uses subsidies and tax deduction to support small hydropower.

The barriers in Western Europe are aplenty. In particular, Austria, Belgium and Germany exists a strong opposition to small hydropower development by powerful administrations, non-governmental organizations and the fishing lobby, mainly due to ecological and fishing issues. The environmental impacts have led the German government to establish mitigation measures. The topography of the Netherlands is not very suitable to develop small hydropower plants and it is difficult to obtain permits.

Policy decisions sometimes have a negative impact on small hydropower. In Belgium, the new classification of plants could have a negative effect for very small operators. Environmental legislations such as those related to Natura 2000 and the EU Water Framework Directive increase mitigation costs and limit the economic small hydropower potential. In Austria there is a gap between the policy which encourages hydropower and the reality of granting procedures. The new policy regarding the FITs in Switzerland has led to an overload at planning offices and public authorities. Also, different procedures for each canton have created a challenge for investors. Financial barriers differ among countries. In Austria, budget for the support scheme is limited; in Switzerland profitability is low due to high demand for engineering services and high prices for hydropower equipment.

Oceania

Box 5
Countries and territories with small hydropower in Oceania

Australia and New Zealand
Australia
New Zealand
Pacific Island Countries and Territories
Melanesia
Fiji
New Caledonia
Papua New Guinea
Solomon Islands
Vanuatu
Micronesia
Federated States of Micronesia
Polynesia
French Polynesia
Samoa

Australia and New Zealand

Both Australia and New Zealand use small hydropower. Together they have a small hydropower potential estimated at 932 MW (for plants up to 10 MW), of which 310 MW has been developed.

In Australia, renewable energy certificates provide incentives to upgrade and redevelop ageing hydropower plants. There is no governmental policy on small hydropower in New Zealand. However investigation for new sites is actively being pursued. Furthermore, a price for carbon aims to help the economic competitiveness of new renewable electricity.

Main barriers to small hydropower development are environmental protected areas and competing uses for water. Barriers specific to Australia are public acceptance, extreme variations in climate, remoteness of sites and overall high costs of generation and transmission. Barriers specific to New Zealand are administrative in nature (i.e. long and expensive consenting process) and high construction costs. Environmental and social issues also pose as a barrier to the widespread development of small hydropower. Incentives for renewable energy, in part to combat the potential effects of climate change, are focused primarily on wind energy and solar power which are considered to have greater potential.

Pacific Island Countries and Territories

Eight out of the twenty-two countries or territories use small hydropower. The Pacific Island Countries and Territories (PICTs) have a small hydropower potential estimated at 306 MW (for plants up to 10 MW), of which 103 MW has been developed. Papua New Guinea has the highest potential among the countries (153 MW).

At the national level, Fiji is the only country with a specific renewable energy policy and a master plan for small hydropower. Most of the other countries have national energy policies that support the use of renewables and/or renewable energy programmes, however, the need for improved (rural) electrification is a key issue.

The Pacific Islands Energy Policy and an associated strategic action plan are critical at the regional level. Renewable energy is among the 10 areas of development addressed in this initiative, with the aim to increase the share of renewable energy resources in the energy mix. Similarly, the Framework for Action on Energy Security in the Pacific and its associated implementation plan (2011-2015), includes four key priorities, namely resource assessment, investment in renewable energy, capacity development and an increase in the share of renewable energy in the energy mix. International finance also plays a role in the small hydropower development in the Pacific region. The Asian Development Bank has been involved in the Town Electrification Programme of Papua New Guinea; the World Bank has a 10-year project Pacific Islands Sustainable Energy Finance Project (2007-2017) which supports micro hydropower. Local financial institutions are incentivized to participate in sustainable energy finance in support of equipment purchase. However, apart from Fiji, little progress has been achieved in other participating countries.

In general, incentive mechanisms for small hydropower project development seem to be missing for most countries. Lack of funding for project execution is a barrier mentioned for the Solomon Islands and Papua New Guinea. Steep topography may lead to rapid runoff and landslips in Fiji, providing less suitable conditions for small hydropower. Outdated renewable energy assessments are a problem in Papua New Guinea. In Vanuatu, barriers to small hydropower are often those that are common for renewable energy, which include high capital costs, lack of political will, lack of in-country capacity and issues related to land ownership. Capacity for the construction of small hydropower in the PICTs exists, however external funding sources often bring their own experts. Investments made into various renewable energy technologies should consider climate change effects on the environment. In the case of small hydropower, this means the consideration of impacts on water availability particularly during the dry season.

Conclusion

The *World Small Hydropower Development Report 2013 (WSHPDR 2013)* contains data compiled on installed capacity and potential of small hydropower for 152 countries. The Secretariat has in phases of research and data collection, faced many obstacles, from linguistic, data accessibility to the different standards of reporting. There are cases where resource potential of a country is unclear, as there is no globally agreed small hydropower definition and many reports on small hydropower do not always indicate clearly the definition applied.

It can be concluded that small hydropower is a suitable renewable energy technology in the context of rural electrification efforts, energy diversification, industrial development and exploration of existing infrastructure. Rural electrification has significantly improved in China and in India thanks to small hydropower. At the national-level, small hydropower programmes in developing regions and at regional-level in Western Africa, have reflected the importance given by some governments to small hydropower as a energy solution for rural electrification and productive use.

Fossil-fuel dependent regions with high or relatively high electricity access have come to realize the importance of clean and renewable energy. Therefore many countries in Western and Central Asia are discovering or rediscovering small hydropower as an energy option and many are interested in refurbishing their old plants.

Small hydropower technology has gradually adapted to meet environmental concerns while technical innovators aim to explore the use of existing infrastructures.

The *WSHPDR 2013* proposes a more detailed policy and barrier analysis to identify critical capacity needs and identification of suitable financing mechanisms. The importance and advantages of small hydropower as the solution to rural electrification and inclusive sustainable industrial development has probably been underestimated, particularly in comparison to other small-scale renewable energies.

The following are some recommendations that aim at the national and regional/international level. They are served as a starting point and are in no way comprehensive.

Recommendations

National level

Resource assessment and water management

1. More hydrological data needs to be collected over a longer period of time. In order to achieve this goal, technical equipments such as a network of gauging stations are required along with human capacity building.

2. Small hydropower potential sites need to be reassessed due to the constantly changing hydrological and environmental conditions affecting the watershed. Environmental regulations and technological improvements should also be considered. When drafting master plans, it is important to balance the multiple demands and functions of water resources.

3. Screen small hydropower plants that need to be upgraded or refurbished in order to gain an overview. Investments should be promoted to reactivate old plants and increase their efficiency based on technical innovation.

4. Potential multi-purpose sites need to be identified. Across the world there are many water reservoirs and dams constructed for irrigation or as drinking water collection that do not yet produce electricity but small hydropower turbines could be installed and running concurrently.

5. Potential non-conventional sites based on technical innovation need to be identified. Existing infrastructure such as water pipes in buildings, or water channels with very low head could serve as potential small hydropower sites.

6. Implement regulations on the use of waterways to avoid conflict between agriculture, fishery, electricity generators and biodiversity.

Rural electrification

1. Improve the reporting of the impact of small hydropower on rural electrification by keeping track of on- and off-grid installed and potential small hydropower capacity.

2. The productive use of electricity from small hydropower plants in rural settings should be better developed and reported in order to share lessons learnt and improve inclusive sustainable industrial development.

3. New Business models for sustainable small hydropower development for rural electrification need to be developed and promoted.

Planning, financing and implementation

1. Increase local capacities to conduct feasibility studies, for construction, operation and maintenance of small hydropower plants.

2. Build or improve local manufacturing capacity to produce components for small hydropower plants.

3. High initial costs need to be overcome with easier/improved access to finance for project developers. Awareness of small hydropower should be raised among local banking institutions or microfinance institutions in order to improve the risk assessment and provide conducive loan conditions.

4. Improved electricity network planning will help to identify the need for investment into grid infrastructure. This will help to better inform the economic feasibility of potential sites. Small hydropower plants in remote areas are often not economically feasible because mini-grid or connections to the central grid need to be built.

5. Improve collaboration among agencies responsible for water resources, environment and electricity. Avoid overlapped mandates and conflicts and reduce duration needed for approval/authorization processes.

6. Simplify administrative procedures for small hydropower plants located in existing infrastructure such as irrigation channels, water supply systems, dams or wastewater treatment facilities, and for the rehabilitation of old schemes.

7. Improve timely land allocation by ensuring land records are clear and up-to-date to avoid conflict over land rights/ownership and concessions/permits.

8. Create a one-stop shop for small hydropower plants to streamline project implementation.

International and regional level

1. Develop a regional network of professional/mechanical workshops to satisfy local/regional equipment demand.

2. Remove linguistic barriers of knowledge exchange by providing information in several regional languages and create a knowledge platform.

3. Create a network of focal points (e.g. Ministry of Water Resources and/or Energy of one country in order to connect relevant stakeholders within the region.

4. Use existing international technical training resources to train trainers in their region.

5. South-South and triangular cooperation among developing countries, developed countries and international organizations (including international banks) for technology-transfer, capacity building and financing should help to facilitate the transition from individual pilot small hydropower projects towards the successful implementation of full-scale small hydropower programmes. International banking institutions can help to kick-start programmes and overcome funding barriers for countries in need.

6. Coordination, collaboration and knowledge sharing among regional and international organizations that include small-scale hydropower in their scope of work should continue and be expanded.

7. Promote the implementation of international projects aiming at the development of local small hydropower capacities, policies and investment.

Introduction

A world-first assessment on the global status of small hydropower

As a leading UN agency in the provision of renewable energy solutions for inclusive sustainable industrial development, UNIDO is collaborating with the International Center on Small Hydro Power (ICSHP), based in China, to develop a small hydropower knowledge portal www.smallhydroworld.org and to publish the *World Small Hydropower Development Report 2013 (WSHPDR 2013).* This flagship assessment of UNIDO is a world-first compilation of global small hydropower data, and will be a crucial policy and investment guide for renewable energy provision through small hydropower. It aims at identifying the world's small hydropower development status and its potential in different countries and regions by engaging with stakeholders to share information.

Small hydropower is one of the most suitable energy solutions for fostering inclusive sustainable development and industrialization. Small hydropower is a mature technology that can be easily operated and maintained. It has the lowest electricity generation prices of all off-grid technologies, and has the flexibility to be adapted to various geographical and infrastructural circumstances.

Information is the first essential step for policy and investment decisions. Much of the world's small hydropower potential remains untapped. First step to remedying the situation is through dissemination of reliable data that can inform policy development and energy planning, as well as guide investors in entering renewable energy markets.

Global data on small hydropower by region and country is provided.

The assessment is based on the contribution of more than 60 different authors or organizations. It contains 20 regional overviews and 149 country-level reports, which are available to the public. The report includes:

• an overview of the global status of small hydropower with a focus on the untapped potentials of small hydropower;

• an overview of small hydropower development status and potential for 20 geographical regions;

• country-level analysis for 149 countries with an overview of the power and electricity sector of the country, installed small hydropower capacity, and institutional climate for small hydropower development.

The report will be updated biennially to provide current and relevant data.

To ensure that the data and information provided by the report is up-to-date, UNIDO and ICSHP will collaborate with national institutions to facilitate continuous monitoring and collection of small hydropower data. The changes will be reflected regularly on the website while a consolidated print version is planned to be available biennially.

Join us!

UNIDO has the vision to play a special role in promoting a system of international dialogue and engaging small hydropower stakeholders from across the world to make this initiative a hub for all small hydropower related information. UNIDO and ICSHP are actively reaching out to more stakeholders and partners to provide relevant information in order to keep the website up-to date. This shall be a collaborative effort – you are invited to participate in extending the world's small hydropower knowledge base.

Contact us: **renewables@unido.org** or **report@icshp.org** to find out more.

1 Africa

1.1 Eastern Africa

Wim Jonker Klunne, Council for Scientific Research, South Africa; Emmanuel Michael, United Nations Industrial Development Organisation, United Republic of Tanzania

Introduction to the region

The East African region comprises 20 countries, 14 of which use small hydropower at various degrees (see countries listed in table 1). The East African Power Pool (EAPP) plays an important role in the future of energy within the region. One of the main objectives of EAPP is to share grid connections to enable the flow of power from areas of abundance to areas of deficit.

The region is shaped by noticeable plate tectonics giving rise to geographical features such as the Great Rift Valley, Lake Victoria and Mount Kilimanjaro. The climate varies widely from tropical, sub-tropical, equatorial to temperate and arid.[1] Since the end of colonialism, the region has continued to endure internal and external political conflict. In addition, the majority of the Eastern African countries are faced with unreliable electricity supply as a result of fallbacks of national grid leading in widespread use of alternative means to ensure a steady supply of electricity. Despite the political and social challenges and energy barriers, the region attracts significant levels of foreign investment and positive development throughout various sectors in the economy.

Table 1

Overview of countries in Eastern Africa

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Installed electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Burundi[abe]	10.557	89	2.7	52	242	50.5	155
Ethiopia[abe]	91.195	83	17.0	929	4 106	1 850.0	2 800
Kenya[abef]	43.013	78	16.1	1 480	6 692	761.3	2 170
Madagascar[abeg]	22.005	70	19.0	434	1 138	131.6	753
Malawi[abe]	16.323	80	9.0	315	1 676	300.0	1 100
Mauritius[abeh]	1.313	58	99.4	670	2 402	58.3	101
Mozambique[abe]	23.516	62	11.7	2 308	14 980	2 179.0	14 710
Réunion[abe]	0.800	-	-	650	2 546	120.5	633
Rwanda[abe]	11.690	81	6.0	69	160	54.5	130
South Sudan	10.625	..	..	..	..	..	..
Uganda[abi]	33.641	87	9.0	525	1 400	409.0	900
Tanzania (United Rep.)[abe]	46.913	74	13.9	1 051	4 281	562.0	2 640
Zambia[ab]	13.817	64	18.8	1 750	9 597	1 518.0	9 879
Zimbabwe[abe]	12.620	62	41.5	1 990	7 723	700.0	5 521
Total	**338.028**	**-**	**-**	**12 223**	**56 943**	**8 694.7**	**41 492**

Sources:

a. Central Intelligence Agency[1]

b. National Electrification rates: International Energy Agency[2]

c. Clean Energy Information Portal – Reegle[3]

d. Burundi information: International Renewable Energy Agency. Renewable Energy Profiles[4]

e. The International Journal on Hydropower & Dams[5]

f. Kenya, Ministry of Energy[6]

g. Madagascar, Agence de Développement de l'Electrification Rurale[7]

h. Mauritius Ministry of Energy and Public Utilities[8]

i. Uganda Centre for Research in Energy and Energy Conservation[9]

Note: The electrification rate may be reported higher in the country report because national sources are used based on different assumptions, e.g. Zambia. South Sudan has attained its independence on 9 July 2011. Therefore, statistics for South Sudan were difficult to identify or not available at the time of writing.

Small hydropower definition

Countries' official small hydropower definitions are given in table 2.

Table 2
Classification of small hydropower in Eastern Africa

Country	Small (MW)	Mini (MW)	Micro (kW)
Burundi	..	..	..
Ethiopia	..	..	..
Kenya	1.00 – 10.00	0.10– 1.00	< 10
Madagascar	> 10.00	1.00 10.00	50 – 1000
Malawi	..	..	..
Mauritius	0.01 – 0.05	0.0025 – 0.01	< 0.0025
Mozambique	8.00 -15.00		
Reunion	..	..	..
Rwanda	..	..	..
South Sudan	..	..	..
Uganda	< 10.00	< 1.00	< 100
Tanzania (United Rep.)	..	..	..
Zambia	1.00 - 10 .00	0.50 – 1.00	< 300
Zimbabwe	..	0.501 – 5.00	5 – 500

Sources: Most of these definitions were obtained through surveys conducted by ICSHP in 2011, except for Mozambique.

Regional overview

Hydropower plays an important role (above 80 per cent) in electricity generation in Burundi, Ethiopia, Zambia, Mozambique and Malawi and it produces a significant amount of electricity in Uganda, Zimbabwe, Tanzania, Madagascar and Kenya. The island topography of Seychelles is not suitable for hydropower, while in Djibouti, Eritrea, and Somalia, the complete or part desert climate in these countries, coupled with recurring droughts, are not conducive for hydropower development. Small hydropower development in the region is ongoing at a smaller scale:

- A master study plan on hydropower potential for Burundi exists since the 1980s. It includes small hydropower potential sites with capacities of up to 10 MW. Recent optimization studies have shown that these sites could achieve higher installed capacities with the current available technology.[10] Though a large small hydropower potential is known, means to develop the potential are scarce.
- Eritrea does not use any hydropower and its small hydropower potential has not been studied. However, feasibility studies to utilize micro and small hydropower in the inland river basin are required and would be beneficial, since only three per cent of the rural population has access to electricity.[11]
- Ethiopia, with a national electrification rate of 17 per cent, is making efforts in improving rural electrification, particularly off grid electrification, and developing new energy sources. Currently, a rural energy fund exists and its feed-in tariffs (FITs) schemes are in the draft form.
- In Kenya, interest in the development of small hydropower has increased in the last 12 years due to the inadequacies of grid based power supply. There is a commitment to use renewable energy, as can be seen from the FIT policy and National Renewable Energy Development Strategy. Additionally, there is a high private sector interest in small hydropower mainly via small hydropower use on tea plantations (i.e. United Nations Environment Programme project). The Government is motivated to remove legal and regulatory barriers (see country report).[12]
- Interestingly, Madagascar has a very high potential (2,600 MW), however, there is no information on existing small hydropower plants in Madagascar. According to the Rural Electrification Agency, there were four plants with individual capacities of up to 10 MW, with a total installed capacity of 22.51 MW. All of them need renovation since the commissioning about 25 years ago.
- In Malawi, a Renewable Energy Strategy is underway and a Master Plan for Rural Electrification was passed in 2003. It includes a list of potential micro hydropower sites. However, the development of small hydropower is slow and some of the existing small hydropower plants are not operating due to lack of maintenance instruments i.e. availability of spare parts and financial constraints. On the other hand, feasibility studies have been conducted in the past, but one of the main barriers is the lack of investors.
- In Mauritius, two small hydropower plants are under construction and expected to be completed by 2015 in addition to the existence of FIT support systems that are readily available.
- Mozambique's greatest hydropower potential lies on the Zambezi River basin with a growing interest to promote the use of small hydropower for isolated rural communities
- Réunion's hydro potential has been developed with remaining potential for only a few more micro power stations.[13]
- While Rwanda does not have a lot of existing small hydropower there is considerable micro hydropower potential available in the country.
- A non-verifiable source estimates that pre-war Somalia had 4.8 MW of installed hydropower capacity in the lower Juba valley; however, due to the political unrest of the country, no significant data is available.
- In South Sudan, the development of the hydropower sector is not realized due to political and social unrest.
- In Uganda, the development of small, micro- or mini-hydro "has not been very systematically

conducted". Seven projects with a total of 60 MW small hydropower capacities have been announced.[14] Based on the National Renewable Energy Policy, a government programme with an ambitious target of 100 MW hydropower capacities, by 2017, is being anticipated, from mini- and micro-hydropower.

- Tanzania has a substantial small hydropower potential with areas of high potential located in Southern and Western highlands. The Tanzania Electric Supply Company Limited (TANESCO) is currently in the process of developing the available resources.
- The hydropower potential of Zambia is estimated at 6,000 MW, of which 1,858.5 MW has been developed. Development of small hydropower is usually conducted by the private sector.
- The total installed small hydropower capacity in Zimbabwe is unknown. However, some information from certain small hydropower plants has been obtained from the private sector.

The installed small hydropower capacity in Eastern Africa is estimated at 186 MW, while the potential is estimated at 6,208 MW, including Kenya's gross small hydropower potential of 3,000 MW (table 3). Additionally, some countries do not have data available on their small hydropower capacity potential (i.e. Madagascar and Zambia).

Table 3
Small hydropower up to 10 MW in Eastern Africa
(Megawatts)

Country	*Potential*	*Installed capacity*
Burundi	54.0	15.84
Ethiopia	1 500.0	6.15
Kenya	3 000.0	33.00
Madagascar	..	22.51
Malawi	15.0	5.80
Mauritius	9.5	8.70
Mozambique	1 000.0	2.10
Réunion	..	11.00
Rwanda	38.2	23.20
South Sudan	at least 5.0	..
Uganda	210.0	22.42
Tanzania (United Republic of)	310.0	25.00
Zambia	..	31.00
Zimbabwe	120.0	1.92
Total	6 261.7	208.64

Source: See country reports
Note: Ethiopia has more than 600 potential sites, but its potential is not known. Madagascar has a small hydropower potential of up to 2,600 MW, however it defines small hydropower as above 10 MW. The above reported potential for Mozambique may include plants larger than 10 MW.

The Greening the Tea Industry in East Africa (GITEA) project by UNEP initially conducted pre-feasibility studies of 19 potential small hydropower sites in in Kenya, Malawi, Rwanda, Tanzania, and Uganda. Ten sites were selected for further studies and six demonstration projects were identified with the need of an additional investment of close to US$22 million for implementation. Supported by local banks and UNEP's funding, hydropower plants are being developed in key tea areas of Kenya, while the Dutch Government is helping to finance a facility in Rwanda. Plans are being finalized for more plants in Tanzania and Malawi. UNEP also supported preparation of FIT policies for renewable energies in Kenya and Tanzania. Under these policies, national grid utilities are obliged to buy renewable energy from all eligible participants, and to promote investment in hydropower.

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1.1.1 Burundi

Lara Esser and Laxmi Aggarwal, International Center on Small Hydro Power

Key facts

Population	10,557,259[1]
Area	27,830 km[2]
Climate	Equatorial climate
Topography	Hilly and mountainous terrain
Rain Pattern	Average annual rainfall is about 1,500 mm; two wet seasons (February to May, September to November), and two dry seasons (June to August, December to January)[1]

Electricity sector overview

The electrification access in Burundi is 10 per cent which can be considered low in comparison to other countries in the East African Community (EAC).[2] The transmission network includes: high voltage lines (70-110 kV) and medium voltage lines (10-15 kV), whichall require rehabilitation, 110 kV transmission lines are in good condition and the 70 kV transmission lines are in an acceptable condition.[2] [3] The Régie de Production et Distribution d'Eau et d'Électricité (REGIDESO) has sole responsibility of the system. In 2010 the energy deficit was about 15 MW.[3]

In 2008, REGIDESO produced 87 per cent of the domestic electricity, most of it was from hydropower. REGIDESO has a total installed capacity of 35.8 MW, of which 30.8 MW is hydropower and 5.5 MW thermal capacity.[2] There are very few biogas and solar energy installations in the country becauseover 70 per cent of them are out of order either due to vandalism or lack of maintenance.[4] Figure 1 shows the electricity mix of Burundi.

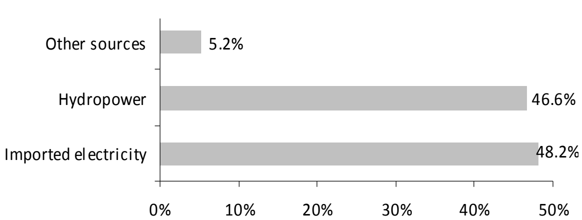

Figure 1 **Electricity generation Burundi**
Source: African Development Bank[4]
Note: Data from 2008.

The Government's strategy for the power sector has called for 20 per cent of its population to have access to electricity by 2020.[4] Burundi generates hydropower from its large hydropower plant Rwegura, with an installed capacity of 18 MW. Additional capacity is available for Burundi from two regional hydro plants: 3 MW from Ruzizi I which has an installed capacity of 29.8 MW and 13.3 MW from Ruzizi II with an installed capacity of 43.8 MW.[2] [5] These plants are shared between the Democratic Republic of Congo, Rwanda and Burundi. Ruzizi I is owned by Société Nationale d'Electricité (SNEL), the national electricity company of the Democratic Republic of Congo, Ruzizi II is owned by the Société International d'Électricité des Pays des Grands Lacs (SINELAC), the intercommunity organization of Rwanda, Democratic Republic of Congo and Burundi.[6] Future plans show that import capacity of Burundi may increase with the installations of Ruzizi III (estimated capacity of 147 MW) and Ruzizi IV (estimated capacity of 287 MW).[2]

Burundi's electricity sector is expected to change with the implementation of the East African Power Pool (EAPP) plans for interconnectivity and a common market within the EAPP countries, as has been achieved by Europe. Most of the EAC countries have been connected while Burundi waits for the high voltage line of 220 kV from Kigoma-Butare-Ngozi-Gietga to be completed and a link from the United Republic of Tanzania to Burundi to be installed.[2]

The country has already experienced changes in the electricity sector with the aid of World Bank. The payment system was altered to a prepayment system in 2011, resulting in 52 per cent of the clients paying in advance. This will in turn aid REGIDESO to ensure secure earnings, easier resource management and will contribute in diminishing the financial risk faced by REGIDESO.[2]

In addition to the World Bank contributions, Burundi has in 2011 established the Control and Regulation Agency for the Water and Electricity Sectors under Decree No. 100/320. This entity is responsible to control, regulate and monitor the sectors to ensure compliance with contracts and clauses. The Burundian Agency for Rural Electrification (ABER) was also implemented at the same time under decree No. 100/318; however it is still under establishment. ABER is to be responsible for electrification projects including small-scale hydropower, solar and wind projects.

Small hydropower sector overview and potential

Burundi is a landlocked nation; it is however, equipped with vast river resources, namely the Malagarasi (475 km) and the Ruzizi (117 km). The hydropower capacity of Burundi is 33.84 MW, not including the international Ruzizi I and II plants.[2] Burundi has 15.84 MW of installed small hydropower capacity if the definition of 10 MW is applied (figure 2). Direction Dénérale de l'Hydraulique et de l'Életrification (DGHER), now ABER, operates eight small- and micro-hydro plants in rural areas, while the non-governmental organizations (NGOs) and ABER *inter alia* operate another 12 micro hydro plants.[4]

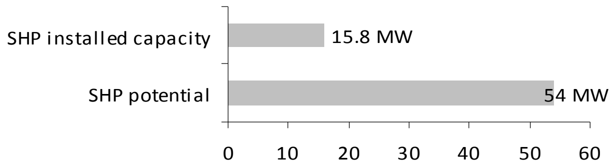

Figure 2 **Small hydropower capacities in Burundi**
Source: Based on author calculations and Burundi Ministry of Energy and Mines[2]

Installed small hydropower capacities in Burundi

Power Plant	*Installed capacity (MW)*	*Remarks*
Mugere	8.00	Refurbished 2003
Nyemanga	2.88	
Ruvyironza	1.50	Refurbished 2005
Gikonge	1.00	Refurbished 2005
Kayenzi	0.85	
Marangara	0.25	
Buhiga	0.24	
6 stand-alone plants	0.47	
12 private plants	0.65	

Sources: Sahiri and Mbazumutima[3], African Development Bank[4], Burundi Ministry of Energy and Mines[2].

In the 1980s, a study by Lahmeyer established that there were 41 potential hydropower sites for Burundi with a capacity of 1,700 MW, of which 300 MW were technically and economically feasible.[6] Recently, REGIDESO launched a study with a stepwise approach. Ten hydropower sites with capacities less than 10 MW, which had been identified in the 1980's master plan, were selected to be screened again. Pre-feasibility studies were conducted for four selected sites, followed by the feasibility study of two selected sites. A 2012-study showed that through optimization for most of the given sites, the real small hydropower potential is much higher than outlined in the master plan study. There have been 156 sites identified with potential of hydropower, out of which fewer than 30 have been explored.[2]

In the short term, the Government intends to develop small run-of-river hydropower plants. An ongoing World Bank project includes US$1.5 million pre-feasibility and feasibility studies of potential hydropower sites with capacities ranging between 1 MW and 7.5 MW, which could be connected to the grid at reasonable cost. It is assumed that these hydropower plants could be realized in approximately two years, considering that no major dam construction is required.[4]

Burundi has significant growth potential in agriculture, notably coffee, tea, and sugar.[1] Tea export itself accounts for 20 per cent of the total national export of Burundi. Members of the East African Tea Trade Association (EATTA) were selected for the initiative known as Greening the Tea Industry in East Africa (GTIEA) implemented by UNEP and the African Development Bank. The GTIEA aims to invest in small hydropower in order to reduce tea production energy costs, currently six small hydro projects are running in four EATTA countries with capacities of 10 MW each.[7]

Renewable energy policy

Renewable energy policies in Burundi were implemented after the Rio conference of 1992. August 2000 experienced the enactment of Law No. 1/014 on the liberalization and regulation of the water and electricity sector, officially removing the title of monopoly from the REGIDESO and allowing the import of energy from Rwanda and the Democratic Republic of Congo, and greater private and or public business participation.[2] The energy sector policy and the poverty reduction strategy, both implemented in 2006, aided in the popularization of renewable energy in Burundi. This then lead to the establishment of the regulator body of Ministry of Energy and Mines in late 2007, which are responsible for policy and regulation of the energy and water sectors.[2]

The recent years have also experienced policy implementations to further enhance renewable energy in Burundi. Year 2010 saw the realization of the presidential decree 100/80 on the structure and mission of the Government that places vital importance on renewable energy. The decree coupled with the Energy Strategy and Action Plan for Burundi (2011) provides a strong platform for the future of renewable energy in Burundi.

In addition to the decrees and other regulatory policies, Burundi has modified many economic instruments to ease process of foreign investment for renewable energy so that it can be executed within the country. Some of these reforms are discussed below.

Burundi has changed investment procedures to what the Government called a 'one-stop shop' effective from March 2012. The registration procedure requires no minimum capital requirements and investors are protected by easier methods to initiate lawsuits against harmful transactions within the country. Moreover, foreign investors are invited to be holders of local companies without an obligation for local participation.[2]

Law No. 1/23 enacted in 2008 defines tax benefits available for investors in Burundi. In addition to Law No. 1/23 an Investment Promotion Agency was created under decree No. 1/177 in 2009 to promote investment and exports within methods of compliance. Current tax benefits consist of, exemption from transfer tax upon acquisition of land and building and exemption from all custom duties from import and capital goods.[2]

A law for public private partnership (PPP) has recently been proposed to the parliament and is soon to be adopted by the Government of Burundi. The law states specific conditions under the term independent power producer (IPP).[2]

Barriers to small hydropower development

Civil conflict in the 1990s had prevented the development of the country's electricity generation infrastructure. Small hydropower development has been consequently affected.

The complex nature of the energy sector further hinders the growth of rural electrification and in turn small hydropower development. Overlapping responsibilities between ministries such as the Ministry of Energy and Mines, the Ministry of Communal Development and the Ministry of Development Planning and Finance (which is responsible for investment planning and coordination with foreign donors), slows down the growth process of small hydropower.[8]

Fiscal barriers to small hydropower development consist of a lack of incentive for foreign investments and high transportation costs for equipments based in the ports of Kenya and the United Republic of Tanzania.[7]

A major constraint is the lack of small hydropower surveys and data availability as a basis for implementation.[8]

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1.1.2 Ethiopia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	91,195,675[1]
Area	1,104,300 km[2]
Climate	Tropical monsoon with wide topographic-induced variation[1]
Topography	High plateau with central mountain range divided by Great Rift Valley[1]
Rain Pattern	Mean annual rainfall ranges from 2,000 mm over some pocket areas in the southwest highlands, and less than 250 mm in the lowlands. In general, annual precipitation ranges from 800 to 2,200 mm in the highlands (altitude >1,500 m) and varies from less than 200-800 mm in the lowlands (altitude <1,500 m).[2] Parts of Ethiopia have uni-modal and others bimodal rainfall patterns.

Electricity sector overview

In 2009, 89 per cent of Ethiopia's population lived in rural areas and rural electrification was estimated at a mere 2-per cent.[3] The Government of Ethiopia launched its Rural Electrification Strategy in 2002 as a large governmental programme for electrification, consisting of three parts: grid extension by the public utility, Ethiopian Electric Power Corporation (EEPCo), private sector led off-grid electrification and promotion of new energy sources.

The Rural Electrification Fund (REF) with its loan programmes for diesel-based and renewable energy-based projects is the main implementing institution. With an initial budget of €29 million, REF has been supporting 180-200 rural micro-hydropower and photovoltaic (PV) mini-grids for educational and health care facilities.[4] The fund provides loans up to 95 per cent of investment needs with a zero interest rate for renewable energy projects. Renewable energy technologies that receive support under this programme include solar PV, mini- and micro-hydro, and biomass co-generation.[3]

According to EEPCo, the number of electrified towns and rural villages has increased significantly in the last five years of the strategic plan period. By July 2011 it had reached a total number of 5,866, bringing the country's electricity access to 46 per cent.[5] In contrast, *World Energy Outlook 2011* reported Ethiopia's 2009 national electrification access as 17 per cent.[6] This difference is probably due to the different reference points and sources.

The EEPCo has two electricity supply systems: the Inter - Connected System (ICS) and the Self Contained System (SCS). The main energy source of ICS is hydropower plants and for the SCS the main sources are mini hydropower schemes and diesel power generators allocated in various areas across the country (figure 1).[5]

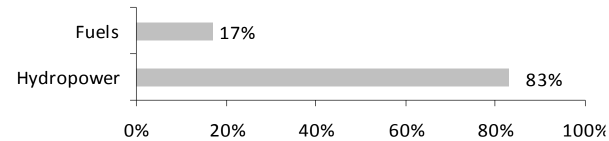

Figure 1 **Electricity generation in Ethiopia**
Source: Ministry of Energy and Mines[7]

Small hydropower sector overview and potential

According to a 2010-German Agency for Technical Cooperation Report, small- and micro-hydropower are not yet developed on a larger scale. Three small hydropower schemes exist in Yadot (0.35 MW), Dembi (0.8 MW) and Sor (5 MW) with a cumulative installed capacity of 6.15 MW (figure 2).[8]

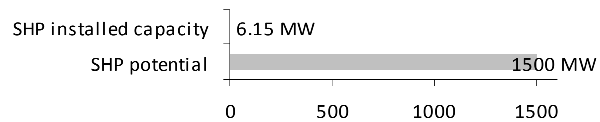

Figure 2 **Small hydropower capacities in Ethiopia**
Source: Shanko[8]

In February 2012, three micro hydropower plants with a cumulative capacity of 125 kW were inaugurated in the villages of Ererte, Gobecho and Hagara Sodicha in Sidama zone in the Southern Nations, Nationalities and the Peoples' Regional State (SNNPR). The plants were implemented in partnership with Sidama Mines, Water and Energy Agency, the Sidama Development Association and local communities, and with the support of the Energy Coordination Office of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).[9]

The Sor small hydropower plant has the potential to be expanded by an additional 5 MW. A feasibility study was undertaken in 1992 and another study conducted with the support of the United Nations Development Programme (UNDP) also calculated the same results.[10] The Supervisory Review and Evaluation Process (SREP) Strategic Draft Report plans to implement this development between 2012 and 2014 by updating the existing feasibility study; design and tender document preparation; installation of additional penstock and additional 5 MW third unit, construction of a rock-fill dam, construction of annexed hydraulic structures (spillway, bottom out late and connection structure at the headrace tunnel) and finally refurbishment of the existing two units.[10]

The following sites in Oromia region have been approved for REF financing: Aleltu (300 kW), Bello (192 kW), Bote (160 kW), Dila (480 kW) and Sonkole (260 kW).[8]

The theoretical potential of hydropower in Ethiopia is estimated to be 30,000–45,000 MW (160,000 GWh/year), with the estimated economically feasible hydropower potential ranging between 15,000 and 30,000 MW.[3] A large potential for mini hydro plants in areas which are remote to the grid but close to consumers seems to exist. More than 600 traditional hydro mills that could be used for hydropower have been identified. A database of hydropower resources and potential sites is being set up by the Ethiopian Government. Non-governmental organizations and churches are also active in the sector, but no private sector company has so far been involved.[3]

The potential for small- and micro-hydropower development is estimated to be 1,500-3,000 MW (10 per cent of the total hydropower potential in Ethiopia). It is limited by the seasonality of rainfall and reduced availability of water. Increased levels of small-scale irrigation farming, as a result of population growth, lead to increases in water needs.[9] In the early 1980s, over 70 micro hydropower potential sites were identified by the Ethiopian Rural Energy Development and Promotion Center (EREDPC) under the Ministry of Mines and Energy of Ethiopia, Ethiopian Evangelical Church Mekane Yesus and a team of experts from People's Republic of China. These sites are however lacking in socio-economic studies.[8]

Supported by GIZ, a south-south knowledge-transfer between Indonesia and Ethiopia started in 2008. Initial attempts have been made to set up local companies to produce micro-hydro equipment. However, most of the installed turbines and generators used are still being imported from abroad.[3]

Renewable energy policy

The Ministry of Mines and Energy (MME) is the leading ministry for national energy policy and expansion of electricity provision. The Ministry of Rural Development is involved in matters of rural electrification. The Ethiopian Energy Agency is the regulating agency for the electricity market and is responsible of price regulations, power purchase agreements, licensing of independent power producers and regulating access to the grid by private producers.[3]

The EREDPC, under the MME, have the mandate to promote renewable energy technologies, including micro-hydropower for rural areas.[3] It is a donor-funded institution.[3] The REF, which operates as part of the EREDPC of the Ethiopian Government, is an institutional focal point for the deployment of renewable energy technologies.[3]

Furthermore, a feed-in tariff (FIT) for renewable energies (now in the fourth draft) is under preparation by the electricity regulatory agency.[3]

The Government of Ethiopia has initiated the Climate-Resilient Green Economy (CRGE) initiative to protect the country against the adverse effects of climate change and to build a green economy that will help realize its ambition of reaching middle-income status before 2025. The CRGE foresees to develop up to 25,000 MW of Ethiopia's generation potential by 2030 (hydro 22,000 MW, geothermal 1,000 MW and wind 2,000 MW).[10]

Legislation on small hydropower

An environmental impact assessment is needed for all hydropower plants, but it is not enforced by the regulator for micro-hydropower projects. If the micro hydropower project is supported by a loan from the rural electrification fund then such assessment and approval from all neighbouring upstream and downstream countries is required (regulation by World Bank). Other requirements for off-grid plants and those connected to mini-grids are a distribution licence, which can be obtained from the regulator. Although rules are not transparent, the regulator is supporting this procedure. An investment licence is also required (except for cooperatives) and water rights have been checked by the Ministry (if the owner is not the community which normally already possesses the water rights).[3]

Barriers to small hydropower development

In order to boost the small hydropower capacity in Ethiopia, improvements can be made in the following areas:

- Despite a long history of micro hydropower in Ethiopia, local skills to manufacture, operate and maintain the plants are not well developed. The schemes built in the 1940s were fully controlled and managed by foreign experts.[8]
- Small- and micro-hydropower equipment and components are not available off-the-shelf in local market.
- Relatively low return on investment is currently discouraging individual private investment in small hydropower, but cooperatives with members that will benefit from getting access to electricity may be

potential developers, since their primary motive is not return on investment.[8]

- Competitive water uses and demand may prevent small hydropower development. An increasing population could create more demand for water by upstream users.[8]

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1.1.3 Kenya

Patrick Thaddayos Balla, Global Village Energy Partnership International, Kenya

Key facts

Population	43,013,341[1]
Area	580 367 km[2]
Climate	Varies from tropical along coast to arid in interior[1]
Topography	Low plains rise to central highlands bisected by Great Rift Valley; fertile plateau in west[1]
Rain Pattern	Two rainy seasons: March to May and October to early December.

Electricity sector overview

Electricity access in Kenya is estimated at 28.9 per cent.[i] Access in the Nairobi province is reported to be 53.47 per cent and in Central provinces 42.4 per cent.[2] These are the top two provinces in terms of electricity access. The provinces with lowest access to electricity are North Eastern province at 14 per cent and Western province at 14.7 per cent.[2] According to the National Information and Communication Technology Survey 2010, the grid is the main source of electricity with 25 per cent of households connected to it, while 15.3 per cent of the homes were connected to other types of electricity sources. Only 13 per cent of rural households are connected to the grid, compared to a 58-per cent of urban households that had their premises connected to the grid. A wide disparity was observed between urban and rural households not connected to any form of electricity.[3]

Electricity generation in Kenya is liberalized with hydropower dominating the electricity mix (figure 1). The combined installed capacity was 1,533 MW as of December 2011, with an estimation of 76 per cent by main power generating company, six independent power producers (IPPs) account for the balance.[4]

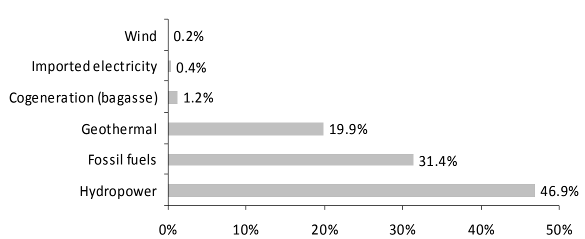

Figure 1 **Electricity generation in Kenya**
Source: Kenya Ministry of Energy[4]

Small hydropower sector overview and potential

Small hydropower technology has been harnessed for over a century in Kenya, mainly for grinding food grains and in a few cases for electricity. Until recently, there have been a few small-scale hydropower schemes mainly owned by missionaries and tea plantations, but the developers did not link this sector to local technical capacity development. Several small hydropower schemes are in operation by private entrepreneurs and communities for local consumption.

Interest in the development of small hydropower in Kenya has revived in the last 12 years, partly due to the inadequacies in the grid-based power supply, the technological push and increased awareness on the role of small hydropower in the country's electricity mix.[5] A number of projects have been planned or constructed by communities and the private sector in this period.

Since 2006, a new wave of small hydropower projects had been planned and commissioned, mostly by private tea companies (Unilever and James Finlay Tea) and Kenya Tea Development Agency (KTDA). Other private sector players and community NGOs are implementing a number of projects. With the introduction of the feed-in tariff (FIT) policy in 2008, small-scale candidate sites are likely to come up and serve well for the electricity supply of villages, small businesses or farms.

Table 1
Small hydropower schemes in Kenya

Scheme	*Ownership*	*Location (River)*	*Installed capacity (MW)*	*Year*
Tana 1 & 2	KenGen	Upper Tana	4.0000	1952
Tana 3	KenGen	Upper Tana	2.4000	1952
Tana 4	KenGen	Upper Tana	4.0000	1954
Tana 5	KenGen	Upper Tana	2.4000	1955
Tana 6	KenGen	Upper Tana	2.0000	1956
Ndula	KenGen	Thika River	2.0000	1924
Wanjii	KenGen	Maragua	7.4000	1955
Gogo	KenGen	Migori	2.0000	1952
Sagana	KenGen	Upper Tana	1.5000	1952
Mesco	KenGen	Maragua	0.3800	1919
Sosiani	KenGen	Sosiani	0.4000	1955
Tenwek	Tenwek Missionary Hospital	Bomet	0.3200	1987
Unilever	Unilever Tea Company	Kericho	2.2000	-
James Finlay	James Finlay Tea Company	Kericho	2.4000	1934-1999
Savani	Eastern Produce		0.0950	1927
Imenti Tea Factory	KTDA	Imenti river	0.9000	2009
Diguna	Missionary	-	0.4000	1997
Tungu Kabiru	Community	River Tungu	0.0140	2000
Mujwa	Missionary		0.0070	-
Thima	Community	Mukengeria	0.0020	2001
Kathamba	Community	Kathamba	0.0012	2001

Source: Republic of Kenya[6], Balla[5]

Notes: Listed are only operational schemes. KenGen - Kenya Electricity Generating Company, KTDA – Kenya Tea Development Agency.

Small hydropower schemes operating in Kenya comprise small (1-10 MW), micro (<10 MW) and pico (0.1-1 MW), hydropower. These have been developed by the Government, private sector, communities and missionaries.

Table 1 summarizes some of the documented small hydropower schemes implemented in Kenya, with a combined capacity of approximately 33 MW.

The KTDA has plans to construct 10 mini-hydropower plants with a total capacity of 22 MW. KTDA formed a new unit known as KTDA Power Co (KPC) to implement the power projects. Imenti tea factory managed by KTDA is already producing 0.9 MW and supplies about 0.6 MW to the national grid through the power purchase agreement (PPA) signed in June 2009.[7]

Tana River Development Authority (TARDA) is implementing seven mini hydro projects with 3.2 MW at a cost of €1.3 million, financed by the European Union.[8] German Agency for Technical Cooperation (GTZ), Kenya Industrial Research and Development Institute and the Nairobi-based NGO Green Power has been involved in mapping of mini-hydro electricity generation potential, and pre-feasibility studies of 14 potential sites in Western Kenya. Green Power has also been involved in the development of 17 micro hydropower plants in the Kirinyaga district. The sites are at different stages of implementation.

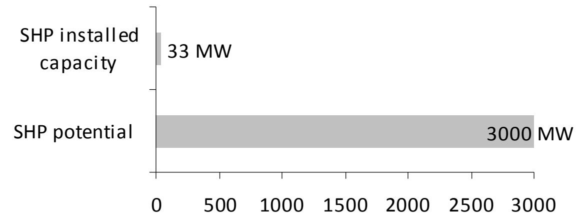

Figure 2 **Small hydropower capacities in Kenya**
Source: Balla[5], Government of Kenya[9]

The overall hydropower potential of Kenya, estimated in 1991, amounts to approximately 30,000 GWh/year, representing 6,000 MW of installed capacity. It is also estimated that almost over half the potential is attributable to small rivers. The energy bill company estimates small hydropower potential to be 3,000 MW (figure 2).[9] The potential small hydropower sites are mainly located in the south-west of Kenya (Lake Victoria drainage basin in Nyanza and Western Provinces and adjacent districts of Rift Valley Province); southwest of Mount Kenya – Aberdare Mountains (Central Province, Mt. Kenya adjoining districts of Eastern Province and Laikipia District of Rift Valley Province). The small hydropower potential is concentrated in districts with high population density and high energy demand thus providing favourable conditions for the deployment of small hydropower on a commercial basis.[8]

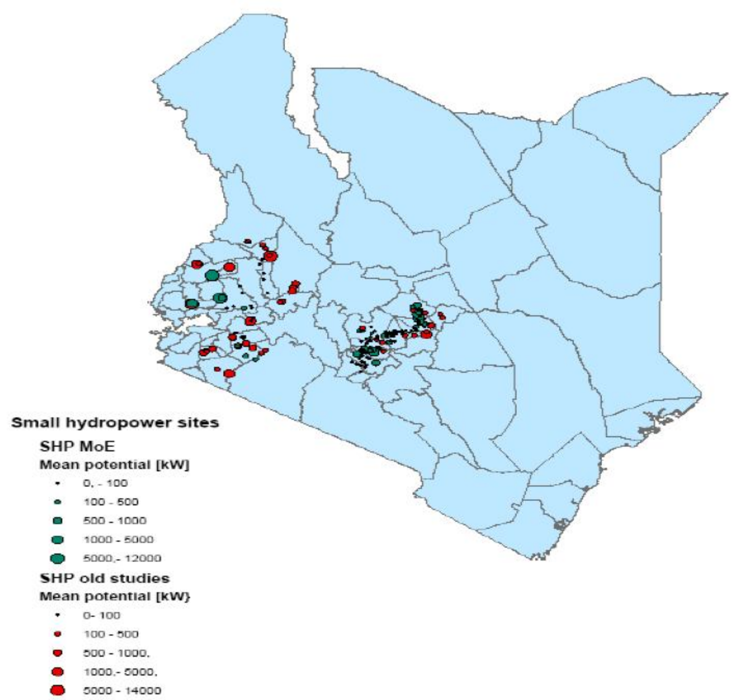

Figure 3 **Small Hydropower schemes in Kenya**
Source: Kenya, Ministry of Energy[4]
Notes: Schemes include currently investigated and or implemented.

Renewable energy policy

In Energy Act of 2006 and the FIT policy, there is a commitment to promote electricity generation from renewable energy sources. The Government intends to set up a Green Energy Fund Facility under the National Task Force on Accelerated Development of Green Energy with the purpose to lend funds to viable Renewable Energy projects at concessional rates.[6] The National Renewable Energy Development Strategy, as set in the Least Cost Power Development Plan (LCPDP), Rural Electrification Master Plan, the Kenya National Climate Change Response Strategy and Kenya Vision 2030, reiterates the commitment to accelerate the use of renewable energy.[10]

Legislation on small hydropower

The Kenyan Government, through the Ministry of Energy, supports small hydropower by continuously collecting hydrological data, undertaking pre-feasibility and feasibility studies of viable sites, enabling dissemination of information on small hydropower. It is also creating investor and consumer awareness on the economic potential offered as an alternative source of energy and is implementing community-based pilot projects where feasible to promote acceptance. In 2008, a FIT policy (revised in January 2010) was developed to attract investment and development of small and mini hydropower plants.[11]

Table 2
Small hydropower feed-in tariffs in Kenya

	Plant capacity (MW)	*Maximum firm power tariff (US$/kWh) at the interconnection point*	*Maximum non-firm power tariff (US$/kWh) at the interconnection point*
Small hydro	0.50-0.99	0.12	0.10
	1.00-5.00	0.10	0.08
	5.10–100	0.08	0.06

Sources: Scaling up Renewable Energy Programme[12], Republic of Kenya[6], Kenya Institute for Public Policy Research and Analysis[2]

A stepped fixed FIT applies to electricity generated from small hydropower and supplied in bulk to the grid operator at the interconnection point, as shown in table 2. The tariffs are granted for 20 years from the date of commissioning of the small hydropower plant. The firm power tariff applies to the first 150 MW of small hydro, firm power generating stations developed in the country. The non-firm power tariff applies to the first 50 MW of small hydro non-firm power generating stations developed in the country. The tariff applies to individual small hydropower plants with effective generation capacity not exceeding 10 MW.

IPPs are taking advantage of the FIT to generate and sell power. Previously, none of the IPPs generated power using hydro, but Imenti mini hydro has been the first IPP to generate and sell power to the national grid. According to the LCPDP revised document of 2011, about 19 expression of interest have been received at Energy Regulatory Commission of which 16 have been approved giving an expected capacity of 81 MW. Only two have negotiated a PPA and out the two only one, a 0.9 MW plant, has started generating electricity.

The Government is removing existing legal and regulatory barriers and has amended the Electric Power Act of 1997 to allow vertically integrated mini-grid systems for rural electrification using small hydropower even in areas where licences have been issued to the public electricity supplier.[13] For capacities between 100 and 3,000 kW permits for generation are required, rather than licences. For capacities lower than 100 kW, no permit will be required.[14] Other strategies include:

- Promoting research, development, and demonstration of the manufacture of cost effective small hydro technologies;
- Removing duties on imported small hydropower hardware;
- Formulating and enforcing standards and codes of practice on small hydropower to safeguard consumer interests;
- Promoting development of local capacity for manufacture, installation, maintenance and operation of small hydropower technologies hydropower turbines;
- Providing tax incentives to producers of small hydropower technologies and related accessories;
- Providing fiscal incentives to financial institutions that offer credit facilities for the development of small hydropower schemes.

Barriers to small hydropower development

In order to encourage the development of small hydropower in the country, the following areas can be improved:

- High installation cost averaging US$3,000 per kW, inadequate hydrological data, the effects of climate change, deforestation and degradation of water catchments areas, and the limited local capacity and infrastructure to manufacture small hydro components combined impede development of small-scale hydropower in Kenya.
- Electro-mechanical equipment for the small hydropower schemes has to be imported from other countries, especially Asia and Europe.

- Financial institutions are not willing to lend the whole small hydropower project amount upfront because of high risks associated with funding community projects, hence hindering development at this level. Also, for community-managed small hydropower schemes, maintenance and management remains a challenge.

Note

i. According to the *World Energy Outlook 2011*, electricity access for Kenya is reported to be 16.1 per cent.

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1.1.4 Madagascar

Lara Esser, International Center on Small Hydro Power

Key facts

Population	22,005,222[1]
Area	587,041 km[2]
Climate	Tropical climate along the coast, temperate in the inland and arid in the south. The wet season is from the end of December to April. River discharge decreases gradually after April. The dry season starts in the middle of October and continues to the end of December, during which the output of most hydropower plants decreases.[1]
Topography	The island has a high plateau and mountains in its centre, with narrow coastal plains.
Rain Pattern	Most rain falls during summer (November to April), with rainfall during winter (May to October) restricted to the southern and eastern coasts. In the south rainfall may remain low (on average less than 800 mm each year), in contrast to regions in the northeast of the country which on average receive more than 3,500 mm of annual rainfall.[2]

Electricity sector overview

Information on the country's electrification rate varies. According to the German Agency for Technical Cooperation-Poverty-Oriented Basic Energy Services-European Union Energy Initiative (GTZ-HERA-EUEI) - and as of 2010, the electrification rate in Madagascar was about 23 per cent with a large difference between urban areas (rate above 60 per cent) and rural areas (less than 10 per cent).[3] According to the Rural Electrification Agency, the national electrification rate was 10.56 per cent in urban areas and 4.07 per cent in rural areas.[4] There are three grids in the country: Antananarivo Grid, Toamasina Grid and Fianarantsoa Grid.[5] The majority of electricity is generated using hydropower (figure 1).

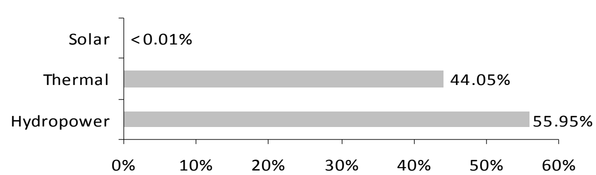

Figure 1 **Electricity generation in Madagascar**
Source: Jiro sy Rano Malagasy[6]
Note: Data from 2010.

Since 2004, the fully state-owned utility responsible for the provision of electricity and water services in the country has ceded its electricity activities to the Rural Electrification Agency (REA). REA decided to promote private sector participation in rural electrification and developed local energy plans with the aim of providing electricity to the entire country by the end of 2010.[3] It offers a maximum of 70 per cent of investment costs to private operators, who contribute the remainder and receive the concession to utilize the plant for 10-20 years.[3] Local commercial banks are also interested to partially finance small hydropower projects and could provide approximately 30-60 per cent of the investment costs.[3]

The Ministry of Energy and Mines (MEM) is the authority having jurisdiction over the energy sector, taking charge of the investment and the development strategy policy, including foreign assistance requests. MEM issues permits for plants larger than 1 MW. Smaller plants are handled by the REA.[3] The electricity sector is regulated under the Office de Régulation de l'Electricité (ORE).

JIRAMA (Jiro sy Rano Malagasy), the state-managed company that provides electricity and water services takes charge of the technical aspects of the power sector.[5] It operates and maintains power stations, transmission and distribution lines in the comparatively widespread electrification region, and obtains its income from the sale of electricity.[7] In general, the majority of electric power plants are operated by JIRAMA, and the rest by the private power utility companies. In the past years, about 50 small new electrification projects were realized by private companies.[7]

Small hydropower sector overview and potential

There is no database for the installed small hydropower plants in Madagascar. According to the REA, there are four plants with a total installed capacity of 22.51 MW (figure 2).[4] All of them need renovation, since they were commissioned averagely 25 years ago.

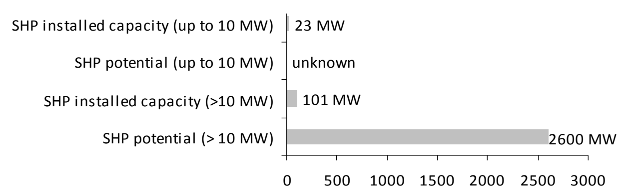

Figure 2 **Small hydropower capacities in Madagascar**
Source: Rakotoarimanana[4]

In 2006, the REA as part of its objective to promote renewable energy projects sponsored seven small hydropower plants which are located in a radius of not more than 120 km of the capital Antananarivo.[4]

Table 1

Installed small hydropower capacity in Madagascar

Date	*Town/ Village*	*District*	*Region*	*Operator*	*Production mode*	*Installed capacity*	
						THER (kVA)	*RE (kW)*
1986	Sahamadio	Fandriana	Amoroni Mania	JIRAFI	MHP + GE	275	160
1992	Milamaina	Fandriana	Amoroni Mania	JIRAFI	MHP + GE	..	..
2003	Antetezambato	Ambositra	Amoroni Mania	ADITSARA	MHP	..	53
2003	Mangamila	Anjozorobe	Analamanga	ELEC /EAU	MHP	15	85
2003	Ranotsara Nord	Iakora	Ihorombe	VITASOA	MHP	..	25
2005	Imerimandroso	Ambatondrazaka	Alaotra Mangoro	SAEE	GE + MHP	60	..
2006	Ankililoaka	Toliara II	Atsimo Andrefana	SM3E	GE + MHP	..	..
2006	Morarano	Amparafaravola	Alaotra Mangoro		MCH + GE	..	..
2006	Amparihints	Ambatondrazaka	Alaotra Mangoro	SAEE	GE + MHP	30	..
2006	Andromba	Ambatondrazaka	Alaotra Mangoro	SAEE	GE + MHP	45	..
2006	Andrebakely	Ambatondrazaka	Alaotra Mangoro	SAEE	GE + MHP	30	..
2006	Vohimena	Ambatondrazaka	Alaotra Mangoro	SAEE	GE + MHP	40	..

Source: United Nations Industrial Development Organisation[8]

Note: MHP – micro hydropower, GE – diesel generator. THER – thermal, kVA – kilovolt ampere, RE – renewable energy

Table 1 shows some of the installed small hydropower in the country.

The theoretical overall hydropower potential of Madagascar has been estimated at 7,000 GW of installed capacity.[5] The economically feasible potential has not yet been determined. According to a questionnaire sent to REA, the small hydropower potential was evaluated in 2010 and the gross potential was 5,600 MW, technical potential 3,200 MW and economically feasible potential was 2,600 MW. The definition used however to define small hydropower was >10 MW.[4] A desktop study by German Agency for Technical Cooperation-Promotion of Rural Electrification by Renewable Energies (GTZ-PERER) assembled a data set of at least 700 potential sites, but the technical and economic potential can be expected to be far lower.[3]

Table 2

Small hydropower potential in Madagascar

Study source	*Potential capacity (MW)*	*Range of sites*	*Number of plants*
ADER[a]	>150.00	19 kW – 10 MW	60
MEM[b]	48.19	40 kW - 6.5 MW	28

Source:

a. Leutwiler[7]

b. NewJec [5]

Note: ADER - Agence pour le Développement de l'Electrification Rurale, MEM - Madagascar Ministry of Enyerg and Mines

There are about 60 potential small hydropower sites ranging between 19 kW and 10 MW in capacity, with a total potential of more than 150 MW. According to the NewJec Report in 2009, 48.19 MW capacity of small hydropower potential was available in Madagascar, with a potential electricity production of 398.28 GWh/year.[7]

GTZ-PERER also supported a large project where 50 small hydropower feasibility studies were to be concluded by the end of 2010. The project activities are linked with the introduction of the software Geosim to establish regional energy investment plans and prioritize sites on the basis of demand and accessibility; however up-to-date information is not available.[3]

In the Sava Region of North Eastern Madagascar, Electricité de Madagascar had finalized the feasibility study for a mini-hydropower plant and distribution networks to be implemented in the Lokoho river basin, in order to supply electricity to the two small towns of Andapa and Sambava and surrounding rural villages.[9] The project would have provided electrical power of up to 6 MW to the surrounding areas if the small hydropower generators had been replaced. However a political crisis in Madagascar occurred in 2009 during which Electricité de Madagascar planned to launch its tenders, since then the project has been frozen.[10]

The hydropower development programme (Programme rivière 2008-2012) aimed to supply eight rural communities with a total of 14,000 inhabitants with electricity from micro-hydropower. The programme included the design and testing of mechanisms in the sector ‘small autonomous networks’ adapted to the rural world, with the active participation of local actors, e.g. Malagasy entrepreneurs involved in the manufacturing of turbines. These innovations in different regions should then serve as benchmark demonstrations.[7]

Some agricultural projects in Madagascar need large amounts of energy, mostly for pumping water for irrigation and feeding ponds for shrimp farming. The option to use hydropower instead of diesel engines is in discussion. Similar projects are being developed for mining sites.[7]

There are currently two local turbine manufacturers in Madagascar: AIDER and Vitasoa, who manufacture Banki and Pelton turbines with a capacity of up to 30 kW. Because of limitations in technical expertise in the country, large turbines and all generators are imported.[3]

Renewable energy policy

The MEM has a policy to promote the development of the abundant renewable energy potentials for rural electrification to replace the existing diesel thermal power plants with renewable energy systems such as small or micro hydropower plants. In 2009, MEM was preparing a power source development plan in cooperation with the ORE.[5]

Barriers to small hydropower development

Lack of funding for private investments and lack of a transparent model for commercialization are important small hydropower development barriers. The fact that the country does not have an electricity network is another barrier to small hydropower development. At least in the coming decade, small hydropower projects will typically not feed into a grid, which is detrimental to the financial viability of these types of projects.[3]

A feed-in tariff (FIT) is neither in place nor on the current policy agenda. JIRAMA has been reluctant to offer favourable FITs.[11] Only two operators of small hydropower plants have managed to conclude individual feed-in contracts with JIRAMA on the basis of a 10-years tenure and a rather low FIT, of approximately €0.04 per kWh.[3]

The other barriers to the development of small hydropower in rural areas are:[7]

- long distance between consumption points and potential sites;
- low population density and low electricity demand;
- low utilization factor;
- prohibitive high capital costs;
- lack of capital and liquidity by entrepreneurs.

Furthermore, economic potential sites for energy production with high heads, which are favourable for development, are located in isolated areas what considerable increases transport costs.[6] Easily accessible sites tend to have low heads and therefore, they are technically and economically less attractive. Site selection among alternatives (i.e. high vs. low head, large vs. small sites) are ultimately political decisions, considering the social and economic synergies and ecological impacts, according to different sites in question, especially given a systemic development of the landscape. Low institutional capacity and experience to manage a strategic resource, such as water, is also a challenge.[6]

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1.1.5 Malawi

Diliza Wanyavinkhumbo Nyasulu, SunPower Technologies, Malawi

Key facts

Population	16,323,044[1]
Area	118,484 km[2]
Climate	Sub-tropical climate, relatively dry and strongly seasonal
Topography	Narrow elongated plateau with rolling plains, rounded hills, some mountains[1]
Rain Pattern	Rainy and dry season exist. The warm-wet season stretches from November to April, during which 95% of the annual precipitation takes place. Annual average rainfall varies from 725 mm to 2,500 mm.[2]

Electricity sector overview

Only an estimated seven per cent of the population in Malawi has access to electricity, even then it is often supplied in a shortage manner with frequent blackouts.[3] The country is experiencing an increased demand for energy which is often met by the use of biomass although Malawi is endowed with a considerable access to alternative energy resources. These include solar, wind, hydro and low yield geothermal resources.[3] Nearly all of Malawi's electricity is generated from hydropower (figure 1).

Malawi experiences power outages caused by prolonged load shedding, which is negatively impacting the productivity of industries that heavily rely on power supply from Electricity Supply Corporation of Malawi (ESCOM).[4] The national utility, ESCOM is the sole provider of electricity in Malawi. It is currently running a project to interconnect its power system with the Southern African Power Pool (SAPP) through interconnection with Mozambique's power system.[5]

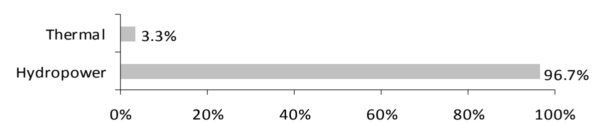

Figure 1 **Electricity generation in Malawi**
Source: Malawi Government Ministry of Natural Resources, Energy and Environment[6]

Small hydropower sector overview and potential

There is one working small hydropower plant of 4.5 MW, which is run by ESCOM. Missionaries, tea estates and lately development partners such as Practical Action contribute with 1.3 MW to off-grid supply (figure 2).[7]

Small hydropower potential in Malawi

District	*Target site*	*Distance from grid (Km)*	*River*	*Estimated flow (m^3/s)*	*Estimated capacity (kW)*
Chitipa	Chisenga	35	Chisenga	0.10	15
Chitipa	Mulembe	35	Kakasu	0.10	15
Chitipa	Nthalire	102	Choyoti	0.20	60
Rumphi	Katowo	45	Hewe	0.20	45
Rumphi	Nchenachena	23	Nchenachena	0.20	30
Nkhatabay	Khondowe	-	Murwezi	0.05	5
Nkhatabay	Ruarwe	-	Lizunkhuni	0.15	50
Nkhatabay	Usisya	50	Sasasa	0.10	20
Mangochi	Kwisimba	38	Ngapani	0.05	5
Mangochi	Katema	23	Mtemankhokwe	0.10	25
Thyolo	Sandama	6	Nswazi	1.00	75

Source: Tokyo Electric Power Services Company[8]

The development of the small hydropower potential sites (table) in Malawi has been slow. The very first development was done by missionaries. However, these sites are no longer in operation due to the lack of maintenance by their owners as well as their limited financial and technical capacity to replace worn out parts. This is because many plants were constructed by overseas companies that also manufactured the plant components and are now non-existent. Some of the small hydropower plants that are not working belong to the utility company, ESCOM, while others belong to the Church.

On the other hand, it is important to note that a considerable number of micro hydropower plants are still functioning in Malawi, such as Livingstonia micro hydropower in Rumphi, Wovwe mini hydro plant in Karonga, Mteso pico hydropower in Chikangawa and Bondo Village and a micro hydropower plant in Mulanje.

There is community-driven micro hydropower development in the rural location of Northern Malawi, District of Nkhatabay. As of 2011, another micro hydropower plant is being developed, for the community by the Mulanje Renewable Energy Agency in the district of Mulanje. The Agency is constructing a 75-kW micro hydropower plant at the Lichenya River, in the Mulanje district. Construction is in its final phase.[9]

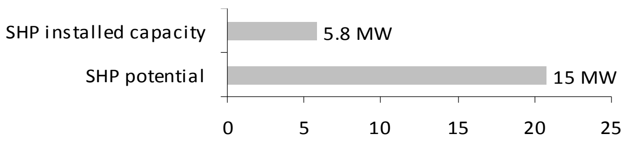

Figure 2 **Small hydropower capacities in Malawi**
Source: Kaunda[7], Government of Malawi[10]

A small hydropower feasibility study determined that Mulunguzi has a power potential of 2 MW. The study was carried out with the assistance from the German Government. In addition, the Malawi Industrial Research and Technology Training Centre have also been researching on small hydropower in the country.

Renewable energy policy

The Department of Energy Affairs in 1999 established the National Sustainable and Renewable Energy Programme (NSREP) as a platform to promote renewable energy technology. The main project under NSREP is the Promotion of Alternative Energy Sources Project (PAESP) which is, however, limited by a lack of funding resources.[6]

The Government of Malawi has recently made strides towards a more pragmatic approach to the energy sector. This resulted in the realization of the Malawi Biomass Energy Strategy (BEST) of 2009. The BEST report states the need to make the bio energy sector more sustainable through incentives for alternative means i.e. green energy. The 2003 National Energy Policy of Malawi, the Malawi Energy Regulation Act (2004) and other legal instruments have given way to a freer market for electricity generation and distribution by removing monopoly previously held by ESCOM.[6]

Energy regulation in Malawi is controlled by the Government-establish Energy Regulatory Authority (MERA) in 2004. However, the MERA is to be superseded by the Malawi Water Energy Regulatory Authority (MWERA).[6]

Legislation on small hydropower

Malawi National Energy Policy (2003) has been the cornerstone of renewable energy in the country.[11] Other Renewable Energy Sources Industry Strategy has been based on the aforementioned policy, encompassing the promotion of renewable energy sources in Malawi, including small hydropower.

Barriers to small hydropower development

Hydropower is the major source of power for Malawi. However, it is being affected by environmental degradation due to farming activities in upstream rivers, as well as by deforestation due to firewood and charcoal production. Moreover, climate change has a significant impact on small hydropower resources as rivers continue to dry up. The need to update inventories on micro hydropower such as that produced by the Japan International Cooperation Agency is required to track the changes of environmental degradation on small hydropower potential.

The major barrier for small hydropower development in Malawi is the limited financial capacity. There are no private investors interested in the development of small hydropower stations in Malawi. The donors are also not forthcoming for the utilization of small hydropower to benefit local communities. To help overcome these barriers, the Government intends to conduct feasibility studies on a number of rivers using its own funds, and later make available the information to potential investors of small hydropower as an independent power producer.

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1.1.6 Mauritius

Lara Esser, International Center on Small Hydro Power

Key facts

Population	1,313,095[1]
Area	2.040 km^2.
Climate	Tropical, with warm, dry winters (May to November) and hot, wet, humid summers (November to May)
Topography	Small coastal plain rising to discontinuous mountains encircling central plateau[1]
Rain Pattern	Long term mean annual rainfall (1971-2000) over the Island is 2,010 mm. Wettest months: February and March. Driest month: October. Mean summer rainfall is 1,344 mm, which is 67% of the annual amount over the Island. Mean winter rainfall is 666 mm. Although there is no marked rainy season, most of the rainfall occurs in summer months.[2]

Electricity sector overview

Electrification rate in Mauritius is 99.4 per cent: 100 per cent in urban areas and 99 per cent in rural areas.[3] Its total installed electricity generation capacity was 740.2 MW in 2010 (annual generation 2688.7 GWh/ year).[3] The annual electricity generation from hydro-power was 100.7 GWh/year.[3] Installed hydropower generation capacity is 59 MW (two large and six small hydropower plants).[3]

Mauritius's electricity is produced by the Central Electricity Board (CEB) and independent power producers (IPPs). In 2008, IPPs contributed 52.27 per cent of the electricity based on thermal sources (i.e. coal and bagasse) which dominate the Mauritian electricity generation (figure1).[4]

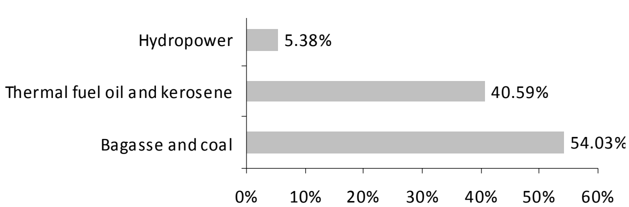

Figure 1 **Electricity generation in Mauritius**
Source: Central Electricity Board[4]
Note: Data from 2008.

Small hydropower sector overview and potential

The classification of small hydropower in Mauritius is quite different from the generally accepted 10-MW capacity value, defining small hydropower up to 50 kW only.

In light of the 10-MW small hydropower definitions, there were only six small hydropower plants in Mauritius in 2010 with a combined capacity of 8.7 MW, which produced 15.2 GWh/year (figure 2). On average the small hydropower plants are over 45 years, in 2008 two of the plants were fully refurbished. One plant was commissioned in 2010 and five of the plants are more than 50 years old.[3]

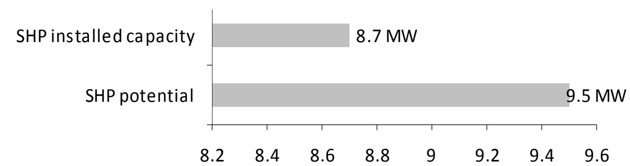

Figure 2 **Small hydropower capacities in Mauritius**
Source: Mauritius, Ministry of Energy and Public Utilities[3]

The large scale hydropower potential of the country has been almost fully tapped. Nevertheless, the Government's long-term strategy encourages the set-up of mini hydropower schemes where economically viable. Additional small hydropower capacity is to be completed by 2015 including one unit at Midlands Dam (0.375 MW) and one unit at the Bagatelle Dam (0.375 MW).[3]

Renewable energy policy

The Mauritian Government aims to have a 24-per cent share of total electricity production from renewable energy sources by 2015, 28 per cent by 2020 and 35 per cent by 2025. Small hydropower should have a share of 3 per cent by 2020 and 2 per cent by 2025.[3]

Legislation on small hydropower

All power-generation projects are subject to an environmental impact assessment (EIA). However, for hydropower projects with capacity up to 50 kW, an EIA waiver may be sought in writing from the EIA department of the Ministry of Environment and Sustainable Development.[3]

Feed-in tariffs (FIT) subsidized by the Government under the Small Scale Distributed Generation (SSDG) scheme support the development of small hydropower.

The Small Scale Distributed Generation (SSDG) scheme was launched in December 2010 to provide an incentive for electricity generation for personal consumption via renewable resources for a total capacity of 2 MW. This target was met in May 2011 thus encouraging the second phase of the SSDG project under which FITs for a further 1 MW were allocated specifically in 2013:[5]

- 100 kW from PV's in residential (50 kW), commercial and industrial (50 kW) sectors in Rodrigues.
- 900 kW from wind, solar and hydropower in Mauritius.

The FIT costs of various renewable sources are decrypted in the table below.

Tariff for renewable resources in Mauritius, over a period of 15 years

Tariff for 15 years	*Wind (Rs/kWh)*	*Hydro (Rs/kWh)*	*Photovoltaic (Rs/kWh)*
Micro (up to 2.5 kW)	20	15	25
Mini (2.5 - 10 kW)	15	15	20
Small (10 - 50 kW)	10	10	15

Source: Central Electricity Board[5]

However, from 6 May 2011 onwards no new applications for a FIT will be accepted as the target of 2 MW and thereafter 1 MW have been met. The CEB is currently examining the applications received to assess the compliance with the Grid Code provided.[6]

Barriers to small hydropower development

According to the Ministry of Energy and Public Utilities, the following are obstacles for small hydropower development: restricted catchment areas, lack of road access to sites, seasonal fluctuations in water flow, high installation costs, relatively flat island topography and very competitive use of water.[3]

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1.1.7 Mozambique

Wim Jonker Klunne, Council for Scientific and Industrial Research, South Africa

Key facts

Population	23,515,934[1]
Area	799,380 km^2
Climate	Tropical to subtropical
Topography	Mostly coastal lowlands, uplands in center, high plateaus in northwest, mountains in west[1]
Rain Pattern	Mean annual rainfall is between 800 to 1,000 mm at the coastal strip, it declines to less than 400 mm in the dry interior bordering Zimbabwe.[1]

Electricity sector overview

The total installed electricity capacity in Mozambique is 2.308 GW in 2009, nearly all generated exclusively from hydropower (99.7 per cent). Mozambique has large reserves of coal. There are utilizable reserves of natural gas that might be as high as 3 trillion cubic feet. Natural gas is exported to South Africa via a pipeline.

The current electricity generation in Mozambique is dominated by hydropower which supplies 95 per cent of the electricity demand followed by 5 per cent supplied via various thermal alternatives (figure 1).

Mozambique is a net exporter of electricity: 73.44 per cent of the 2,075 MW generated by the company, Hidroelectrica de Cahora Bassa (HCB) is exported to South Africa.

The country's electrification access is 14 per cent, estimated at 26 per cent in urban areas and 5 per cent in rural areas. In the latter, kerosene is the main fuel for lighting. The State-owned utility Electricidade de Mozambique (EDM) prepared a Master Plan for the expansion of the country's national power grid and distribution networks with the goal of reaching 15 per cent of the population by 2020, a target that had been achieved in 2010.[2]

In Mozambique's Plan for the Reduction of Absolute Poverty II (PARPA II), the Government has affirmed the critical role of the energy sector in reducing poverty. The importance of the energy sector is also emphasized in the World Bank's 2008–2011 Country Partnership Strategy (CPS), which identifies adequate access to energy resources and services as a key driver of economic growth and poverty alleviation. The CPS prioritizes the provision of energy services to rural schools, administrative posts, hospitals and clinics. At present, energy-related goals set in PARPA II are being turned into strategies such as the Off-grid and Renewable Energy Strategy, Generation and Transmission Master Plan, North–South (Backbone) Transmission Least-Cost Study, and National Biofuels Strategy.[3]

The major players in the supply of electricity in Mozambique are EDM, the state-owned power utility, HCB and MoTraCo.[4] EDM is involved in all parts of the electricity supply chain, including some generation (although it is not the primary generator in the country), transmission, distribution, and consumer connection, supply and billing.

HCB manages and operates the Cahora Bassa hydropower stations and their associated transmission networks that supply power to the Southern African Power Pool (SAPP). The installed capacity of 2,075 MW at the Cahora Bassa dam makes this the primary electricity source for both Mozambique and Southern Africa as a whole.[5]

MoTraCo is the third major supplier of electricity in Mozambique and it's a joint venture company formed by the state power companies in Mozambique, South Africa and Swaziland to transport power from South Africa to the Maputo-based Mozambique Aluminium Smelter (Mozal) plant. The company manages transmission lines in these three countries and was created in 1998 through an equity debt arrangement worth US$120 million.

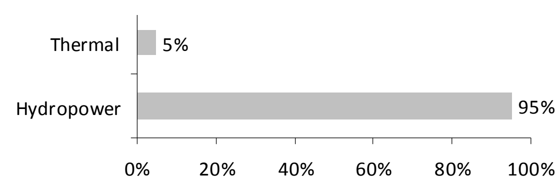

Figure 1 **Electricity generation in Mozambique**
Source: Electricidade de Mozambique[6]

Small hydropower sector overview and potential

Mozambique's greatest hydropower potential lies in the Zambezi River basin at sites such as Cahora Bassa North and Mphanda Nkuwa. So far, about 2,200 MW of generating capacity have been developed. In addition, the potential for small hydropower projects of 190 MW, which includes 6 MW of micro hydropower (plant capacity lower than 2 MW), 18 MW of mini hydro (capacities between 2 MW and 6 MW) and 166 MW of small hydropower (capacities between 8 MW and 15 MW). Potential sites for these micro hydropower schemes are located in the mountainous terrain and perennial streams and rivers of Manica, Tete and Niassa provinces.[3]

A study on medium-sized and large plants reveals that the small hydropower potential is very high in the Central (Sofala, Manica and Zambézia provinces) and Northern (Nampula, Cabo Delgado and Niassa provinces) parts of the country. The South (Maputo, Gaza and Inhambane provinces) is relatively poor in hydropower resources for energy generation. The tea-producing areas, which are concentrated in the districts of Gurue, Ile, Milange and Lugela in Zambézia Province, also have high potential hydropower resources, according to an energy survey undertaken by the National Energy Fund (FUNAE) in 2004. An Intermediate Technology Development Group (ITDG) publication gives an overview of micro hydropower potential in Mozambique, especially in Manica Province, while a scoping study for micro hydropower investments in the provinces of Manica, Niassa and Tete undertaken by ITDG for the Energy Reform and Access Project of the World Bank, identifies the critical issues in developing the hydropower sector.[7 8]

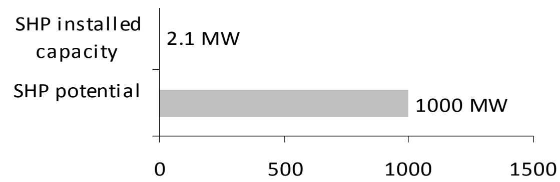

Figure 2 **Small hydropower capacities in Mozambique**
Source: Hankins[4]
Note: The potential may include plants larger than 10 MW and is different than other sources.

In the Policy for Renewable Energy and Master Plan for Off-Grid Electrification, a list of 60 identified hydropower locations is provided.[9] The Department of Energy estimates that over 60 potential micro- and mini-hydropower projects with a potential of up to 1,000 MW exist in the country. The central part of the country (Manica Province) has the best resources (table 1).[4]

Table 1
Government hydropower projects in Mozambique

Project	*Installed capacity (kW)*	*River*	*Pre-feasibility*	*Distance to nearest village (km)*	*Location (District, province)*
Mbahu	2 000	Lucheringo	Yes	30.0	Lichinga, Niassa
Majaua	1 000	Majaua	Yes	-	Milange, Zambezia
Kazula	30	Lazula	Yes	~12.0	Chiuta, Tete
Maue	280	Maue	Yes	~1.0	Angonia, Tete
Mavonde	30	Nhamukwarara	-	3.0	Manica,Manica
Rotanda	30	Rotanda	Yes	~1.5	Sussundenga, Manica
Sembezeia	30	Bonde	-	2.0	Sussundenga, Manica
Honde	75	Mussambizi	Yes	4.0	Barue, Manica
Choa	20	Nhamutsawa	-	~2.5	Barue, Manica

Source: Hankins[4]

Currently six hydro stations are connected to the national grid (table 2), while a substantial number of off-grid systems do exist.

Table 2
Grid connected hydropower stations in Mozambique

Name	*Province*	*Capacity (MW)*
Cahora Bassa	Tete	2 075.00
Mavuzi	Sofala	52.00
Chicamba	Manica	38.40
Corrumana	Maputo	16.60
Cuamba	Niassa	1.10
Lichinga	Niassa	0.75

Source: KPMG[9]

There is a growing interest in Mozambique to promote the use of small-scale hydropower schemes for isolated rural communities. One example of this is the Honde scheme, in the Province of Manica (Bárue District). The project started in 2005 and is able to electrify a 200-household village, a health centre, a school, two maize mills and shops, all by a micro hydropower plant on the Muzambizi River. The total demand was determined to be 65 kW and the scheme was sized at 75 kW taking into account of the demand growth. The project is being implemented by the provincial government of Manica, with support from the German Agency for Technical Cooperation GTZ (now Deutsche Gesellschaft für Internationale Zusammenarbeit - GIZ) .[9]

Besides the national Government of Mozambique, a number of NGOs and bi-lateral donors are active in the micro hydropower field. Practical Action and their Mozambican counterpart Kwaedza Sumukai Manica (KSM) are developing village electrification projects following what they called the 'generator model'. This model is built around a private entrepreneur generating electricity for the community, while the local transmission and distribution infrastructure will be owned by the community.[10] The GIZ has also worked with local entrepreneurs to extend their business from milling to local electricity distribution and has upgraded three systems, supporting local production of turbines. GIZ is currently assisting local education institutes in Chimoio, Manica province, to set up a local hydropower training and knowledge centre.[11 12 13]

Renewable energy policy

The reforms in the energy sector have created the necessary enabling environment for private investments in the sector. Particularly the 1997 Electricity Act foresees the granting of concessions for private energy production, distribution and sales.

The private sector can operate its own generating system, provide electricity to surrounding communities and sell its energy surplus to the state power utility while buying energy from the utility when it is required. Furthermore, the Energy Fund Fundo de Energia (FUNAE), with its focus on rural electrification using renewable energy technologies, will provide good support for possible private investors, as some of the resources needed for the rehabilitation and/or construction of new hydropower schemes can be mobilized locally. However, it is important that the Government actively encourages private sector investment in renewable energy projects in Mozambique and creates clear incentives for investors, manufacturers and developers to utilize renewable energies when making investments in the country. Renewable energy support should not be targeted exclusively at off-grid initiatives and poverty alleviation, and renewables should be encouraged in economically active sectors, including tourism, telecommunications and commercial enterprises, as well as among middle-class households.[3]

Legislation on small hydropower

On the regulatory side, hydropower installations are required to have a water use concession which is regulated under the Water Policy. In fact, the Water Policy mentions the use of water resources for stand-alone and dam-connected hydropower purposes and states that small- and medium-scale hydropower facilities should be encouraged for off-grid electricity in remote areas, extension of the national electricity grid production and transmission capacity, as well as economic development in general.[9]

Barriers to small hydropower development

The main barriers to the development of small hydro projects in Mozambique include the lack of framework to support independent power producers. Reducing the uncertainty of the project revenue streams and increasing the availability of project finance would help to promote economically sustainable projects. The following measures are suggested by the International Renewable Energy Agency to improve project bank-ability:

- Electricidade de Mozambique could take a small equity stake in small hydropower projects to reinforce the credibility of its long-term power purchase agreement;
- The Ministry could work with the donor group to develop a partial risk-guarantee fund with financial institutions in Mozambique to promote lending to small hydro projects;
- A system of feed-in tariffs could be developed to provide long-term power purchase agreements, access to the grid and attractive return on investment;
- Consultations could be held with stakeholders to design a simpler process for environmental impact assessment for small run-of-river hydro plants.[14]

In overall perspective the local situation in Mozambique seems quite favourable to the development of small hydropower, although it has proven to be difficult to attract private sector funding.

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1.1.8 Réunion

Lara Esser and Laxmi Aggarwal, International Center on Small Hydro Power

Key facts

Population	833,000[1]
Area	2,512 km[2]
Climate	Tropical and humid. Warm and humid season (November to- April), drier season (May to October)
Topography	Island with coast and mountain peaks in the interior.
Rain Pattern	The Austral summer is in January and February, which is also the season for tropical cyclones. The country is the record holder for the highest rainfall during 12-, 24-, 48- and 72-hours.[2]

Electricity sector overview

Réunion island is an overseas department and administrative region of France. Réunion has the goal to reach 100 per cent of renewable electricity production by 2030.[3] Electricity is provided by Électricité de France (EDF). The total electricity production in 2008 was 2,546 GWh, from a mix of thermal and renewable sources, with coal being the dominating energy source (figure 1). Interestingly, the electricity production in 1982 relied solely on hydropower.[4] Data in 2009 showed that projects that generate electricity increased to 2,618 GWh, of which 67.5 per cent is from fossil fuels (petroleum and coal) and 32.5 per cent from renewable energy.[5] The breakdown of the various energy sources is unavailable, hence this report projected the data from 2008 instead (figure 1). The average growth of electricity production in Réunion had decreased from 5.3 per cent per year between 2000 and 2005 to 3.6 per cent per year from 2006 to 2009 as a result of a demand management program authorized in 2000 and an increased use of costly fossil fuel.[5]

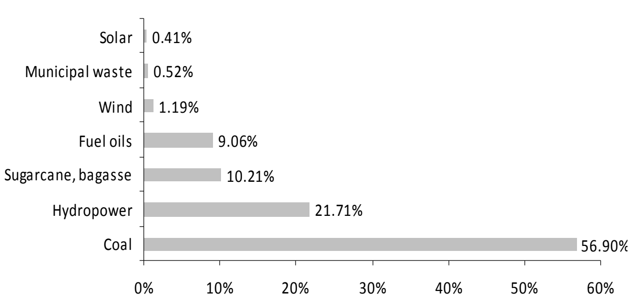

Figure 1 **Electricity generation in Réunion**
Source: Drouineau et al.[4]
Note: Data from 2008, as data projections for 2009 do not provide sufficient detailed breakdown of the contribution of various energy sources.

Réunion has invested in a diverse range of renewable energy sources but the most developed source is hydropower as it was one of the first renewable sources used on the island.[5]

Small hydropower sector overview and potential

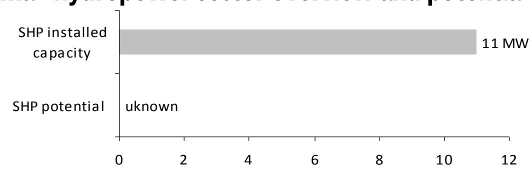

Figure 2 **Small hydropower capacities in Réunion**
Source: Grenelle de l'Environnement à la Réunion, Réussir l'Innovation[6], Forum for Energy and Development[7]

Hydropower is produced at Rivière de l'Est (78 MW), Takamaka I (17 MW) and II (26 MW), Bras de la Plaine (5 MW) and Langevin (4 MW) power stations as well as Bras des Lianes (2 MW).[4 7] Though the large- and small-hydropower potential has been tapped, there still are a number of potential sites, where micro hydropower stations can be installed.[7]

A technical report from 2008 indicated that there were four run-of-river type stations with a total installed capacity of 10.5 MW (62.65 GWh) and three stations with a total capacity of 106.5 MW (550,000 GWh).[8] There is no pumped storage technology on the island.

Taking into consideration environmental issues, there are several further categories for the realization of hydropower potential, such as irrigation infrastructure.

Small hydropower potential in Réunion

(Megawatts)

Category of potential	*Potential capacity*
Difficult to realize	59.10
Under strict conditions	50.53
Normal	11.47
Total	**121.10**

Source: Comité de bassin de la Réunion[8]
Note: Irrigation sites are not considered to be affected by environmental issues.

Renewable energy policy

In 2000, the Regional Council of Réunion implemented the Plan Régional des Énergies Renouvelables et de l'Utilisation Rationnelle de l'Énergie (PRERURE) that played as a precursor for the Grenelle de l'Environnement à la Réunion – Réussir l'Innovation (GERRI) project which has the objective to integrate environmental innovation, mobility, energy and its uses, urban planning, construction and tourism into society by 2030.

The Overseas Territories Orientation Law, in place since December 2000, is the platform pushing for the decentralization of the French overseas departments and the implementation of PRERURE. It is important to take into consideration the support provided by the European Union (EU). This includes direct support in the form of research funding via tenders and indirect support by the means of helping the regional authorities to enable the application of EU policy in overseas departments.[5]

A goal of self-sufficiency by 2030 under the GERRI project is proposed in light of the estimated population stabilization at one million people by 2030.[5] The renewable energy sources available on the island are wind, solar, geothermal, wave, tidal, hydro and energy from biomass, landfill gas, gas stations, wastewater treatment and biogas. Act No. 2005-781 of 13 July 2005 lays down the guidelines of the programme for energy policy and renewable energy in Article 29.[6]

In addition, incentive mechanisms are also in place to encourage the development of renewable sources, including tax exemption, direct subsidies and feed-in-tariffs (FITs) controlled by the EDF.[5] Private plants however, have a tax credit rate that varies between 25 per cent and 50 per cent based on the technology of the project.

Barriers to small hydropower development

The main disadvantage to small hydropower development is the cost of technologies which increases due to the island's insularity seen through the cost of transportation and taxes. As a result, higher capital costs hinder contractors' willingness to undergo financial risk and investment in Réunion.[5] Based on the country's geographical characteristics, contractors are also faced with the risk of climatic variation and destruction coupled with volcanic activity which increases the risk factor for investors.

Environmental impact assessments are stringent and often a difficult barrier to small hydropower development due to the classification of Réunion as a World Heritage Site, under the United Nations Educational, Scientific and Cultural Organization (UNESCO). This has a further domino effect on the price of land per square metre that over the last 10 years has experienced a significant increase amplifying initial investment expenditure.[5]

Coordination between departments and authorities, both local and overseas, are ineffectual prolonging the implementation process for project owners coupled with a lack of local technical support creates another disincentive for potential investors.

The final major barrier to small hydropower development is the lack of information and often contradictory sources with different and misleading data further slowing down the process of development. Currently, the Réunion Regional Energy Agency (ARER) is in the process of compiling renewable energy technology information providing a one-stop data shop for potential investors. In the near future this could decrease the initial research stage of most projects and encourage contractors to establish projects in Réunion.[5]

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1.1.9 Rwanda

Lara Esser and Laxmi Aggarwal, International Center on Small Hydro Power

Key facts

Population	11,689,696[1]
Area	26,338 km^2
Climate	Temperate; mild in mountains
Topography	Mostly grassy uplands and hills; relief is mountainous with altitude declining from west to east.
Rain Pattern	Two rainy seasons (February to April, November to January).[1] Eastern and south-eastern regions are more affected by prolonged droughts while the northern and western regions experience abundant rainfall that at times cause erosion, flooding and landslides. The spatial variability has been attributed to the complex topography and the existence of large water bodies within the Great Lakes Region.[2]

Electricity sector overview

The energy policy in Rwanda focuses mainly on the electrification of the country, which has increased significantly from 6 per cent in 2005 to 12 per cent in 2010 through the electrification roll-out programme. The Ministry of Infrastructure (MINIFRA) has bundled the activities of several donors and pushed the promotion of renewable energies.[4]

The Government of Rwanda has set out clear targets of 1,000 MW production and 50 per cent of connections by 2017.[5]

In the framework of the National Energy Policy, hydropower plays an important role in the electrification of the country as it is the main renewable energy source for electricity generation (figure 1). This includes micro hydropower and isolated mini-grids, which should be encouraged by a simplified legal and regulatory framework and governmental investments.[4]

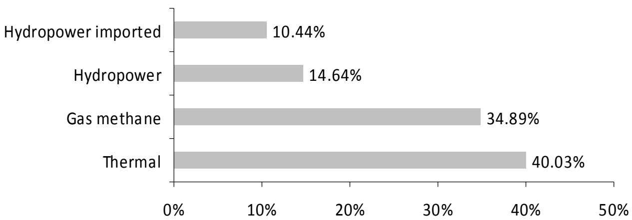

Figure 1 **Electricity generation in Rwanda**
Source: Rwanda Environmental Management Authority[3]

Rwanda Electricity Corporation (RECO), formerly known as ELECTROGAZ, the government-owned utility, , will in the short to medium term, still be the dominant player in the electricity market which is regulated by the independent Rwanda Utilities Regulator Authority (RURA). However, independent power producers (IPPs) are also encouraged in the generation sector. Self-contained off-grid schemes are encouraged: these can be owned and operated by RECO or by private developers. The National Energy Policy foresees three types of licensing issued by RURA:

- Single buyer licence***:*** RECO is to be licensed as the single buyer of electricity. It will enter into agreements with private developers of generation projects for the purchase of electricity;
- IPP licences: All generation projects or concessions involving private investors are to be licenced by RURA.
- Off-grid licences: Concessions are granted by RURA to private companies to generate, supply and distribute electricity within an area of the country not covered by RECO. The tariff and other supply provisions are to be regulated by RURA.

Within the electrification roll-out programme, the Rwandan Government and various donors provide funding to a number of small hydropower projects. Different donors are funding micro hydropower under different schemes among them is the United Nations Industrial Development Organization (UNIDO), the World Bank and the African Development Bank (AfDB). A part from this, the Energising Development Private Sector Participation (EnDev PSP) programme, involves private investor schemes. The programme finances 50 per cent of the total costs, while private developers cover the remaining 50 per cent. The programme motivates banks to offer lending for micro hydropower investments. Imported capital goods such as micro hydropower equipment are exempt from the value added tax (VAT) payment.

Requests for small hydropower permissions are given by the regulatory authority RURA.[4]

Small hydropower sector overview and potential

In 2009, hydropower contributed 20 MW to 55 MW installed capacity at four small hydropower stations and a number of independent micro-hydropower stations (table 1).[4] In October 2011, three more micro-hydro plants were inaugurated, with a total capacity of 3.2 MW. They are located in Keya, in Rubavu District and Cyimbili and Nkora in Rutsiro District and feed into the national grid to increase the power output by five per cent. The three plants were co-funded by the Governments of Rwanda and Belgium, at the cost of more than Rwandan Franc (RWF) at 9 billion (about €11 million).[5] Besides the micro hydropower inaugurated plants, Belgium also supports the construction of Rukarara II power plant in Nyamagabe with a capacity of 2 MW.

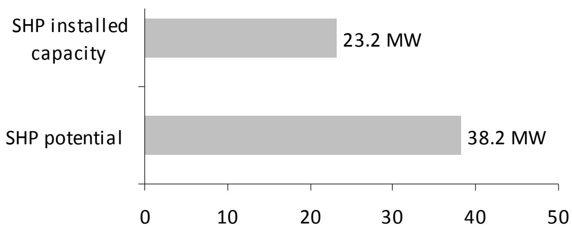

Figure 2 **Small hydropower capacities for Rwanda**
Source: German Agency for Technical Cooperation - Poverty-Oriented Basic Energy Services (HERA) - European Union Energy Initiative[4], Rwanda, Ministry of Infrastructure[5]

Note: Data is based on mixed results from various sources.

In 2009, there were 15 micro hydropower plants under construction and another 21 planned by the Government, bilateral donors and private investors, totalling to an additional capacity of 13 MW (table 2).[4]

The information collected was however contradictory. It was also reported that as of 2010, 333 hydro sites in the country with a combined capacity of 96 MW were identified, of which the technical small hydropower potential was estimated at only 10 MW. In general, the potential for micro hydropower is considered to be good due to the country's geographical conditions and high population density.[4]

Table 1
Installed small hydropower capacity in Rwanda

Category	*Name*	*Installed capacity (MW)*	*Available capacity (MW)*	*Ownership*
On-grid hydropower	Gihira	1.80	1.80	Public, Rehab
	Gisenyi	1.20	0.60	Public, Rehab
	Rukarara	9.00	9.00	Public
	Rugezi	2.20	2.00	Public, commissioned July 2011
	Nkora, Keya, Cymbili	3.20	2.00	Public, commissioned July 2011
	Murunda (REPRO)	0.10	0.10	Private (PSP hydro (GTZ-EnDev))
Off-grid micro hydropower	Nyamyotsi I	0.10	0.10	Public (UNIDO)
	Mutobo	0.20	0.20	Public (UNIDO)
	Agatobwe	0.20	0.20	Public
	Nyamyotsi II	0.10	0.10	Public (UNIDO)
	Rushaki	0.04	0.04	Private

Source: Muyange[6]
Note: Data valid as of 2012.This table omits the contributions made by Ruzizi hydropower projects shared by Burundi, Democratic Republic of Congo and Rwanda as they are above the 10 MW small hydropower definitions.

Table 2
Small hydropower plants under construction in Rwanda

Name	*Installed capacity (MW)*	*Developer/producer*	*Ownership*
Mukungwa II	2.500	Government of Rwanda	Public
Nyirabuhombohombo	0.500	Government of Rwanda	Public
Gashashi	0.200	Government of Rwanda	Public
Nyabahanga	0.200	Government of Rwanda	Public
Janja	0.400	Government of Rwanda	Public
Nshili	0.400	Government of Rwanda	Public
Rukararav II	2.000	Government of Rwanda	Public
Rubagabaga	0.314	Calimax	PPP
Musarara	0.438	Sogem Rwanda	PPP
Giciye	4.000	Rwanda Mountain Tea	PPP
Mazimeru	0.500	ENNY	Private
Ruhwa	0.200	Government of Rwanda	Public
Gatubwe	0.200	UNIDO	Public

Source: Rwanda Ministry of Infrastructure in German Agency for Technical Cooperation- Poverty-Oriented Basic Energy Services (HERA)- European Union Energy Initiative[4], Muyange[6]
Note: UNIDO – United Nations Industrial Development Organisation. List may not be comprehensive.

Different donor agencies have assisted Rwanda in its efforts to build a local small hydropower industry, following different approaches. UNIDO followed the route of village level management at the four small hydropower systems they are supporting. Experience gained in implementation led to revert to management models in which the systems are operated through private businesses.[4] The Dutch/German-funded EnDev programme followed a pure private sector approach from the outset. Under this programme, five business consortia have been contracted to implement small hydropower schemes. Typical participants are local businessmen, NGOs, social institutions (hospitals), and local and foreign investors. The EnDev programme provides 30-50 per cent investment subsidy, technical assistance, business support, etc., while the developer is responsible for financial closure (15 per cent equity and loans), construction, permits, etc.[7] Experience to date, however, indicates a very strong preference of private investors to supply at least a portion of the electricity generated to the national electricity grid (and hence to existing customers, which is contrary to the objectives of the donors) as the interconnection gave great comfort to the banks, who appreciated a guaranteed sale of electricity produced.[4]

A 2011 report on the pico-hydropower situation in Rwanda by the Global Village Energy Partnership International (GVEP International) and Entec analysed the potential commercial market for off-grid hydropower plants in Rwanda, with individual generation capacities of 50 kW or less. They suggest the market can be developed through specific interventions by the Government, development partners or the private sector, such as training of local developers or financial investments. At least seven project developers from the private sector operate in the country and have realized around 30 pico-hydropower plants in recent years.[8]

Renewable energy policy

Given its history, Rwanda has only recently been able to draft and enhance its environmental protection instruments. Thus the Electricity Law was enacted in July 2011 with the aim to liberalize and regulate the sector, to attract private investment while encouraging a more competitive market.[9] A Draft Energy Policy is also in place, highlighting the need to maximize use of indigenous energy, improve access and transparency and most importantly to promote the use of renewable energy technology and conducive instruments such as feed-in tariffs (FIT).[9]

The Government of Rwanda is currently in the process of developing a solar energy policy and a Solar Map, furthermore, renewable energy feed-in-tariffs (REFITs) are already available for small hydropower and are to be extended towards solar generation.

Legislation on small hydropower

The Government of Rwanda issued a REFIT in February 2012 for small and mini-hydropower. The REFIT guarantees access to the grid for renewable energy generators and obliges the national utility Energy, Water and Sanitation Authority (EWSA) to purchase the renewable energy generated. It applies to hydropower plants from 50 kW to 10 MW. REFITS are valid up to three years.[4]

Moreover, the National Energy Strategy strongly states the specific objective to increase micro-hydro, medium-hydro and cross-border hydropower projects to about 333 MW.[10]

Barriers to small hydropower development

One of the major barriers to the development of small hydropower, despite the motivation and instruments provided by the Government of Rwanda, is the country's history which provides no incentive for foreign investment.

Rwanda has a vast potential for producing clean energy using small hydropower, however, efforts are often limited by weak technical capabilities and private sector actors. In addition, the lack of financial institutions and the low income of the rural population further hinder the process of small hydropower development in Rwanda.[10]

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1.1.10 South Sudan

Ater Amogpai, University of Juba, College of Engineering and Architecture, South Sudan; Kai Whiting, International Center on Small Hydro Power

Key facts

Population	10,625,176[1]
Area	644,329 km[2]
Climate	Equatorial climate, with high temperature, high rainfall and very high humidity
Topography	Plains in the north and centre to southern highlands. The White Nile is a major geographic feature of the country supporting agriculture and extensive wild animal populations. The centre of the country contains a large swampy area of more than 100,000 km^2 fed by the waters of the White Nile.
Rain pattern	Rainfall is the heaviest in the upland areas of the south but diminishes in the north.[2]

Electricity sector overview

Only one per cent of the population has access to power, though intermittently during a 24-hour period. Only seven per cent of the urban areas in South Sudan are electrified and virtually no rural areas have electricity.[3] This is because the formal energy sector is limited to only the South Sudanese Electricity Cooperation which operates eight diesel generators with a capacity of 1.5 MW each.

With the help of foreign aid such as United States Agency for International Development (USAID), South Sudan has built independent grid systems in cities such as Yei, Kepoeta, Malakal, and Maridi. However, a large portion of the energy is from independently operated diesel generators belonging to businesses and private homes.[4]

The country is planning to build about half a dozen hydropower and thermal power plants to help end the near permanent blackouts across the country and to attract investments in manufacturing industries.[9] China is thought to be providing the capital for significant investment in the energy sector to support both the oil and hydropower sector.[5]

In 2012, the installed capacity of electric power was about 26.8 MW in South Sudan. Some estimates, however, put this figure at 62 MW of installed capacity - around 3 MW per million people, indicative of a severe lag compared to other Eastern African states.[6] This electric power is divided amongst six South Sudanese towns: Juba, the capital (12 MW), Malakal (4.8 MW), Wau (4 MW), Bor (2 MW), Yambio (2 MW) and Rumbek (2 MW). However, this amount of power needs to be increased to at least 230 MW in order to minimally satisfy the current demand. Juba at the moment needs at least 80 MW (according to power engineers at Juba Power Station) whereas the remaining five towns need at least 150 MW, at 30 MW each. Most of the diesel generators in use are made and brought from Finland. However, these generators frequently stop operating due to technical problems and fuel shortages.

The total electric power required by South Sudan is estimated to be 450 MW. In the coming decades, this amount of electric power is expected to increase along with a booming population and establishment of new industries.

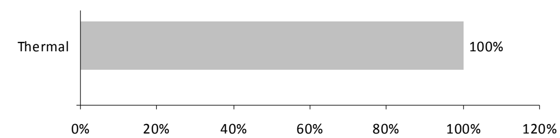

Figure 1 **Electricity generation in South Sudan**
Note: Based on installed capacity.

Small hydropower sector overview and potential

South Sudan holds one of the richest agricultural areas in Africa. The White Nile valley has fertile soils and abundant water supplies, which could be developed for small hydropower.[2] Around 28 per cent of the Nile water flows through South Sudan to Sudan and onward to Egypt but the meteorological and hydrological data collection network for this area and elsewhere were destroyed during the conflict and is currently non-existent.[3]

The potential of hydropower plants capacity is estimated to be 5,583 MW in South Sudan. The small hydropower potential is yet unknown. Below is a list of hydropower plants studied in some of the South Sudanese states with a total potential capacity of approximately 2,225.5 MW (see table). It is estimated that the Fula rapids could yield 60 MW of electric capacity. A rapid only refers to the high-current part of a river. Meanwhile, there are several 700 MW to 800 MW large dam projects envisioned for the White Nile.[6]

Studied hydropower plants in South Sudan

Plant	*Capacity (MW)*	*Location*	*Status quo*
Grand Fula	1 080.0	Central Equatoria State	Feasibility study and EIA completed
Fula	40.0	Central Equatoria State	Feasibility study and EIA completed
Shukole	200.0	Central Equatoria State	Feasibility study and EIA completed
Lakki	200.0	Central Equatoria State	Feasibility study and EIA completed
Beden	540.0	Central Equatoria State	Feasibility study and EIA completed
..	25.5	Western Equatoria State	..
Juba	120.0	Central Equatoria State	Studied
Sue	12.0-15.0	Western Bahr El-Ghazal State	Studied
Kinyeti	5.0	Eastern Equatoria State	Feasibility study completed

Source: Ackermann, updated with Ministry of Electricity and Dams[7]
Note: EIA – environmental impact assessment

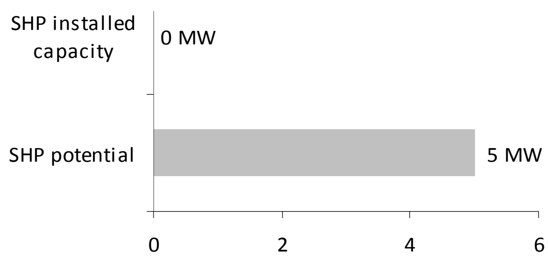

Figure 2 **Small hydropower capacities up to 10 MW in South Sudan**

Those large hydropower plants to be built along the river from Nimuli to Juba may take decades to be commissioned. Therefore, the construction of medium- and small-hydropower plants is needed to improve the current poor situation of electric power in the country. Building a local hydropower plant with installed capacity of 1 MW to 25 MW is possible. The authors believe that such hydropower plants could be built to generate electricity in Torit, Yei, Wau and other towns in South Sudan.

Renewable energy policy

Hydropower, solar energy, wind power, and biomass are the main renewable energy sources in South Sudan. Currently, biomass and petroleum products are the main energy sources in use in South Sudan.[8]

The availability of sunlight in South Sudan is around seven hours per day.[9] Photovoltaic technology thus offers an attractive off-grid solution. The annual average wind velocity is about 2.5 metre per second in South Sudan.[9] At this speed a developed wind sector is not commercially viable. However, small wind turbines are promising devices for household electricity generation as well as pumping water. Hydropower also holds a key role in South Sudan's electricity generation, with the White Nile flow being sufficient for hydropower power production.

Barriers for small hydropower development

There are many challenges that hinder the small hydropower development. These include technical, and ecological issues as well as challenging accessibility and remoteness of the sites.[6] Others are:

- The lack of priority and attention afforded to water resource management. Scarcity of meteorological and hydrological data due to the conflict: it will take some time to generate the lost information and systems;
- Lack of renewable energy policy, legislation and poor technical and institutional capacity;[3 10]
- Social tensions: South Sudan is a newly established landlocked country which has gained independence in July 2011 following two prolonged conflicts which lasted from 1983 to 2005, six years of autonomy (from 2005) and a referendum in which 98 per cent voted in favour of a South Sudanese state;
- Political instability.

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1.1.11 Uganda

Eva Maate Tusiime, Newplan Ltd., Uganda

Key facts

Population	33,640,833[1]
Area	241,000 km[2]
Climate	Tropical; generally rainy with two dry seasons (December to February, June to August); semiarid in northeast.
Topography	Mostly plateau with rim of mountains[1]
Rain Pattern	Uganda receives most of its rain between March and June, with rainfall of more than 500 mm during this season.[2]

Electricity sector overview

Uganda's electrification access of 6 per cent (or 9 per cent according to the *World Energy Outlook 2011*) is the lowest in sub-Saharan Africa and the world.[3] In the rural areas, the access drops to 2 per cent with Northern and North-eastern Uganda registering the lowest electrification rates. Another estimated 1 per cent of the population uses fuel generator sets, car batteries and solar photovoltaic systems for lighting.[4]

Electricity access is a major requirement for development, and electricity demand in Uganda is high for industrial and domestic use. However, the demand for power is more than the generation capacity, which is dominated by hydropower (figure 1). Much of the electricity transmission network at present is poorly maintained and the country experiences frequent power cuts (load shedding).

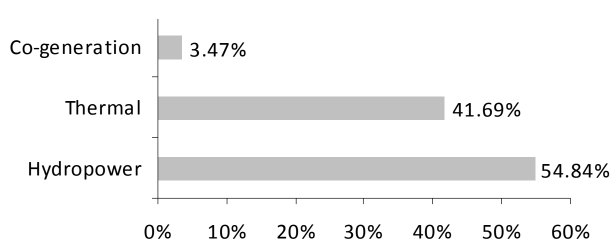

Figure 1 **Electricity generation in Uganda**
Source: Electricity Regulatory Authority[5]

Small hydropower sector overview and potential

A number of small hydropower plants with a combined capacity of just over 50 MW are in operation in various parts of the country as shown in table 1 (please note two plants included have capacities above 10 MW). The country definitions of small hydropower is less than 10 MW, mini is defined at 1 MW and micro at 0.1 MW. However, there has been very little small hydropower development in Uganda. In the past, approximately 8 MW has been developed at four sites by the then Uganda Electricity Board, who later developed two sites and private developers who built another two. These sites were Mubuku I (5 MW), Maziba I (1 MW), Kisizi (0.075 NIW) and the 1.25 MW Kikagati station (which has now been decommissioned). The Maziba hydropower plant was also shut down in 2001 due to siltation problems. Plans are underway to rehabilitate this power plant.

Uganda has considerable potential for hydropower development, estimated at over 2,500 MW located mainly on the Nile River. Other Non-Nile River sites with potential capacities ranging between 0.5 and up to 5 MW are scattered throughout the country with potential for mini- and micro-hydropower development. To date less than 10 per cent of this potential has been developed.

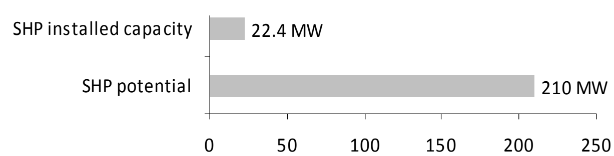

Figure 2 **Small hydropower capacities up to 10 MW in Uganda**
Source: Electricity Regulatory Authority[6]

A number of small hydropower sites with a total potential of about 210 MW (figure 2) have been identified through different studies. The level of the studies is uneven, with some sites having been studied to feasibility stage. Small hydropower sites under construction are shown in table 2 and potential small hydropower sites for development in table 3.

Recent developments in the sector have seen other small hydropower plants being developed mainly by the private sector (table 1). In addition, Uganda's Electricity Regulatory Authority (ERA) has issued a number of permits and licences for generation of electricity from small hydropower projects, which are at various stages of development.

The Uganda Constitution of 1995 has provisions for enhancing conservation and management of the environment and natural resources. The National Environment Act (NEA), Cap. 153, mandates the National Environment Management Authority (NEMA) as 'the principal Agency in Uganda responsible for the management of the environment by coordinating, monitoring, regulating, and supervising all activities in the field of environment'.[9]

Table 1

Installed small hydropower capacity in Uganda

Site	*District*	*Installed capacity (MW)*	*Status/ ownership*
Mubuku I	Kasese	5.40	Kilembe Mined Ltd.
Mubuku II/Bugoye Hydropower Project	Kasese	13.00	Tronder Power Ltd.
Mubuku III	Kasese	9.90	Kasese Cobalt Company Ltd.
Mpanga PowerStation	Kamwenge	18.00	Eco Power Ltd.
Ishasha Hydropower station	Kanungu	6.60	Imperial Group of Companies
Kuluva	Moyo	0.12	Kuluva Hospital
Kagando	Kasese	0.06	Kagando Hospital
Kisiizi	Rukungiri	0.06	Kisiizi Hospital

Source: Electricity Regulatory Authority, Uganda[7]

Note: Listed plants are all operating.

Table 2

Small hydropower plants under construction in Uganda

Site	*District*	*Installed capacity (MW)*	*Ownership*
Nyagak	Nebbi	3.5	WenereCo
Buseruka	Hoima	9.0	HydroMax Ltd.

Source: Electricity Regulatory Authority, Uganda[7]

Table 3

Potential small hydropower sites in Uganda

Site	*District*	*Estimated capacity (MW)*
Nyamabuye	Kisoro	2.20
Mvepi	Arua	2.40
Sogahi	Kabarole	2.00
Ela	Arua	1.50
Ririma	Kapchorwa	1.50
Haisesero	Kabale	1.00
Nyahuka	Bundibugyo	0.65
Sezibwa	Mukono	0.50
Rwigo	Bundibugyo	0.48
Nyarwodo	Nebbi	0.40
Agoi	Arua	0.35
Kitumba	Kabale	0.20
Tokwe	Bundibugyo	0.40
Amua	Moyo	0.12
Ngiti	Bundibugyo	0.15
Leya	Moyo	0.12
Nyakibale	Rukungiri	0.10
Miria Adua	Arua	0.10
Manafwa	Mbale	0.15

Source: Tumwesigye[8]

Within the field of hydropower development, NEMA is mandated to award environmental clearances, following the review and approval of Environmental Audits, Environmental Impact Assessment (EIA) statements and Resettlement Action Plans (RAP). The clearance allows NEMA to ensure that the project and its mitigation plans comply with Ugandan standards for environmental and social impact. Where the project is on a protected river or wetland, NEMA will require the developer to also apply for permission to operate on the river/wetland involved.

The National Water Policy of 1999 states that the development of water for energy production shall be subjected to an EIA in accordance with the procedures established by NEMA.[10]

According to the Water Act Cap 152, authorization has to be given to use water, construct or operate any works. The extraction permit is issued by the Directorate of Water Development.[11]

The Land Act, Cap. 227, makes provision for the ownership and management of land, and provides for the compulsory acquisition of land for public purposes. It states that construction of dams and hydropower plants are public works and any person authorized to execute public works may enter into mutual agreement with the owner or occupier of the land in accordance with the Act. A RAP is normally prepared and undertaken by the developer. Compensation and resettlement activities are expected to be fulfilled by the developer.[12]

Renewable energy policy

The Ugandan Government's Policy Vision for Renewable Energy is to make modern renewable energy a substantial part of the national energy consumption. The overall policy goal is to increase the use of modern renewable energy, increasing from the current 4 per cent to 61 per cent of the total energy consumption by the year 2017.[13]

This policy set out the Government's vision, strategic goals, principles, objectives and targets for promoting and implementing renewable energy sources like hydropower, biomass, peat, solar, geothermal and wind in Uganda.

The National Energy Policy of 2002 was also set up with the objectives of, among others:

- Increasing access to modern, affordable and reliable energy services;
- Improving energy governance and administration;
- Managing energy related environmental impacts.

Legislation on small hydropower

The Government offers investors incentives in the form of value added tax (VAT) exemption on hydropower and related road projects. The challenge with this is that although the developers enjoy the exemption, their suppliers are not. The suppliers therefore find it difficult to recover the VAT they paid to supply materials to the developers and are usually unwilling to work on such projects yet the Government stipulates that local suppliers and contractors should be involved as much as possible. Suppliers tend to increase their prices in order to recover the VAT which affects the developers who have to absorb the higher costs.[14]

Therefore, the application of these incentives is still vague. It is not uncommon for the developers to continue paying VAT on hydropower projects. The process of claiming the VAT may sometimes be frustrating to the developers.

Barriers to small hydropower development

Although considerable potential for hydropower development exists in Uganda, very few developments have been carried out in the last 10 years. The existing barriers can be broadly categorized into design, technical, technological, socio-environmental, and financial:

- *Design challenges:* Small hydropower sites are sometimes located on rivers around agricultural areas. Thus the sediment load in the rivers may increase, thereby necessitating the use of de-silting basins and flushing trenches as part of the design. This increases the cost of the project.
- *Technology:* The technology to bore through waterway structures like tunnels is not readily available in Uganda. Therefore, in planning the waterway structures, this has to be taken into account. The lack of appropriate technology may result in having a longer waterway than planned since tunnels may not be an easy option to pursue.
- *Technical capacity gaps:* With all the potential that has been identified through various studies, until 2011, there was no university in Uganda offering a course on the development and design of hydropower schemes of any size. The specialization to undertake feasibility studies, designing and costing of hydropower projects has been mainly undertaken by foreign consultants.
- *Socio-environmental barriers:* Many sites for hydropower development are located in populated areas. The inhabitants are usually the owners of the land required for the project. Therefore, developing a hydropower plant in such areas will necessitate displacing and relocating population to other areas. It must be noted that in Uganda, the process of land acquisition is slow and expensive, since land is individually owned. Even when the affected persons may have been compensated, the process of registering the land in the names of the developer may end up being very expensive and time consuming.
- *Financial barriers*: Several studies had been carried out concerning the lack of participation from the private sector in the development of hydropower projects. They concluded that among other factors, the cost of borrowing in Uganda is the highest in the world. Moreover, the development banks in the country are limited by their net worth. Although some commercial banks have ventured into lending to developers of such projects, they generally prefer to lend only short term (five years at most).[14]
- *Other challenges*: The need for guarantees from the Government against the transmission body's failure to meet its payment obligations, the need for a political risk guarantee from the World Bank, long lead times for projects, and investors often fail to raise the equity required by the lenders. These factors make it unfavourable for potential developers to engage in hydropower generation in Uganda.[14]

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1.1.12 United Republic of Tanzania

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Key facts

Population	46,912,768[1]
Area	945,749 km[2]
Climate	Tropical (hot and humid) along the coast with a rainy season March to May. Temperate in highlands with short rains (Vuli) November to December and long rains (Masika) February to May.
Topography	Plains along coast; central plateau; highlands in north, south
Rain Pattern	The mean annual rainfall varies from 500-2,500 mm and above. The average duration of the dry season is 5-6 months. Rainfall patterns have recently become much more unpredictable with some areas/zones receiving extremely minimum and maximum rainfall per year.[2]

Electricity sector overview

The electricity sector in Tanzania is dominated by the state-owned Tanzania Electric Supply Company Limited (TANESCO) that was established in 1964. It was set up in a vertically integrated structure, carrying out generation, transmission, distribution and supply. TANESCO operates the grid network and isolated supply systems in Kagera, Kigoma, Rukwa, Ruvuma, Mtwara and Lindi. Due to slow development in the sector and the general global trend in the electricity supply industry, the Government lifted the monopoly held by the public utility in 1992 through the National Energy Policy to allow involvement of the private sector in the electricity industry. This major policy reform enabled independent power producers to operate in the generation segment. Furthermore, interconnections with Zambia and Uganda enable imports of relatively small amounts of electricity.

For many years, the power sector in Tanzania was dominated by hydropower, only when the country encountered a severe drought in 2004, it had employed additional thermal plants (figure 1). Up until the last decade, rural electrification had been solely a Government responsibility with support development partners such as the United Nations Industrial Development Organization (UNIDO). Hence, most of the small hydropower plants were installed by donors, missionaries and the Government through TANESCO.

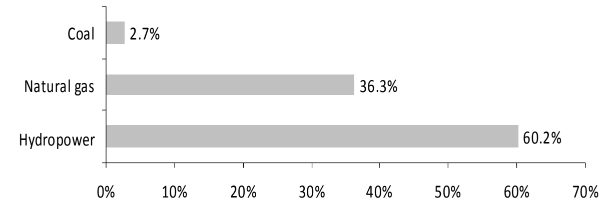

Figure 1 **Electricity generation in the United Republic of Tanzania**
Source: Tradingeconomics[3]
Note: Data from 2009.

In 2010, Tanzania's total installed electricity generation capacity was 1,219 MW, of which hydropower comprised 561 MW and thermal 658 MW. The contribution of non-hydro renewable energy for power generation is less than five per cent.

At the moment, the electrification rate stands at 14 per cent countrywide and two per cent for rural areas. Efforts are being made to increase access in rural areas. The Rural Energy Agency has been established to oversee the implementation of rural electrification projects, using the Rural Energy Fund as provided in the Rural Energy Act.

Small hydropower sector overview and potential

The history of small hydropower in Tanzania traces back to the colonial era, where most of the operational small hydropower plants were installed with the help of church missionaries. Forty-five sites with a total installed capacity of 25 MW have been developed so far, of which only 17.6 MW are currently in operation (figure 2). Most of the schemes have capacities lower than 5 MW, as shown in figure 3. TANESCO owns 15 per cent of the small hydropower plants and private investors own 85 per cent. In terms of installed capacity, TANESCO owns 69 per cent. The database of the Rural Energy Agency shows that 13 projects with a total capacity of 28.8 MW are in various stages of development.[5]

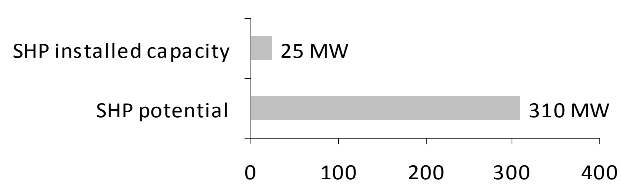

Figure 2 **Small hydropower capacities in the United Republic of Tanzania**

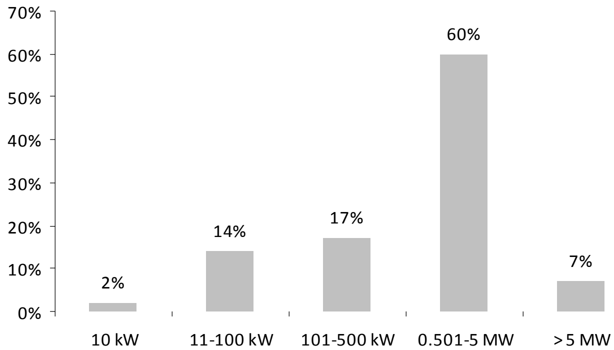

Figure 3 **Installed small hydropower capacities in the United Republic of Tanzania**
Source: Tanzania Electric Supply Company Limited[5]

Tanzania has substantial potential of small hydropower. Areas with high potential include the Southern and Western highlands; the best geographical areas for developing small-scale hydropower are those with steep rivers flowing all year round. Geographically speaking, most of the hydropower potential of Tanzania is located in the rift valley escarpments in the West, South West and North East Tanzania. Central Tanzania is relatively flat and dry and has no hydropower potential.[8] Studies show that 12 out of 21 administrative regions of mainland Tanzania are blessed with mini-hydropower resources but only 3 regions (Mbeya, Iringa, and Kilimanjaro) have managed to develop them.[5]

The total potential for small hydropower generation (capacities <10 MW) is estimated at 315 MW, of which only 25 MW have been developed. Studies, that have included economic analyses, show a number of sites that could produce electricity at competitive cost to supply power to the national grid and through mini-grids to villages in the community.

Table 1
Installed small hydropower capacity in the United Republic of Tanzania

Site name	*District/Region*	*Year installed*	*Installed capacity (kW)*	*Developer/Owner*
Nyumba ya Mungu	Same/Kilimanjaro	-	8 000.0	TANESCO
Tosamaganga	Iringa	1951	1 220.0	TANESCO
Kikuletwa	Moshi/Kilimanjaro	-	1 160.0	TANESCO
Kitai	Songea/Ruvuma	1976	45.0	Prisons Dept/ Government
Nyagao	Lindi	1974	15.8	RC Mission
Isoko	Tukuyu/Mbeya	-	7.3	Mission (not specified)
Uwemba	Njombe/Iringa	1971	800.0	Benedict Fathers
Bulongwa	Njombe/Iringa	-	180.0	Mission (not specified)
Kaengesa	Sumbawanga/Rukwa	1967	44.0	RC Mission
Rungwe	Tukuyu/Mbeya	1964	21.2	Moravian Mission
Nyangao	Nyangao/Lindi	-	38.8	Mission (not specified)
Peramiho	Songea Rural/Ruvuma	1962	34.6	Benedict Fathers
Isoko	Tukuyu/Mbeya	1973	15.5	Moravian Mission
Ndanda	Lindi	-	14.4	Mission (not specified)
Ngaresero	Arusha	1982	15.0	M.H Leach
Sakare	Soni/Tanga	1948	6.3	Benedict Fathers
Mbarari	Mbarari/Mbeya	1972	700.0	NAFCO/Government
Ndolage	Bukoba/Kagera	1961	55.0	RC Mission
Ikonda	Makete/Iringa	1975	40.0	RC Mission
Mbalizi	Mbalizi/Mbeya	1958	340.0	TANESCO
Lugarawa	Iringa	1979	140.0	RC Mission
Mavanga	Iringa	2002	150.0	RC mission/Mavanga Village community
Matembwe	Njombe/Iringa	1986	150.0	RC mission/ CEFA/ Matembwe Village Community
Ndolela	Songea Rural/ Ruvuma	-	100.0	Tea Estate
Chipole	Mbinga/Songea	-	400.0	RC Mission
Mngeta	Ifakara/Morogoro	-	600.0	Government parastatal
Uvinza Mine	Uvinza/Kigoma	-	600.0	Private
Kabanga	Kasulu/Kigoma	-	100.0	Mission
Maguu	Mbinga/Ruvuma	-	100.0	Mission
Lupa	Ifakara/Morogoro	-	200.0	Mission

Source: Michael[7], National Environmental Management Council[7]
Notes: This list is in comprehensive. RC – Roman Catholic

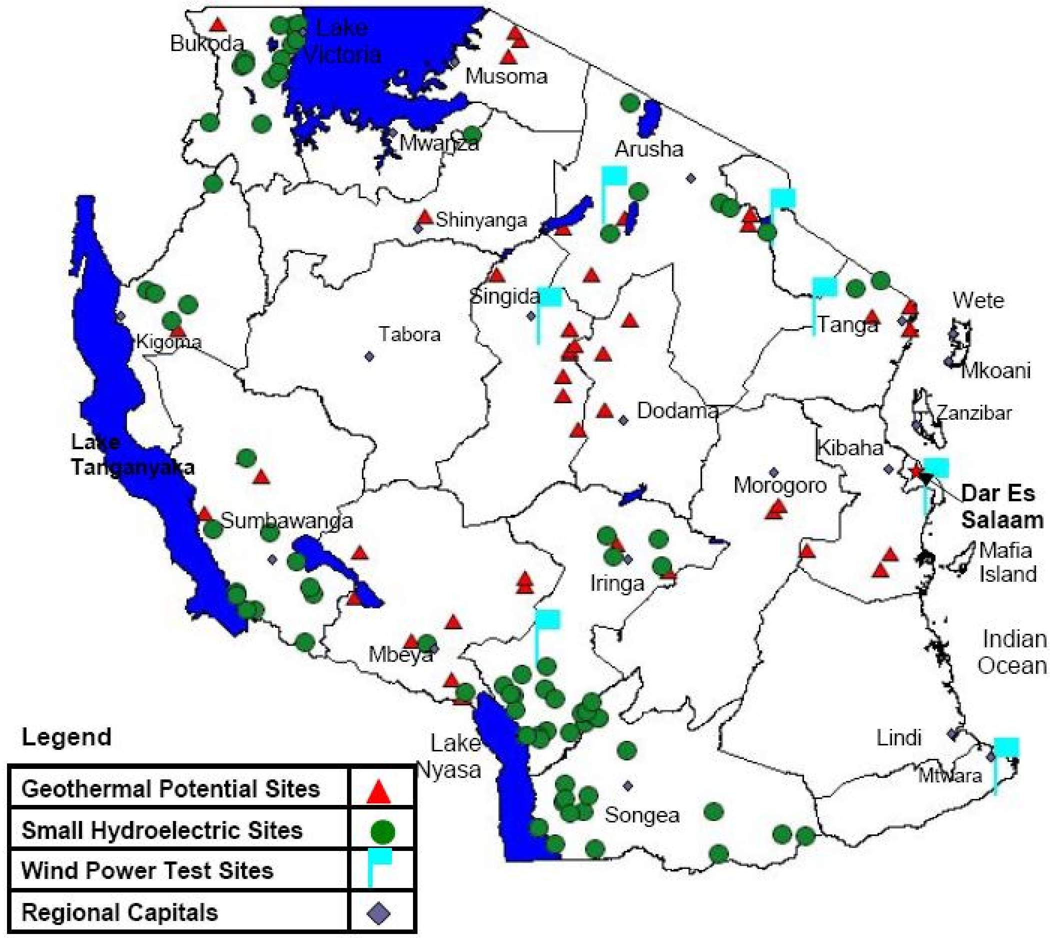

Figure 4 **Map of potential small renewable power sites in the United Republic of Tanzania**
Source: Michael[6]

In the on-going small-hydro inventory studies which are being carried out by TANESCO, and financed by the Ministry of Energy and Minerals (MEM), a total of 131 small hydro sites countrywide with a total capacity of 250 MW have been identified. The study comprised both desk studies and fieldwork. Reconnaissance studies of new potential sites and confirmation of existing information have been completed for Rukwa, Kagera and Ruvuma regions. Further studies in collaboration with the Rural Energy Agency have been carried out in Iringa, Mbeya, Morogoro and Kigoma regions.

Another study that focused on the mini hydropower potentials was the Rural Electrification Master Plan study that was commissioned by MEM and implemented by TANESCO. The objectives of the Rural Electrification Master Plan study was to examine the technical, economic, social, and environmental aspects of a lowest-cost solution of supplying electricity to un-electrified rural areas, defining appropriate programmes and priority projects for expansion of the electricity networks, as well as development of renewable energy supply systems for the country over 15-20 years. In addition to other sources of electricity, five small hydro sites from the small hydropower database were appraised during this study.

All projects in Tanzania need to demonstrate that they take care of the environmental issues in their plans. Under these regulations it is mandatory to undertake full Environmental Impact Assessment (EIA) for all projects with capacities above 1 MW. For projects with capacities below 1 MW, it is necessary to take into consideration of the environmental issues in their plans by undertaking simplistic Environmental Impact Studies (EIS). The National Environmental Management Council is responsible for approving the EIA/EIS conducted.

Below is a list of pre-feasibility studies conducted in 2009/2010 by the Rural Energy Agency.

Table 2

Potential small hydropower sites in the United Republic of Tanzania

S/N	Site	Load Centres	District/ Region	Head (m)	Discharge (m3/sec)	Capacity (kW)
1	Luwika	Mbamba Bay	Mbinga	359.5	1.500	5 800.0
2	Sunda Falls	Tunduru	Ruvuma	13.5	26.000	3 000.0
3	Mtambo	Mpanda	Rukwa	17.0	13.500	2 000.0
4	Malindindo	Malindindo	Mbinga	38.0	0.500	1 58.4
5	Lingatunda	Madaba	Songea Rural	160.0	2.500	3 400.0
6	Macheke	Ludewa	Ludewa	23.0	1.500	287.0
7	Isigula	Ludewa	Ludewa	200.0	1.200	2 000.0
8	Imalinyi	Imalinyi village	Njombe	13.0	2.500	270.0
9	Maruruma	Maruruma	Mufindi	20.0	2.000	333.5
10	Luganga	Luganga	Iringa Rural	77.0	2.000	1 300.0
11	Songwe	Idunda	Rungwe -Mbeya	75.0	1.500	720.0
12	Kiboigizi	Karagwe District	Kagera	90.0	3.800	3 200.0
13	Kenge	Bukoba	Kagera	10.0	24.000	2 400.0
14	Luamfi	Namanyere	Rukwa	40.0	9.000	1 200.0
15	Kawa	Kasanga and Ngorotwa	Sumbawanga	65.0	0.300	130.0
16	Mkuti	Kigoma Rural	Kigoma	23.0	3.300	650.0
17	Ngongi	Ngongi	Ruvuma	270.7	1.090	3 100.0
18	Mngaka	Paradiso	Mbinga -Ruvuma	15.0	7.640	900.0
19	Mngaka	Lipumba	Mbinga- Ruvuma	25.0	4.424	870.0
20	Lumeme	Mbinga	Ruvuma	301.2	1.310	4 200.0
21	Kiwira	Ibililo	Rungwe - Mbeya	20.0	10.000	1 350.0
22	Kitewaka	Ludewa township,	Ludewa	50.0	9.884	4 200.0
23	Mtigalala falls	Kitonga Kilolo -	Iringa	70.0	10.000	5 000.0

Source: Rural Energy Agency[4]

Renewable energy policy

There is no existing policy for renewable energy in Tanzania. The Government, through its Ministry of Energy and Minerals, is in the process of developing a related policy for renewable energy at large, and small hydropower will be part of it.

In its agenda of making renewable energy industry an integral part of its rural energy and power sector development strategies, the Government has issued the following policies:

(i) Rural electrification policy statement which indicates that all lower cost technical options should be considered, including renewable energy;

(ii) Rural Energy Act (2005) which established the Rural Energy Agency and Fund (REA/F), with the main task to promote access to modern energy services and allocate performance-based subsidies for rural energy including renewable energy systems;

(iii) Energy and Water Utility Regulatory Authority Act (2001) which provides the regulator with the responsibility of tariff setting affecting also the independent renewable energy power producers.

To ensure adequate supply, the Electricity Act (2008) created procedures for providing electricity from different sources. The Energy and Water Utility Regulatory Authority (EWURA) has designed a model for Standardized Small Power Purchase Agreement/Tariff (SSPPA/T) for private producers with project capacities lower than 10 MW. SSPPA will be annually reviewed to reflect operating costs.

Barriers to small hydropower development

The key barriers hindering the development of small hydropower in Tanzania, as in most African countries, can be summarized as follows:

- Lack of infrastructure in the design and manufacture of turbines, installation and operation.
- Lack of access to appropriate technologies for pico-, micro-, mini- and small-hydropower. Lack of indigenous technology and low level of technology to harness the existing hydropower potential. Networking, best practices sharing and information dissemination through forums and conferences, are necessary.
- Lack of local capacity (local skills and know-how as well as the lack of self-initiatives) in developing small hydropower projects. There is a need for technical assistance in the planning, development and implementation of small hydropower projects.
- Insufficient information about potential sites (hydrological data).
- Inadequate small hydropower awareness, incentives and motivation.
- Inadequate private sector participation in small hydropower development.
- Lack of joint ventures (public and private sector partnership).

- Lack of investment capital to develop the existing hydropower potentials. Records show that most of the developed capacity in the African region was realized through grants or soft loans from foreign development institutions or countries. Very few sites have been developed through internal resources of the related countries.
- High competition for investment capital worldwide.

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1.1.13 Zambia

Malama Chileshe, Zambia

Key facts

Population	13,817,479[1]
Area	752,614 km[2]
Climate	Tropical; modified by altitude[1]
Topography	Mostly high plateau with some hills and mountains[1]
Rain Pattern	Rainy season: October to April. The annual rainfall decreases from an average of 1,200 mm in the north to an average of 600 mm in the south. Rainfall is 508-1,270 mm per year.[2]

Electricity sector overview

Prior to 2007, no power plant had been built in Zambia for 30 years.[3] The only power plant which has been added since then is the Zengamena mini hydropower plant, rated at 750 kW, which began operating in 2007. In December 2012, a 1-MW small hydropower plant at Shiwang'andu in the Northern Province of Zambia was commissioned, enabling 25,000 people to access electricity. In addition, new works in the Lusiwasi (12 MW) and Lunzua (750 kW) hydropower stations are also in the pipeline. A number of large hydropower projects, which are at various stages of implementation, are also expected to begin coming on stream in 2017. Such projects have been made possible by the alterations of the Zambia Electricity Supply Corporation Limited (ZESCO) tariffs to reveal their truer costs.[4]

The level of electrification in Zambia is still very low, only about 26 per cent of the total population has access to electricity. By 2030, it is hoped that electrification will increase from the current 3.1 per cent to 50 per cent in rural areas, from 48 per cent to 90 per cent in urban areas, which would then meet the nationwide target ratio of 60 per cent.[5] Those with access to electricity in rural areas have a subsidized tariff priced at an average US$0.63, but costs reach US$0.48, produced from the eight diesel power stations operated by the parastatal company ZESCO.[4] Currently installed electricity generation capacity in Zambia stands at 1,948.5 MW, dominated by hydropower (figure 1).

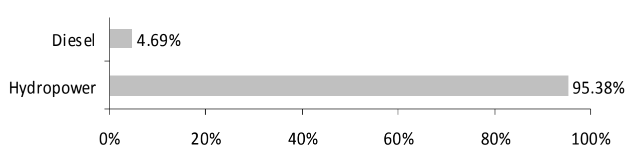

Figure 1 **Electricity generation in Zambia**
Source: Honourable Konga[6]

March 2012 saw severe electricity shortages as peak demand surpassed supply. In August 2012, ZESCO announced plans to increase tariffs by an average of 26 per cent by November 2012. It intends to invest in new power infrastructure in a bid to increase the generation capacity, to meet key performance indicators such as metering, quality of supply, new connections and loss reduction, and to mitigate annual rise in operational costs due to inflation and commodity price changes. Increases are also said to be necessary to achieve the Government's plans to increase access to electricity from the current 20 per cent to 50 per cent, in line with the vision 2030 and the rural electrification master plan. The higher-priced tariffs are also expected to address the national deficit of 250 MW, including the copper mining problems in 2012.[7] The electricity shortage should be overcome by December 2013, when 360 MW is added to the 660 MW that the Kariba North Bank hydropower station.[8] To meet short-term needs, up to 60 MW are expected to be imported from neighbouring countries.[7] In September 2012, ZESCO announced its intention of the Zambian Kwacha 26.4 trillion (US$5.3 billion) expenditure over the next five years to mitigate the current power deficit.[9]

Small hydropower sector overview and potential

Currently the country's installed capacity of small hydropower is 31 MW (figure 2).[10] The estimated hydropower potential of Zambia is estimated to be 6,000 MW, of which 1,858.5 MW has been developed.[10] The specific small hydropower potential remains unknown.

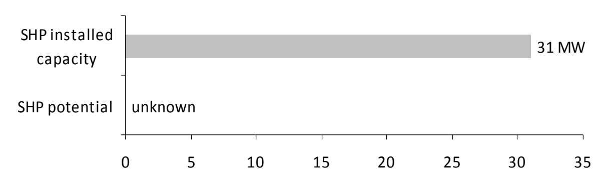

Figure 2 **Small hydropower capacities in Zambia**
Source: Ministry of Lands, Energy and Water Development[10]

Figure 3 **Shiwangandu hydropower station in Zambia**
Source: Chileshe[11]

The Zengamena power station is a privately-owned project with a capacity of 0.75 MW. As of 2010, the company had about 250 customers. There are plans to extend the capacity by another 0.750 MW. Being an off-grid power plant, the challenges faced by the company include complaints from customers for charging a higher tariff than those by the state utility ZESCO.[6]

Figure 4 **Zengamena hydropower station in Zambia**
Source: Chileshe[12]

The Zambian Rural Electrification Authority has carried out studies and designs for the following sites, with potentials ranging up to 3 MW: Chilinga (Nyimba District), Mumbotuta (Milenge District), Chikata (Kabompo District, Mujila (Mwinilunga District and Chavuma (Chavuma District). The development of these sites is key in the electrification of remote areas where grid extension is prohibitively expensive. Some private companies have also expressed to the Government interest to develop other sites in various parts of the country. However, these expressions of interest have not yet resulted in any developments.

Renewable energy policy

Under the Sixth National Development Report (2011-2015) the strategies employed to increase the prevalence of renewable energy are as follows:[13]

- To promote the development and use of solar technology systems;
- To introduce an appropriate cost-effective renewable energy feed-in tariff;
- To promote the production of electricity from geothermal energy;
- To promote the use of biogas for cooking, lighting and electricity generation.

Legislation on small hydropower

The Government of Zambia has put in place a National Energy Policy of 2008 that encompasses a range of energy options, including hydropower. Among the policy measures relevant to small hydropower development adopted in the National Energy Policy are the following:

- Encourage the development of identified potential hydro sites;
- Move towards cost reflective tariffs;
- Adopting an open access transmission regime;
- Application of smart subsidy mechanisms.[10]

The Government, with its appropriate institutions, is already working towards achieving some of the policy measures. Since the Energy Policy was adopted, it has supported the increment of electricity tariffs towards economic levels to encourage investment in the sector. The Government has also been working on adopting an open-access to the transmission network which is principally owned by ZESCO and Copperbelt Energy Corporation. As a first step towards this objective, a *Grid Code*, which is a technical document providing guidelines on how electricity industry players should interact, has been finalized and is awaiting adoption. In addition, the Government through the Energy Regulation Board has also authorized higher tariffs for Zengamena mini-hydro than those for the state utility ZESCO, given that the former is connected to an isolated mini-grid. However, the implementation of the policy measure on smart subsidies has not taken off due to the lack of financial resources. The Rural Electrification Authority did however make a small contribution towards the construction of Zengamena mini-hydropower station.

Barriers to small hydropower development

The development of small hydropower plants has been hampered by some of the following challenges:

- Low Electricity Tariffs: For a long time, electricity tariffs in Zambia were low due to heavy subsidies. The Government has decided to promote a gradual migration towards cost-reflective tariffs. However, the challenge remains as to whether or not some of the communities where off-grid projects are developed can afford to pay the cost-reflective tariff.

- Accessibility: A number of potential small hydro-power sites are located in areas where the road network is bad.
- Lack of connectivity to the national grid: Most of the sites are located far from the national grid. This poses a challenge as the generated electricity must be consumed by the surrounding communities, who may not have the capacity to absorb all the power.

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1.1.14 Zimbabwe

Wim Jonker Klunne, Council for Scientific and Industrial Research, South Africa

Key facts

Population	12,619,600[1]
Area	390,759 km[2]
Climate	Tropical; moderated by altitude[1]
Topography	Mostly high plateau with higher central plateau (high savannah); mountains in east[2]
Rain Pattern	Rainy season: November to March.[1] Rainfall decreases from east to west. The eastern mountains receive more than 1,000 mm annually, while Harare has 810 mm and Bulawayo 610 mm. The south and southwest receive little rainfall.[3]

Electricity sector overview

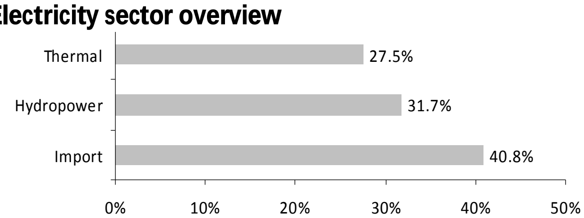

Figure 1 **Electricity generation in Zimbabwe**
Source: Tradingeconomics[4], Clean Energy Portal – Reegle[1]
Note: Data from 2009.

In rural Zimbabwe, 80-90 per cent of people are heavily dependent on wood fuel. Rural populations light their homes with kerosene and carry out essential food processing tasks such as milling grain, using diesel-powered systems. Access to electricity is estimated nationally at nearly 40 per cent, but access to electricity in the rural areas of the country is about 19 per cent, due to very high costs of extending the national electricity grids. Electricity consumption was 998 kWh per capita in 2006.[1]

In accordance to the government policy to embark on reforms of the electricity sector, a new Electricity Act was enacted in 2002, bringing about the restructuring and unbundling of the Zimbabwe Electricity Supply Authority (ZESA) from a vertically integrated utility into separate successor companies focusing on generation, transmission and distribution, and service companies. The new Act also provided for the setting up of an autonomous regulatory body that would encourage new investment in the electricity sector through appropriate regulatory, fiscal and environmental frameworks, harmonized with those of the South African Development Countries (SADC) and through strategic partnerships.

In 2005, the Zimbabwe Electricity Regulatory Commission was established in accordance with section 5 of the Electricity Act. However, in line with regional trends in the regulation of the energy sector a policy for the establishment of an all-encompassing energy sector regulator that seeks to harmonize regulation in the energy sector is being adopted. In this regard, the Ministry was in the process in 2012 of enacting the Energy Amendment Bill which seeks to synchronize the Petroleum Act, the Electricity Act and other renewable energy Acts that will provide for, among other things, the setting up of an energy regulator to harmonize regulation in the energy sector as a whole.[5]

Small hydropower sector overview and potential

The total hydropower potential on Zambezi River for Zimbabwe and Zambia is 7,200 MW. There is a potential to generate 120 MW from small and mini-hydropower resources (20 MW from existing dams, 60 MW from proposed dams and 43 MW from run-of-river sites).[6]

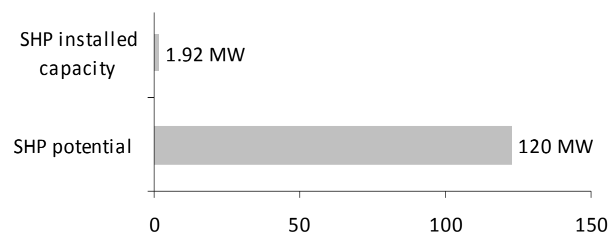

Figure 2 **Small hydropower capacities in Zimbabwe**
Source: Mbohwa[7], Shakya[8]

The total installed small hydropower capacity in Zimbabwe is unknown, however, there is information on a few projects (see figure 2). A plant of 750 kW at Rusito, in the Chimanimani area, is connected to the national grid and has a Power Purchase Agreement (PPA) with the national utility ZESA. Other plants are installed at Kwenda (80 kW), Sithole-Chikate (30 kW), Svinurai (10 kW), Mutsikira (10 kW), Rusitu (700 kW), Nyafaru (40 kW), Aberfoyle (30 kW) and Claremont (250 kW).[7 8]

Recently the Masvingo Rural District Council has approved a US$13 million, 5-MW small hydropower project at Lake Mutirikwi. The application was made by the Great Zimbabwe Hydro-Power Company, jointly owned by a Zimbabwean company, ZOL, and its South African partner, NuPlanet. The plant is one of two currently being developed in Zimbabwe. It will be situated on the 52 year-old, 63 metre crested Mtirikwi Dam near Masvingo and will consist of one 5-MW

Francis turbine. Project commissioning is expected to begin by March 2014.[9] The site has a very delicate hydrology that called for an intense interaction between the developers and the downstream users of the water. The project is expected to enter into a Clean Development Mechanism Programme of Activities for small hydropower in southern Africa.[10 11] Another 5-MW facility at Tokwe-Murkosi is planned for completion in 2013.[12]

Detailed plans do exist for the Manyuchi dam hydropower plant. ZESA has long had plans to generate electricity from the dam, but so far nothing has materialized due to the shortage of funding. Studies, however, show that the water availability should make it possible to drive two 350-kW turbines 6,000 hours per year to generate 4.2 GWh of electricity per year.[13]

Table 1 gives an overview of small hydropower projects prioritized by the Zimbabwe Government for future development. Table 2 provides examples of implemented micro hydropower schemes in Zimbabwe.

Table 1

Priority small hydropower projects in Zimbabwe

District	*Site*	*Type of plant*	*Capacity (MW)*
Mwenezi	Manyuchi	Dam	1.4
Masvingo	Mutirikwi	Dam	5.0
Mutasa	Osborne	Dam	3.0
Bikita	Siya	Dam	0.9
Mutasa	Duru	Run-of-river	2.3
Nyanga	Tsanga	Run-of-river	3.3

Source: Ministry of Energy and Power Development[5]

Table 2

Micro hydropower schemes in Zimbabwe

Name	*Capacity (kW)*	*Head (m)*	*Flow (l/sec)*	*Turbine; Number of jets*	*Uses of power*
Chipendeke	25	41.00	100	Pelton ; 3 jets	Household; end use, clinic, primary school
Dazi	20	121.00	30	Pelton; 1 jet	Household; end use, clinic, primary school
Nyafaru	20	25.18	150	Crossflow; 1 jet	Primary and secondary schools, boarding school facilities, clinic

Source: Khennas and Barnett[14]

Note: The schemes are part of the part of the Practical Action project.

Renewable energy policy

A draft policy energy framework was passed in 2008. The objectives of the Energy Policy are:[15]

- To ensure accelerated economic development;
- To facilitate rural development;
- To promote small-medium scale enterprises;
- To ensure environmentally friendly energy development;
- To ensure efficient utilization of energy resources.

Barriers to small hydropower development

With the current economic and political situation in Zimbabwe improving, the drive by the Government to encourage independent power producers, the prospects for the development of small hydropower are promising. The Government has in section 3.5 of their Energy Policy 2008 commented on the reasons for the limited penetration of renewable energy technologies in general including small hydropower:[16]

- No clear policy and strategy;
- Limited qualified and experienced personnel;
- High upfront costs for the installation of the technologies;
- Poor appreciation and demonstration of benefits;
- Poor back-up service especially in remote rural areas;
- Lack of foreign currency to import components;
- Application of ineffective marketing strategies (technology drive).

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1.2 Middle Africa

Matty Fombong, Rural World Resources, Cameroon

Introduction to the region

The Middle African region comprises nine countries: Angola, Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Chad, Equatorial Guinea, Gabon, São Tomé and Príncipe. All the countries belong to the Economic Community of Central African States (ECCAS) and the Central African Economic and Monetary Community (CEMAC).

The region is characterized by the Congo Basin, which is home to one of the largest tropical forest and wetland reserves. In addition, the region holds a vast, but largely untapped, mining, mineral and agricultural potential. The climate varies from tropical to semi-arid; in a few cases a desert environment can be found.

Table 1
Overview of countries in Middle Africa

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Installed electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Installed hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Angola[abc]	18.056	70.0	26.2	1 300	4 172	782.4	3 141
Cameroon[ab]	20.129	47.9	48.7	816	5 700	720.0	4 232
Central African Republic[ade]	5.057	61.0	3.0	46	160	24.6	130
Dem. Rep. of Congo[ab]	73.599	65.7	11.1	2 442	7 452	2 403.4	7 509
São Tomé and Príncipe[a]	0.183	38.0	60.0	16	41	9.0	10
Total	**117.024**	**-**	**-**	**4620**	**17 615**	**3939.4**	**15 022**

Sources:
a. International Energy Agency[1]
b. International Journal on Hydropower and Dams[2]
c. Sigma Group[3]
d. International Renewable Energy Agency[4]
e. Clean Energy Portal Reegle[5]
Notes: Electricity generation data is mostly available for 2008, while annual hydropower generation is available for 2010.

Table 1 provides overview information on the five countries (Angola, Cameroon, Central African Republic, Democratic Republic of Congo, São Tomé and Príncipe) for which detailed country reports are available.

The region has the continent's largest hydro-electric potential and there is considerable interstate cooperation in the field of hydropower electricity generation.[7] The countries are members of the Central African Power Pool (CAPP) created in 2003, with the vision to use the Central African hydropower potential, estimated at more than 650 TWh/year. CAPP aimed to develop the hydro potential via inter-connected national networks, inter alia, which would in turn create a free regional electricity market, increase access to electricity to rural populations, improve the reliability of the electricity system and quality of supply in the whole region, thus reducing poverty and encouraging development.

In comparison with the other sub-regions of the continent, the Central African sub-region stands out as the one with the least infrastructure network, in particular transport and energy, which negatively impacts the production capacities and regional trade, as well as, the social conditions and welfare.[6] It is also the least populated sub-region and has the lowest GDP.[7] Additionally, it contains five post-conflict countries (i.e. Angola, Central African Republic, Republic of Congo, Democratic Republic of Congo and Chad) and an underdeveloped private sector.[6]

Small hydropower definition

The concept of small hydropower was introduced to the region less than a decade ago; therefore no official definition of small hydropower exists currently.

Regional overview

Four out of the nine countries (Angola, Central African Republic, Democratic Republic of Congo and São Tomé and Príncipe) use small hydropower (table 2). Cameroon previously used small hydropower and has considerable potential that can be tapped into. Chad, on the other hand, does not use hydropower and has no significant hydro potential, since a large part of its area falls under the Sahara desert. Equatorial Guinea is looking towards tapping into its substantial large hydropower potential, while its small hydropower resource potential has not yet been assessed.[2] Gabon has several large hydropower plants and one of the highest potentials for hydropower in Africa. It is currently working on feasibility studies to increase the electricity access in rural areas by the use of micro- and mini-hydropower stations.[5] The Republic of Congo with the capital Brazzaville mainly uses hydro plants to generate more than 90 per cent of the national production – only four per cent of its technically feasible hydropower potential. The Republic of Congo has the Grand Inga series of hydropower projects on the Congo River at the Inga Falls, and if completed, they could be the largest in the world. In addition, ten potential small hydropower schemes have been identified in the Republic of Congo with proposed capacities ranging from 5-10 MW.[2] In May 2011, a memorandum of cooperation concerning the reconstruction of an urban power grid and small hydropower projects was signed between the Ministry of Energy and Hydraulics of the Republic of Congo and China, this provides a positive outlook for the future of small hydropower in the Republic of Congo.[9]

The engagement of small hydropower development in the sub-region is principally due to favourable government policies: such are the cases in Cameroon, Democratic Republic of Congo (where focus is on large hydro) and Angola. Lack of small hydropower development in Chad, São Tomé and Príncipe is caused by the limited availability of hydropower potential, while in places like Gabon and Equatorial Guinea, it is due to lack of appropriate government policy.

Table 2
Small hydropower up to 10 MW in Middle Africa
(Megawatts)

Country	*Potential*	*Installed capacity*
Angola	at least 134.0	10.0
Cameroon	at least 22.0	0.0
CAR	at least 41.1	34.2
DRC	at least 100.9	25.6
São Tomé and Príncipe	at least 30.0	6.0
Total	**328.0**	**75.8**

Sources: See country reports

After a decade of small hydropower introduction to Central Africa, most governments have included small hydropower into their energy plans. More than half of the governments have started to search for funding for studies and implementation. A few small hydropower schemes are under execution in a couple of countries. With the rise in fossil fuel costs, the global clamour for renewable energies and the availability of international funding, most countries with small hydropower potential are attempting to develop it. The engagement in small hydropower development in Central Africa is increasing and will soon become a major component of energy resources in the medium- and long-term.

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1.2.1 Angola

Lara Esser, International Center on Small Hydro Power

Key facts

Population	18,056,072[1]
Area	1,246,700 km²
Climate	Semi-arid in south and along coast to Luanda; the north has a cool, dry season (May to October) and a hot, rainy season (November to April). Temperature varies from 10°C to 31°C
Topography	Forty-seven hydrographical basins, well irrigated by rivers coming from the central plateau
Rain Pattern	Hot summer months are very dry, with almost no rainfall (June to August). Wet season (October to April) with 100-250 mm per month. The wettest region is the north-east, and the total rainfall decreases southwards and towards the western coast.[2]

Electricity overview

The national electrification rate was 26.2 per cent, with 13.7 million people not having access to electricity in 2011.[4] The Angolan Government has a National Electrification Programme, which has set a target of increasing production to 7,000 MW, enabling an annual per capita consumption of 4,000 kWh by 2016 – an eightfold increase in current consumption. The medium-term goal is to develop capacity of 4,646 MW by 2017. There are also bottlenecks in the transmission and distribution networks that need to be overcome.[5]

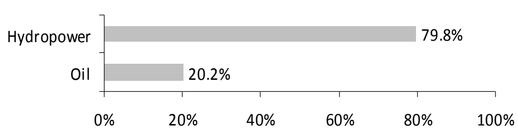

Figure 1 **Electricity generation in Angola**
Source: Trading economics[3]
Note: Data from 2010.

The Angolan Strategic Programme for Rural Electrification is part of the National Programme and also includes mini-hydro. Priority actions include the building of new power plants (hydropower plants and the reinforcement and expansion of the transmission network to new municipalities and the construction of transmission lines associated to the new power lines).[5]

There is a focus on the existing hydropower potential in Angola and its strategic role in the regional energy sector, the investment opportunities and the efforts put forward by the Angolan Government to attract private sector involvement in the energy sector.[5]

Small hydropower sector overview and potential

Angola has enormous hydropower potential. Hydropower currently provides three quarters of the country's electricity (figure 1). However, the civil war destroyed facilities and the Government has not succeeded in keeping supply in line with expanding demand. The technical hydropower potential is around 80 TWh/year and the economically available hydropower potential is 72 TWh/year (18 GW). Less than 900 MW (out of 18 GW overall potential) have been developed so far.[6]

The colonial policy was highly oriented towards medium- and large-hydropower schemes with the objective to provide big cities and centres with electricity. Pico-, micro-, mini- and small- hydropower schemes for supplying indigenous people with electricity were given less priority.

In 1975, when Angola became independent, there were three separated electricity grid systems. Only 12 per cent of the Angolan population had access to electricity, of which 90 per cent were in Luanda, the capital. According to the *2011 World Atlas and Industry Guide*, Angola has started reconstructing Cavango small hydropower plant (10 MW) in the centre of the country, which was damaged during the civil war. In July 2011, the Angolan Ministry of Energy and Water announced that it intended to build 150 micro-hydroelectric projects. It said that so far the administrative procedures had already been concluded, but neither specific localities to build the projects nor the time to start operating were given. A public tender to select a construction company, would open soon. This action is part of the strategic plan of the sector aimed to improve and expand the power network countrywide.[7]

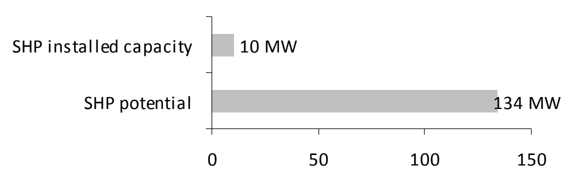

Figure 2 **Small hydropower capacities in Angola**
Source: *Hydro World*[7], Unknown[8]

Installed small hydropower capacity was 10 MW in 2008 (figure 2). The small hydropower development programme (launched in 2008) by the Ministry of Energy and Water aims to support preliminary studies, technical and economic feasibility studies, environmental studies, engineering project design and construction of pico-, micro-, mini- and small-hydropower schemes with capacity up to 10 MW, including transportation, distribution, public lighting and optional infrastructures. More than 112 projects have already been identified (table). Projects are listed and grouped into short-, medium- and long-term projects. Prioritization of projects was carried

Potential micro hydropower sites up to 10 MW in Angola

Province	*River*	*Waterfall/Locality*	*Expected power (kW)*
Bengo	Loge	Freitas Morna/ Ambriz	6 000 - 7 000
Bengo	Lifune	Nambuangong/ Nambuangongo	400
Benguela	Catumbela	Chicuma/ Chicuma	8
Benguela	Catumbela	Catumbela/ Cuvera	..
Benguela	Cuiva	Cuiva / Ganda	..
Benguela	..	F.Sisalana/ Ganda	..
Benguela	..	F. A Cubal/ Cubal	..
Benguela	..	F. Portelas/ Caimbambo	..
Benguela	F.S. André	../ Chongoroi	..
Benguela	F.Caála	../ Balombo	..
Benguela	F.Fasil	../Bocoio	..
Benguela	Mamducha	../ Bocoio	..
Benguela	Açucareira	../ Catumbela	..
Bié	Gango Muanga	Tunbo/-	9 300
Bíe	Gango	Tassongue/-	1 100 - 3 000
Bíe	Gango	Quipelo/-	6 000- 1 500
Bíe	Gango	Lunga/-	5 500- 10 000
Bíe	Cutatu	Embal Andulo/Andulo	6 900 - 15 000
Bíe	Luvulo	Samalanca/-	2 500 - 5 000
Bíe	Cutatu	Cutatu/ Andulo	4 100 - 10 000
Bíe	Cune	Chivava/-	7 200 - 15 000
Bíe	Kuquema	Cundende/ Kamakupa	700 - 1 000
Bíe	Cuito	Chimbenda/-	300 - 1 000
Bíe	Cuemba	Cuemba/-	6200 - 15 000
Bíe	Cunje	Quissol/-	1 800 - 15 000
Bíe	Cuanza	Cativa/-	8 400 - 15 000
Bíe	Cuanza	Cuanza/ Dando, Cama Cupa, Catabola, Chipeta,	..
Bíe	Cuceque, Nedegiva	-/ Nedegiva, Cassombi, Muamdoge,	..
Bié	Membia	Membia/ Andulo	80 - 500
Bié	Cunje	Cunje/ Catabola	2640
Bié	Cuemba	Cuemba/ Cuemba	275 - 500
Bié	Kuito	Kuito1/ Cidade Kuito	100
Bié	Kuito	Kuito2 / Cidade de Kuito	100 - 600
Bié	Cuhinga	Cuhinga/ N'Harêa	2 400
Cabinda	Luali	Luali/ Buco Zau	1 500 - 750
Cabinda	Luali	Luali/ Buco Zau	2 500 - 750
Cabinda	Ngoti e LufoNgoti	-/ Belize	
Cunene	Calueque	Caluueque/ Calueque	20 - 50
Huambo	Culele	Culele/ Babaera	
Huambo	Calai	Chissola/ Cuima, Chissola	4 300 - 6 500
Huambo	Cuando	Lucunde/ Cataala-Nova	6 500 - 6 500
Huambo	Cuando	Lava Cuando/ Lava do Cuando	
Huambo	Cuando	Cuando/ Huambo	1 200 - 3 200
Huambo	Cuando	Caringo/ Caringo	3 400 - 5 000
Huambo	Cuando	Gungue/ Gungue	4 000 - 5 300
Huambo	Cuando	Lucunde/ Lucunde	6 500
Huambo	Capati	Cabundi/ Cabundi	3 600 - 14.5
Huambo	Cului	Catembulo/ Catembo	5 000
Huambo	Cuando	Carngo/ -	3 400 - 5 000
Huíla	Cuhui	-/ Jamba	400 (500 KVA)
Huíla	Cuvango	-/ Cuvango	160 (200 KVA)
Huíla	Caculuva	-/ Chibia	16 (20 KVA)
Huíla	Chicungo	-/ Chicungo	
Huíla	Cavunge	-/ Chicoma	
Huíla	Simo	-/ N'Gola	
Huíla	Kubango	Kuvango/ Mongonga Kuvango	2 866 (kVA)
Huíla	Cuvundi	Cuvundii/ Chicomba	624 (kVA)
K.Kubango	LombaLomba	-/ Mavinga	
K.Kubango	Cutato	Cutato/ Cutato	
K.Kubango	Cuito Moleo Cuito	M´pupa/ Dirico, Licua	
K.Kubango	Cubango	Maculungungo/ Caiundo	2 500 - 5 000

Source: Unknown[8]
Note: This is an incomplete list.

out according to social, economic and political objectives. The main goal is to create the National Data Bank on the Angolan small hydropower potential in 2008-2013.[8]

The programme will implement up to 50 projects to the preliminary and feasibility study stage and construct 30 hydropower schemes. Up to 20 pico- and micro-units are expected to be imported during this period and will be sold to small rural consumers.
Furthermore, the programme wants to develop conditions for the launching of siderurgical (iron- and steel-works), metal-mechanic and electric industries for the local manufacturing of some components. In terms of population welfare, more than 4.4 million people in local and rural areas from 15 provinces will benefit from the programme and more than 7,000 permanent and temporary jobs will be created. The total cost of the programme (2008-2013) is estimated at more than US$900 million. The Government will be responsible for 60 per cent and private investment should cover the rest (40 per cent).[8]

Renewable energy policy

The Angolan Ministry of Energy and Water Affairs is responsible for the National Energy Policy, including the promotion of renewable energy sources. In September 2012, the Ministry indicated that it was in the process of creating legislation to regulate the renewable energy sector. The idea behind it was to deploy renewable sources to enable the expansion of electricity to homes in need and to ensure that citizens pay a fair price for energy.[9]

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1.2.2 Cameroon

Matty Fombong, Rural World Resources International, Cameroon

Key facts

Population	20,129,878[1]
Area	475,650 km[2]
Climate	The climate varies with the terrain, from tropical along coast to semi-arid and hot in north.
Topography	The southern forests are of dense vegetation, with abundant rainfall resulting in a vast river network. The high plateaus of the west form an area of rich volcanic soil, which favours agriculture. Savannah and steppe in the north, where cattle breeding predominates. In the southwest, Cameroon's maritime border with the Atlantic Ocean is about 420 km.
Rain Pattern	Annual rainfall is highest in the coastal and mountainous regions. Main wet season (May to November) for the country comes when the West African monsoon wind blows from the south-west, bringing moist air from the ocean. The wettest regions receive more than 400 mm per month of rainfall, but the semi-arid northern regions receive less than 100 mm per month. The southern plateau region has two shorter rainy seasons (May to June, October to November).[2]

Electricity sector overview

In 2010, grid electricity access was approximately 15 per cent in rural areas and 50 per cent in urban areas, while the percentage of households with electricity was 32 per cent. The country's current 32 per cent electrification remains low and is a handicap to the production of goods and services. In rural areas, the rate is only about 3.5 per cent. The government's objective is to ramp up the country's electrification rate to over 48 per cent and the rural electrification rate to over 20 per cent by 2020.

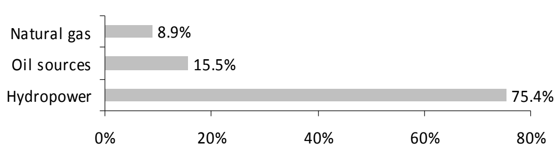

Figure 1 **Electricity generation in Cameroon**
Source: Trading Economics[3]

Although Cameroon is an oil-producing country and has large gas reserves, extraction is limited. Cameroon's energy balance shows a clear predominance of renewable energy sources, particularly biomass. In 2010, the total installed electricity capacity was 816 MW (thermal: 12 per cent, hydro: 88 per cent). Figure 1 gives on overview of the electricity generation mix.

The electricity grid (1,800 km of high voltage [90KV] and 12,000 km of medium voltage [30KV] lines) primarily runs between the capital, Yaoundé and the major port city of Douala. Much of the North of the country is yet to be connected to the grid. The sole transmission and distribution system is owned by the vertically integrated power utility American Electricity Supply-Sonel (AES-Sonel). Cameroon is also inter-connected to its neighbouring countries, i.e. with Nigeria, Equatorial Guinea, Nigeria and Chad.

To stem power cuts, and seasonal load shedding a national electricity development programme has been developed, targeting mainly the construction of large hydropower projects. Cameroon hopes to triple electricity output to 3,000 MW by 2020 through a series of hydro and thermal generation projects.

Private producers may now obtain licence and concession agreements to generate electricity from small hydropower resources and then sell directly to consumers in non-grid localities or sell to AES-Sonel where it already has installations.

From 2011 to 2013 a project including the Rural Energy Agency aims to upgrade power supply in terms of quality in two localities already electrified by the AES-Sonel utility, with a diesel generator set by means of hydropower injection. This should be the first example for a rural electrification project in the country carried out by an investor from the private sector within the existing regulatory framework.[4]

Small hydropower sector overview and potential

The hydropower types in Cameroon are not well-defined. Cameroon has the second largest hydropower potential in sub-Saharan Africa (table). Total potential is estimated about 20-23 GW, with a production potential of 103 TWh per year (figure 2). There are three main hydro facilities with a total installed capacity of 735 MW.

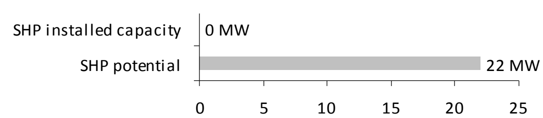

Figure 2 **Small hydropower capacities in Cameroon**

Mini- and micro-hydro projects were first developed during the colonial period. They fell into disrepair shortly after independence due to lack of spare parts and technical know-how. The power stations were ravaged by vandals for parts and copper scrap. None have been rehabilitated so far.

In 2005, experts from the International Center on Small Hydro Power evaluated the rehabilitation of the two of the abandoned small hydropower sites: Yoke and Mallale in the south west region. However there was no follow-up after the study. Recently the Government has announced a tender for the construction of a 3-MW mini hydro station in the south west region known as Ngassona Falls 210.

The Cameroon Government has obtained a loan from the International Development Association of the World Bank, for financing rural electrification through the Fund for Rural Energy and intends to use a portion of these funds to subsidize local initiative projects for rural electrification, which shall be signed with project promoters selected at the end of the present call for tenders.

Hydropower potential in Cameroon

(Megawatts)

Size	*Potential output*
Large hydro	**3968.00**
15 sites (above 10 MW each)	
Pumped storage	**1100.00**
Abi Falls [a]	2.00
Aswenjway [a]	2.00
Firsoh [a]	1.00
Menka [a]	1.00
Mirzam Birtah1 [a]	4.00
Mirzam Birtah 2	3.00
Ngassona 210	3.00
Yoke (rehabilitation)	2.00
Mini hydro (1- 10 MW capacities)	**18.00**
Ako [a]	0.20
Akoaja [a]	0.30
Bambui-bambili [a]	0.45
Bonambufei-Teze	0.25
Fumnjuh [private storage] [a]	0.20
Itoh-Jikijem [a]	0.22
Kwang-Melumdi [a]	0.25
Mallaley (rehabilitation] [a]	0.40
Menka [a]	0.10
Menteh [a]	0.15
Mundum [a]	0.10
Ngunoh Aku [a]	0.25
Njinikom [a]	0.13
Ombe [a]	0.80
Shingar [a]	0.10
Micro hydro (< 1 MW each) [a]	**3.90**
Total	**5089.90**

Note: a. Sites surveyed by Rural World Resources International

Cameroon considers Environmental Impact Assessment (EIA) as crucial to any hydropower project, whether big or small. Authorization, concession right or licence for any hydropower project must include a detailed EIA carried out by a competent authority in the field. Only generation and utilizations below 100 kW in private property may be exonerated from expert EIA submission but it must be included nonetheless.

Renewable energy policy

The Government's policy seeks to get the country out of under-development through the implementation of an energy plan under the long-term Energy Sector Development Plan (PDSE 2030) and the Poverty Reduction Strategy Paper. Cameroon's development objectives targeting 2035, envisage substantial investments in the energy sector by 2035 and the inclusion of renewables. The policy goals of the Government are to warrant energy independence through increased production and delivery of electricity, of oil and gas (petroleum resources) and to guarantee their contribution to economic development.

Barriers to small hydropower development

Power production, transportation and sale have been liberalized in Cameroon. Since the sole electricity supplier is deficient, a protocol has been arranged with the Government for the power corporation to buy electricity from private producers through a power purchase agreement. The government grants the rights for development (without licence) of small hydropower to individuals, corporations and communities for self-use in private property that does not involve transportation through public territory or the sale of electricity. Commercialized small hydro-power development must undergo rigorous control and entails a licence and a concession agreement with the competent authorities.

Barriers to small hydropower development at moment also include difficulties in obtaining authorizations, concession rights and licences; acquiring appropriate funding and technology, and the risk of hindrance to operation and maintenance by high taxes, pilfering and local sabotage of structures. The greatest barrier for small hydropower exploitation in Cameroon is red tape.

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1.2.3 Central African Republic

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	5,057,208[1]
Area	623,000 km²
Climate	Tropical climate, with a distinct dry season (December to May) followed by a wet season. Annual average temperature is about 24°C with little variation.
Topography	Vast, flat to rolling, monotonous plateau; scattered hills in northeast and southwest[1]
Rain Pattern	Annual average rainfall is 1,500 mm.

Electricity overview

In 2003, only three per cent of the population had access to electricity, partly as a result of the infrastructural damage to the power sector caused by the war.[2 3]

A total of 162 GWh was produced by Énergie Centrafricaine (ENERCA), of which 130 GWh from hydropower.[2] However, additionally there are private producers also using diesel, petrol generators and solar PV and micro hydropower[4]. Detailed information was not available.

The Central African Republic's total installed electrical capacity is 39 MW. Currently, only eight per cent of the urban population has access to electricity, the provision has been unpredictable.[5]

An increasing proportion of people living in towns are using diesel- or petrol-powered generators to produce their own private electricity, including businesses (e.g. mining, logging companies, agro-industries), planters as well as religious missions.[4] Connecting to the grid is expensive, and firms - most of which are small and informal - wait around seven months to get connected.[6]

Among the energy sources utilized 87.7 per cent is wood, 10.9 per cent oil and 1.4 per cent hydropower. The oil consumption is not uniform in the whole country; it is high though in mining regions where petrol is used for pumping water.
Power cuts due to ageing machinery, difficulties in finding replacement parts for maintenance and the negative impact of multiple power cuts on different services and the economy, as well as household use, led to the decision to liberalize the energy sector by the Government and the Ministry of Mines, Energy and Water Resources. In 2005, the Parliament adopted the Electricity Code favouring foreign and private investments.[7]

Small hydropower sector overview and potential

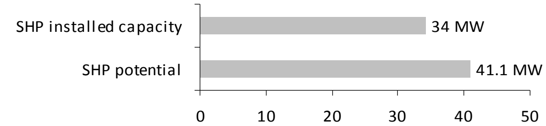

Figure 1 **Small hydropower capacities in the Central African Republic**

There are records of nine small hydropower plants operating in the Central African Republic. Some of these are installed in towns (e.g. six small hydropower plants with aggregated installed capacity of 5 MW, representing 12.82 per cent of the country's total installed capacity in small hydropower (see table 1) and two other small hydropower stations are located in the area of the Boali falls, with an aggregated installed capacity of 18.65 MW (representing 87.18 per cent of the country's total installed capacity in small hydropower (table 2). Boali 1 and 2 have only been partially refurbished in the last years and are hence in a terrible state.[4] In 2007 the government started construction of Boali 3, an additional 10-MW hydropower plant which was not yet operational in 2011.[5]

Table 1
Installed small hydropower capacity under 10 MW in the Central African Republic

Project ID	*Head (m)*	*Flow rate of water Q (m^3/s)*	*Output (kW)*
Kembe	14	1.2	500
Soungbe	9.5	1.4	1 400
Toutoubou	60	1.40	712
Baïdou	5.5	12.30	2 320
Mbeko	6.0	1.60	350
Bria	2.5	18	300
Total			**5 582**

Eleven potential small hydropower schemes have so far been identified in Central African Republic, which would add an aggregated capacity of 6.832 MW (see table 3).

Renewable energy policy

In 2004, the Central-African government adopted a national energy policy framework favouring renewable energies, with a view to reduce poverty over the period of 2005-2015.[4] The Poverty Reduction Strategy Paper (2008-2010) mentions the need to diversify energy sources, by expanding rural electrification, building micro hydropower plants, electrifying villages using PV systems and developing biomass energy.[4]

Table 2

Small hydropower plants in the Central African Republic

Name	*Technical specifications*	*Installed capacity*
Boali 1 (built in 1954)	Type: Francis Turbine (horizontal axe) Water flow : Q= 20 m³/s, Head: H= 52 m Unit capacity= 1,750 kW Power loss = 150 kW	N= 8,750 kW
Boali 2 (built in 1976)	Type: Francis turbine (vertical axe) Water flow: Q= 36 m³/s Head: H= 64m	N= 9,900 kW
Boali 3 (dam already built but still awaiting for turbine installation due to financing (about €20,000 000).	Type: Kaplan Unit capacity= 5000kW Negotiation ongoing for China Private Group's assistance for completing project	N= 10 MW

Table 3

Potential small hydropower schemes in the Central African Republic

River	*Locality*	*Site name*	*Head (m)*	*Flow (m3/s)*	*Power (kW)*	*Level of studies*
Loamé	Boda	Gbassem	15.00	6.00	720	Front-end engineering and design
Toutoubou	Carnot	Toutoubou	60.80	1.50	760	Feasibility
Baïdou	Bambari	Bac	5.00	14.00	560	Feasibility
Mbéko	M'baïki	Mbéko	60.00	1.75	840	Feasibility
Lobaye	Baoro	Pont	6.00	1.50	70	Preliminary
Ouham	Bossangoa	Soumbé	5.00	10.00	1600	Preliminary
Nana	Kaga-Bandoro	Nana	18.00	13.40	1950	Preliminary
Mambéré	Baboua	Gbassem	..	..	..	..
Lomé	Dédé-Mokouba	Dédé-Mokouba	2.00	1.50	20	Identification
Mbounou	Maloum	Maloum	3.00	0.36	12	Identification
Mba	Dimbi	Dimbi	10.00	2.00	300	Identification

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1.2.4 Democratic Republic of the Congo

Roger Limoko Bosomba, Société Nationale d'Électricité, Direction de l'Électrification Rurale, Democratic Republic of Congo

Key facts

Population	73,599,190[1]
Area	2,345,000 km²
Climate	Tropical; hot and humid in equatorial river basin; cooler and drier in southern highlands; cooler and wetter in eastern highlands; north of Equator. Wet season is from April to October, dry season is from December to February; south of Equator. Wet season is from November to March, dry season is from April to October. Temperatures range from 25°C to 37°C
Topography	Large Congo River basin in the centre of the country covered by equatorial rain-forest. The whole land is forested, more or less thickly. There are plains and slopes in the west, hills in the north and south and mountains in the east.
Rain Pattern	Frequent rainfalls throughout the year over the whole country. Average annual rainfall is 1,200 mm, with the heaviest rains in November and December.

Electricity overview

The country has oil, gas and uranium reserves. Electrification is essentially based on large hydro-power plants, with the most important site being Site d'Inga in the South-West of the country (figure 1). It alone already contains an assessed total of 44 GW. The Inga site includes large hydropower plants Inga I (351 MW installed capacity; 2.4 TWh/year electricity production; built in 1972) and Inga II (installed capacity of 1,424 MW; 10.4 TWh/year electricity production; built in 1982). Two more projects at the same site are under consideration: in the medium term Inga III (3,500 MW) and in the long term Grand Inga Scheme (39,000 MW).[3] Furthermore, there is an on-going rehabilitation programme for Inga II.

The electrification rate is 11.1 per cent with 58.7 million people without access to electricity.[2] A Rural Electrification Programme was launched in 2004 and it aims to stabilize the rural population and to reduce rural exodus[3] The programme should benefit 80,000 identified communities (100-500 kW/centre) as well as contribute to the reliability, restoration and extension of the national grid. It will also enable the export of excess electricity for financing some national electrification projects. But until now, the programme has not properly started. No financial support has been made available to Société Nationale d'Électricité (SNEL) - the state-owned electricity utility in charge of power generation, transmission and distribution - to materialize any project. As a result, SNEL has only been able to achieve one-seventh of the electrification target.

The electricity sector is liberalized and some private companies produce and sell electricity to consumers (Société d'électrification du Nord Kivu with 2 MW in Butembo, and Électricité du Congo (EDC) generating 1.2 to 9 MW in Tshikapa). There are also some auto-producers who generate electricity for their own use[3]
It is difficult to estimate the installed capacity of hydropower in the Democratic Republic of the Congo. SNEL and its facilities, i.e. the State, represent 99 per cent of the installed capacity.

The Ministry of Energy is in charge of the energy sector and potable water. It defines the national energy policy. There is no independent regulator in the Democratic Republic of the Congo. The problem of involving the private sector in the electricity supply industry is the main concern of the Government. It is hoped that the legal and regulatory framework will soon be defined. There is one division within the Ministry of Energy in charge of Rural Electrification, which works with the Rural Electrification cell of SNEL.[3]

Table 1
Installed power capacity in the Democratic Republic of Congo

	Year 2005[a]	*Year 2010*[b]
Installed capacity (total)	2436.90 MW	2 442 MW
- Hydro	2418.30 MW	
- Thermo	18.60 MW	..
Gross production (total)	7 193 484 MWh	7 518 GWh
- Hydro	7 186 523 MWh	7 509 GWh
- Thermo	6 961 MWh	..
Net production (total)	7 178 253 MWh	..
- Hydro	7 171 441 MWh	
- Thermo	6 812 MWh	..
Energy sold	5 741 926 MWh	

Sources:
a. Limoko, and Bampufu[4]
b. Trading Economics[5]
Note: Based on the public works SNEL.

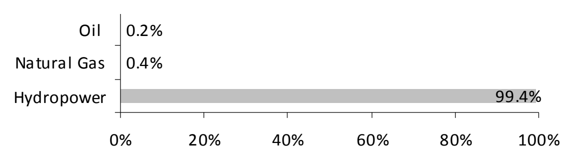

Figure 1 **Electricity generation in the Democratic Republic of the Congo**
Source: Trading Economics[5]

Small hydropower sector overview and potential

The gross theoretical hydropower potential is 1,397 TWh/year (evaluated in 1997). The total technical hydropower potential for the country is around

100,000 MW (evaluated in 1997). The economically feasible potential is 419,210 GWh/year (evaluated in 1991 based on sites in operation, studied and inventoried, assuming 100 per cent load factor), see table 3 for potential sites. Less than one per cent of the technically feasible potential has been developed.

In 2011, the national installed hydropower capacity was 2,418.30 MW. There are 11 hydropower plants with capacities larger than 10 MW. There are five small hydropower plants with a total installed capacity of 25.61 MW (figure 2). The youngest plant, Mobayi Mbongo in the province of Ecuador to the north, was built in 1989 (table 2).

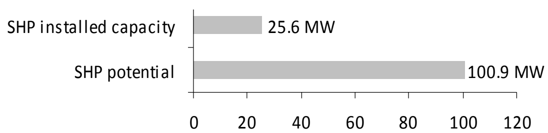

Figure 2 **Small hydropower capacities in the Democratic Republic of the Congo**

Table 2
Installed small hydropower capacity in the Democratic Republic of Congo

Name (Province)	*Commissioning (Year)*	*Owner*	*Capacity (MW)*
Moba	..	Public	1.00
Mpozo (Bas Congo)	1960s	Public	2.21
Lungudi (Kasai Occidental)	1960s	Public	2.00
Kilubi (Katanga)	1960s	Public	9.90
Mobayi Mbongo	1989	Public	10.50

Note: List is incomprehensive as there are other unknown smaller private plants (self-producers).

Massive hydropower potential is available and more than 350 sites have been identified.

Positive aspects for small hydropower development in the Democratic Republic of Congo are:

- Access to electricity and drinking water is a right in the new Constitution;
- The energy sector reform is on-going;
- The electricity sector has been liberalized;
- Hydro sites have been identified and many studies are available;
- There are needs to increase the national electricity access rate through development of the country's abundant hydropower resources;
- Incentive policies are provided to attract foreign investors.

Table 3
Small hydro potential under 10 MW in the Democratic Republic of Congo

Name (Province)	Potential capacity (MW)
Kakobola [a]	6
Ruki	5.3
Lepudungu	3
Ruwenzori I	6
Ruwenzori II	6
Kisalala [b]	7.5
Rutshuru	4
Ngingwe	3
Binza	5
Osso	3
Mwenga	9.5
Piana Mwanga II	8.4
Delporte	5
Tshilomba [b]	3 (or 2.4 to 7)
BRI de Lubilanji II	4.2
Tshala II	12
Katende/Bombo	10
Lukenie	3
Butembo [b]	1- 6
Lubilanji 2 [b]	4.2

Sources: Dikangala and Bavueza[3], International Journal on Hydropower and Dams[6]
Notes:
a. In planning, construction
b. In planning, missing funding

Barriers to small hydropower development

In general, infrastructure development has been hindered in the Democratic Republic of the Congo due to instabilities caused by the country's democratization process in the past 50 years. Building of small hydropower plants near viable economic centres, as planned by the rural electrification programme, has been a challenge until now also due to lack of funds.

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1.2.5 São Tomé and Príncipe

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	183,176[1]
Area	960 km[2]
Climate	Tropical, hot and humid, with one rainy season (October to May)
Topography	Island, volcanic, mountainous
Rain Pattern	Annual rainfall is 5,000 mm in the southwest and 1,000 mm in the north.

Electricity overview

The fact that 40 per cent of the population lack access to electricity has been identified by the São Toméan Government and international donors as a central constraint to the island nation's development.[2]

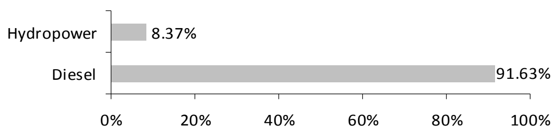

Figure 1 **Electricity generation in São Tomé and Príncipe**
Source: Ministry of Planning and Finance[3]

The country's generation and transmission systems need considerable investment for maintenance and capacity expansion.[2] There is a high degree of reliance on traditional biomass fuels for basic energy needs. An estimated 30 GWh/year are available from biomass utilization. Sustainable use of forestry resources is therefore of paramount concern.

Daily blackouts on the islands of São Tomé and Príncipe have driven large electricity customers off-grid and towards the alternative of diesel generators. Furthermore, the national utility is running at high technical and financial losses. According to the estimates of World Bank, about 70 per cent of the grid needs urgent maintenance. Governance and management account for heavy financial losses of the utility; high generation costs, low efficiency and, notably, the dependence on oil imports are also important factors for the renewable energy sector development.[2]

Of the total installed generation capacity of 16 MW about 2 MW is a hydropower plant, while the remainder are conventional thermal turbines (figure 1). The country and its energy sector are dependent on oil imports from Angola (approximately 650 barrels of oil per day), and imposes a heavy burden for its balance of payments. In the future, the demand for electricity will increase, for example the harbour being constructed in São Tomé alone will need about 21 MW of installed capacity.

Empresa de Água e Electricidade (EMAE) manages water and electricity supply. A European Union Energy Initiative Partnership Dialogue Facility project intends to provide capacity development in technological renewable energy solutions that are available on the islands through the provision of training in solar photovoltaic, wind energy, and micro hydropower.[2]

The country's total installed electricity capacity in 2007 was 15.6 MW (hydro: 58 per cent, petroleum products: 42 per cent).[4] Electricity is provided by EMAE, a 100-per cent vertically-integrated company, which falls under the jurisdiction of the Ministry of the Environment, Infrastructure and Natural Resources. This Ministry is also responsible for the development of the energy sector, including capacity building. Empresa Nacional de Combustíveis e Oleos (ENCO) is responsible for the wholesale of oil and petroleum products in the country.[4]

Autoridade Geral de Regulação (AGER), under the Ministry of Telecommunications, developed capabilities in the power business. AGER prepared the Bill of Law to define rights and obligations of concessionaries and licensees in the generation, transmission, distribution and marketing of energy.[4]

Small hydropower sector overview and potential

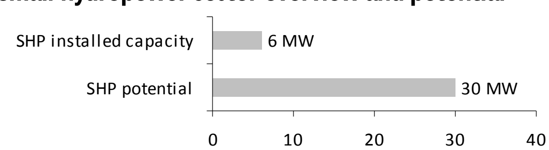

Figure 2 **Small hydropower capacities in São Tomé and Príncipe**
Source: International Journal on Hydropower and Dams[5]

It was announced in 2008 that the Portuguese company Soares da Costa planned to finance, build, own and operate 12 small hydropower plants with a total capacity of 30 MW. Under the contract, the company will also operate existing small hydropower plants in the country. Construction of the first new plant, Roca Bombaim (4 MW) started in early 2008. All output of the plants will be sold to the State company EMEA.[5] According to the Clean Energy Portal-Reegle, a privately owned micro-hydropower system already exists on the Augustino Neto plantation.[4]

The Government has announced that it was very keen to develop hydropower capacities to reduce dependence on thermal power production. No governmental agency is currently involved in the promotion of, or research on the use of sustainable energy in the country.[4]

Studies conducted by EMAE conclude that the country has potential for additional hydropower generation, but more analysis needs to be carried out. Preliminary feasibility studies for 14 sites suggest investment costs ranging from US$3,000 to US$10,000 per installed kW.[4]

Renewable energy policy

Currently the Government has a strong focus on crude oil production with oil expected to start flowing in 2016. Agreements with Nigeria and infrastructural development for fossil fuel excavation dominate political activity. There have been some efforts to consider diversification practices to avoid the negative impact of low growth and high unemployment outside of the oil sector.[6] It will be important that other energy options with a longer term future are considered for the sustainable development of the islands.

Barriers to small hydropower development

Reportedly, a vision for the energy sector is missing and planning capacity in the Ministry and the national utility needs to be enhanced. Various donors have small, insular projects that are neither integrated into a wider vision or strategy, nor are they connected to the relatively small grid.[3] The focus of the Government on future oil production is also diverting attention from small hydropower development.

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1.3 Northern Africa

Hussein Elhag, African Energy Commission, Algeria

Introduction to the region

Northern Africa is an ensemble of seven countries including Algeria, Egypt, Morocco, Sudan, Libya, Tunisia and Western Sahara. Five of these countries currently use hydropower, including small hydropower.

The climate is an important factor. Morocco, Algeria, and Tunisia comprise of desert areas and contrasting coastal mountainous areas. Egypt's Nile Valley and Delta interrupt its desert plateau and the Nile River flows through Sudan. Libya does not use any hydropower, particularly since it is mainly covered by desert and flat terrain. Libya, as of September 2012, has no plan to develop hydroelectric power and any plans to develop have so far not been materialized.[1]

Due to its climate and desert conditions, this region has abundant solar power potential often suppressing any incentive to invest in hydro technology. The North African region contains one of the major initiatives called DESERTEC. The Desertec industrial initiative (Dii) is a coalition of companies that would like to build a vast network of solar and wind farms across North Africa and the Middle East to provide 15 per cent of Europe's electricity supply by 2050.[2] Plans for the first phase of a solar farm of 500 MW in Morocco were well advanced by the end of 2012.[3]

Table 1
Overview of countries in North Africa

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Installed electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Algeria	37.367	56	99.3	11 332	45 170	282	560
Egypt	83.688	57	99.6	24 726	139 000	2 800	12 863
Morocco[b]	32.309	43	97.0-98.0	6 344	22 851	1 700	3 631
Sudan[c]	34.206	60	35.9	1 268	4 323	550	7 250
Tunisia[d]	10.732	33	99.5	3 598	14 866	~ 70	300
Total	**198.302**	**-**	**-**	**47 268**	**226 210**	**5 402**	**24 604**

Sources:
a. The International Journal on Hydropower and Dams[4]
b. Morocco Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique[5]
c. Reegle[6]
d. Tunesia Société Tunisienne de l'Electricité et du Gaz Energies Renouvelables[7]
Note: South Sudan attained its independence on 9 of July 2011, therefore the Sudan 2010 hydropower production data includes data from South Sudan.

The countries of North Africa facing the Mediterranean Sea are currently enjoying the highest electrification rates in Africa, some of which above 99 per cent, thanks to the rich gas and oil resources in the region. However, these countries are likely to run out of hydrocarbon resources by 2050 and are therefore cautiously tapping on other energy resources mainly solar, wind and nuclear. Despite the promising future of renewable energy businesses in the region, most of these countries have taken solid steps towards developing nuclear energy for power generation. Egypt has planned to start the construction of its first nuclear power plant and it is expected to enter into operation by 2020. Algeria, Morocco and Tunisia have similar ambitious plans.

Small hydropower definition

Apart from Tunisia and Morocco, the other countries do not have any official small hydropower definition. In Morocco, only hydropower plants below 12 MW are considered as renewable energy (table 2).[8]

Table 2
Classification of small hydropower in Northern Africa

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*	*Pico (kW)*
Morocco	2≤-≤8	0.5≤-≤2	5≤-≤500	-≤5
Tunisia	1-10	0.1-1	20-100	<20

Sources: Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique[5], Société Tunisienne de l'Electricité et du Gaz Energies Renouvelables[7]

Regional overview and potential

Five countries in North Africa use small hydropower.

- Over 90 per cent of the electricity production in Algeria is based on natural gas, therefore interest and investment in small hydropower, let alone the hydro sector, is at a minimum despite the existence of hydropower resources.[9]
- Egypt has a well-developed hydropower sector that has been strengthened by governmental policies. The remaining potential cannot be calculated due

to the lack of data, however opinions and views gathered during research showed that most of the resources have already been developed.
- Although hydropower in Morocco is hindered by climatic disadvantages, potential for micro and mini small hydropower is prominent in the country.
- Sudan, despite its volatile history, has experienced higher interest in the energy sector after the introduction of the year 2000 Energy Laws.
- Tunisia greatly relies on its natural gas reserve as well as imports from neighbouring country Algeria, thus, it has not invested in hydropower, except for its northern area. Significant potential for small hydropower is available in the country and the Government is motivated to promote the use of hydropower, however, efforts are obscured by a lack of awareness and incentives.

The total known installed small hydropower capacity in North Africa based on the information that was available is around 115 MW. The potential of small hydropower was estimated to be approximately 184 MW. The statistics have been underestimated, due to the lack of information.

Morocco, followed by Tunisia, has the most amount of installed small hydropower (according to the 10 MW definitions), while Algeria's installed capacity is unknown (table 3).

Table 3
Small hydropower up to 10 MW in Northern Africa
(Megawatt)

Country	*Potential*	*Installed capacity*
Algeria	at least 35	35
Egypt	32	7
Morocco	54	37
Sudan	34	7
Tunisia	at least 29	29
Total	**184**	**115**

Sources: see country reports and references therein.
Notes: The small hydropower gross potential has been reported as river potential for Egypt (68.2 MW) and Tunisia (37.1 MW), however it is not clear what kind of small hydropower classification was applied.[10]

In general, due to the climate and the little-known resource potential of small hydropower in the region, small hydropower development will probably continue to develop slowly. Only Morocco and Sudan have some more feasible sites that could be developed and only Tunisia encourages the use of small hydropower plants as part of its national promotion programme for renewable energy.[11]

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1.3.1 Algeria

Kai Whiting, International Center on Small Hydro Power

Key facts

Population	37,367,226[1]
Area	2,381,741 km[2]
Climate	Arid to semi-arid; mild, wet winters with hot, dry summers along coast; drier with cold winters and hot summers on high plateau; sirocco is a hot, dust/sand-laden wind especially common in summer.
Topography	Consisting mostly of mountains, hills and small plains along the coast
Rain Pattern	Precipitation varies from over 1,200 mm in the coastal basin to very little in the Sahara desert.[1]

Electricity sector overview

Algeria has the tenth largest reserves of natural gas in the world and is the sixth largest gas exporter. The country exports to Europe through two gas pipelines: to Italy via Tunisia, and to Spain via Morocco. Three additional pipelines, namely Medgaz, Galsi and Trans-Saharan were in development as of 2011.[2]

The Algerian Electricity Law in 2002 addresses that the country's energy sector is incompatible with international standards. Under this law the state–owned electricity and gas monopolist Société Nationale de l'Électricité et du Gaz (Sonelgaz) unbundled its activities, and an independent regulatory body was established.

In 2010, total electricity generation was 45 TWh. Figure 1 presents the electricity generation sources in the country.

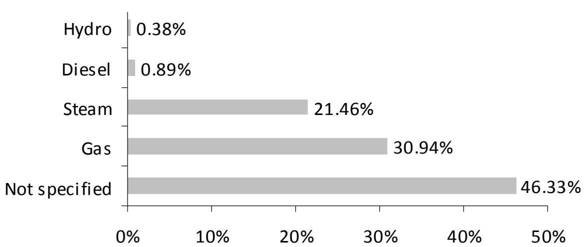

Figure 1 **Electricity generation in Algeria**

Source: Commission de Régulation de l'Électricité et du Gaz[2]

Note: Not specified - producers that are not Sonelgaz.

Over 90 per cent of the electricity production in Algeria uses natural gas (the remaining 10 per cent comes from fuel oil/diesel and hydropower). Algeria has an electrification rate of 99.3 per cent, leaving 200,000 people with no access to electricity.[3]

Currently around 280 MW installed hydropower capacity is in operation (560 GWh/year), with plants of capacities between 1 and 50 MW (table).[4] In the period between 1971 and 2010, the average percentage contribution of hydropower to the total electricity production was four per cent. The highest value was registered in 1973 (26.8 per cent) and the lowest value in 2002 (2 per cent).[5] Hydropower is expected to account for 1.2-1.3 per cent of electricity generation by 2025.[6]

Installed hydropower capacity in Algeria

Plant [a]	*Capacity (MW)*	*Date of commission (Year)*
Ighil Emda	24	1952
Darguinah	66	1952
Erraguene	16	1962
Mansouriah	100	1963
Off irrigation channels or water flow	~43	
Total	**249**	

Source: Maghreb Electricity Committee[7]

Note: a. Owner for all plants is Sonelgaz

Small hydropower sector overview and potential

In light of the international small hydropower definition of 10 MW upper limit capacities, there are at least 35.3 MW of small hydropower plants installed in Algeria (figure 2). However the full installed capacity cannot be confirmed, since a sufficiently detailed list of hydropower plants was not available. The small hydropower potential is unknown.

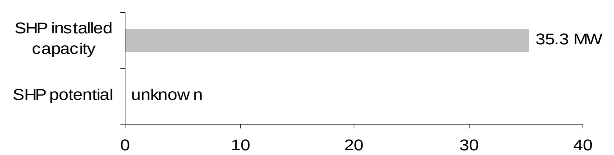

Figure 2 **Small hydropower capacities in Algeria**

Renewable energy policy

The agency responsible for renewable energy is New Energy Algeria (NEAL). Under the 2011 Renewable Energy and Energy Efficiency National Programme for the period between 2011 and 2030, the goal was to generate 40 per cent of energy from renewable resources.[9] This approximates an installed electricity generation capacity of 22 GW: 12 GW for domestic use and 10 GW for exports.[10]

During this period the aim was to reach five per cent of the national electricity supplied from concentrated solar power with thermal storage capacity. Algeria therefore plans to install a total of 650 MW solar energy by 2015.[9] [11]

One of the objectives on renewable energy development by the Ministry of Energy and Mines (MEM) is to supply energy to the isolated zones, far from the gas distribution networks (such as the electricity and oil products). Another objective is to contribute to the preservation of hydrocarbons reserves by the development of renewable energy resources, particularly solar.

Barriers to small hydropower development

All forms of hydropower in the region are facing stagnation in potential expansion due to geographical and climatic limitations. This in turn forces the Government to move funding and opportunities away from the hydropower sector and towards alternative technologies such as wind and solar, which have increasingly become more attractive options.[12] This is reflected by the fact that hydropower is absent from the MEM's Renewable Energy and Energy Efficiency National Programme. Furthermore, researchers in the field have also openly claimed that hydropower was excluded from the evaluations of renewable energy potential.[13]

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1.3.2 Egypt

Kai Whiting and Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	83,688,164[1]
Area	1,001,450 km[2]
Climate	Desert climate is prevalent, with hot, dry summers (May to October) and moderate winters (November to April)
Topography	Vast desert plateau interrupted by the Nile valley and delta
Rain Pattern	Egypt receives less than 80 mm of precipitation annually in most areas, although in the coastal areas it reaches 200 mm.[2]

Electricity sector overview

The electricity supply in Egypt is highly dependent on fossil fuels, generating electricity mostly through conventional thermal power stations. The total installed power capacity in Egypt is 24,726 MW. The percentage of electricity generated from hydropower is 12 per cent and is not likely to increase in the short term as the newer plants being built are mainly based on fossil fuels (figure 1).[3]

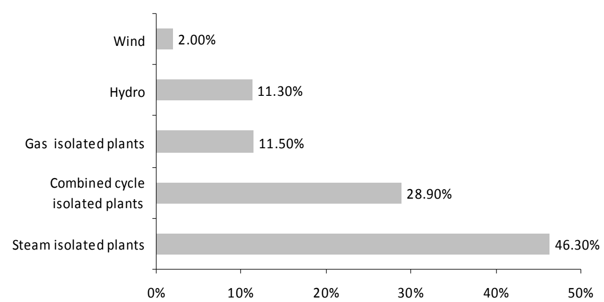

Figure 1 **Electricity generation in Egypt**
Source: Ministry of Electricity and Energy/ Egyptian Electricity Holding Company[4]
Note: Data from 2009/2010.

The electricity consumption in Egypt has been increasing rapidly. Between 2005 and 2009, the commercial sector has experienced the most rapid average annual growth (at 10.2 per cent), followed by public utilities (at 9.4 per cent), government (8.3 per cent), agriculture (at 7.9 per cent), residential (at 7.5 per cent), and industry (at 5.9 per cent).[4] Peak electricity demand has also grown substantially, increasing by over two-fold, from 6,902 MW in 1990 to 24,726 MW in 2010.[1]

As of 2009, the electrification rate in the country reached 99.4 per cent with 99 per cent electrified in rural areas. For the few remaining remote settlements, the decentralized use of renewable energy resources is under consideration, since grid extensions are economically unfeasible.[6]

Ageing infrastructure coupled with rapid increases in demand, especially in the industrial sector, have caused intermittent blackouts (i.e. summer of 2012), as a result there had been protests from customers who were beginning to threaten non-payment.[7] In view of this the planned investment in the sector by the Government has become increasingly necessary.[8]

Small hydropower sector overview and potential

The Egyptian governmental policy has consistently emphasized the importance of hydropower for the country. There is a view that most potential hydropower resources have already been developed. Egypt's hydropower potential is about 3,664 MW with an estimated energy of 15,300 GWh per annum. There are currently five main dams in operation all located on the River Nile. Almost all the electricity generation comes from Aswan High Dam and Aswan Reservoir Dams.[3]

The share of hydropower represented about 9.2 per cent from total electricity generation in 2009-2010. In Egypt, the power generation from hydro resources started in 1960 for the purpose of constructing Aswan Dam to control the Nile water discharge for irrigation.

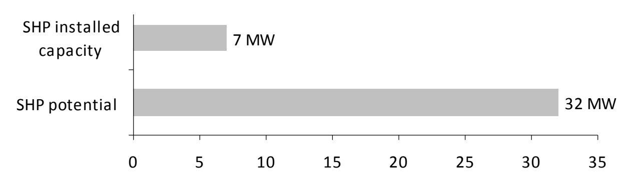

Figure 2 **Small hydropower capacities in Egypt**
Sources: combined from Deutsche Gesellschaft für technische Zusammenarbeit[6], Hydro Power Plant Executive Authority[9], Soliman[10]

The country's Hydro Power Plants Executive Authority (HPPEA) is an affiliate entity to the Ministry of Electricity and Energy. It is responsible for the study, execution and the development of hydropower projects. Egypt has an installed capacity of small hydropower at 6.8 MW (figure 2).[6] The HPPEA and The Egyptian Electricity Holding Company (EEHC) are coordinating planning, preparation of feasibility studies and follow up of the execution of the following hydropower plant projects (see table).

Installed and potential hydropower capacity in Egypt
(Megawatts)

Installed hydropower plants	*Name of plant*	*Installed capacity*
Plants (> 10 MW or larger)	High Dam	2 100
	Aswan Dam I	280
	Aswan Dam II	270
	Esna	86
	Naga Hammadi plant	64
	Damietta	13
Plants (up to <10 MW)	Small Nasa/Hamadi	4.5
	El Lahun	0.8
	El Faiyum	0.8
	El Azab	0.7
Under construction	*Name of plant*	*Planned capacity*
To be commissioned in 2014	New Assuit Barrage hydroelectricity	32.00
To be commissioned in 2014	Zefta	5.50
-	El Sekka/El Hadeed	0.55
-	Wadi El Rayan	0.55
Potential small hydropower sites	*Name of plant*	*Potential capacity*
	El Mokhtalat	1.00
	Tawfiki Rayah	2.45
	Edfina Barrage	1.85
	Assiut Regulator	3.00
	Abbasi Rayah	1.85
	Ibrahimia Canal Intake	1.55
	Beheri Rayah	2.20
	Menoufi Rayah	1.80
	Sharkawia Canal	1.85
	Bahr Yousef Canal	1.00

Sources: German Agency for Technical Cooperation[6], Hydro Power Plant Executive Authority[9], Soliman[10]

Renewable energy policy

The use of renewable energies is seen by some as a good way to fight desertification and dryness in Egypt, because 60 per cent of the country is desert.[11]

In April 2012, the Egyptian Ministry of Electricity finalized drafting a new unified law for electricity, which will be the primary legislation for the energy sector in Egypt. It encourages investors to produce electricity from renewable energies and other sources.[12]

Renewable efforts were traditionally led by hydropower but the dwindling ability to develop further resources has led Egypt to look elsewhere. The country is endowed with abundant wind energy resources. It has the largest installed capacity in Africa and in the Middle East. The Government is set to continue Egypt's dominance in the region with the goal of building about 7,200 MW of wind power capacity by 2020.

Egypt has a national energy strategy, although only adopted at the level of energy policy committee of the governing party. The strategy covers the diversification of the energy mix, higher energy efficiency, and a reform of the electricity, oil and natural gas markets as well as a reduction of energy subsidies. The renewable energy strategy is a fundamental part of the national energy strategy. In February 2008, the Government set a new ambitious target of 20 per cent renewable energy in electricity production by 2020, excluding existing large hydropower plants. The target is based upon 12 per cent wind, 6 per cent hydropower and 2 per cent of other renewable energy sources.[13]

As of 2011 the Ministry of Electricity and Energy established the New and Renewable Energy Authority (NREA) for the purpose of promoting renewable sources and energy efficiency.[14] The Supreme Energy Council approved an energy strategy which, among other measures, recommended preparation of the Egyptian Combined Renewable Energy Master Plan.[15 16]

In April 2012, the Egyptian Government expressed interest to further finance renewable energy and to promote clean electricity generation to combat climate change. The funding of about US$400 million will be financed through the support programme of economic development policies affiliated to the African Development Bank.[12]

Barriers to small hydropower development

One major barrier to the small hydropower development is the low price of electricity, which is highly subsidized. The governmental plan intends to gradually accommodate the electricity prices to the actual cost of the electricity system. The New Electricity Law is supposed to specify the main principles of price regulation.[6] In early 2012, subsidy cutting began for heavy industry but further cuts are (as they have been historically) resisted because of fear of stoking inflation and further civil unrest. However, renewed pressure to tackle the issue arose with the negotiation of an International Monetary Fund (IMF) emergency loan from the IMF to avert a balance of payments crisis.[17] The Government states that it plans to remove all energy subsidies by 2017.

There is an agreed consensus that the majority of viable hydropower resources have already being used. It is estimated that over 85 per cent of the river Nile, has already been exploited, which means that NREA would obtain better marginal gains and financial support by looking into other untapped non-hydro resources.[8]

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1.3.3 Morocco

Kai Whiting and Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	32,309,239[1]
Area	446,550 km[2]
Climate	The prevalent climate is Mediterranean, becoming more extreme in the interior.[1]
Topography	Northern coast and interior are mountainous with large areas of bordering plateaus, inter-montane valleys, and rich coastal plains.
Rain Pattern	Rainfall remains low in comparison to the northern Mediterranean countries. The mean annual rainfall varies between 500 mm to 2,000 mm in the northwest, to less than 100 mm in the southeast.[2]

Electricity sector overview

The Moroccan electricity sector is governed by the state-owned Office National de l'Électricité (ONE). The country is the only one in the region without strong fossil fuel reserves. Therefore, Morocco has to import the majority of its energy. An import dependency at 96 per cent makes it vulnerable to volatile energy markets, and puts a heavy burden on the State, which controls energy prices through the use of subsidies.[3] Since 1996 the country has had access to Spanish energy through two 25-km long AC submarine transmission cables passing through the Strait of Gibraltar.[4] In 2012, the total capacity stands at 1,400 MW with a maximum transfer capacity of 700 MVA. There are post-2020 plans for further reinforcement, by adding a third of the submarine AC cable with the same characteristics of the ones previously installed. This would enable a total thermal capacity of 2,100 MW, while maximum transfer capability could reach 1,400 MVA.[5]

Morocco's only other interconnection for energy imports is with neighbouring Algeria, but at a lower capacity of 800 MW. With no plans yet to develop further, this heightens Morocco's dependency on the Spanish electricity sector.[6]

Coal power plants, fuelled by imported hard coal, form the backbone of the country's generation system at 1.8 GW installed capacity (figure 1). About 12 per cent of Morocco's electricity demand is currently supplied by open cycle and combined cycle gas power generation, and this share is expected to rise with additional combined cycle power plants coming online in the near future. Liquid fuels (used in diesel- or oil-fired steam plants) still provide 13 per cent of the country's total demand, but the use of these energy resources is expected to decrease in the long-term due to escalating oil prices. The share of hydropower, is set to decline in the future due to its limited expansion possibilities.[7] The existing interconnection with Spanish electricity grid is responsible for a 4,595 GWh import and an 8 GWh export.[8] Electricity imports constituted 17 per cent of Morocco's electricity provision in 2011.[9]

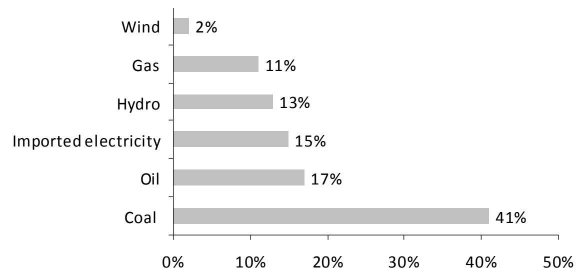

Figure 1 **Electricity generation in Morocco**
Source: Ministry of Energy, Mines, Water and the Environment[10]
Note: Data from 2010.

Although electricity consumption per capita remains low (480 kWh per person/year), the overall electricity demand has grown by approximately 6-8 per cent annually since 2000. A key issue that ONE is steadily addressing is energy poverty. The electrification rate is around 98 per cent, with 100 per cent in urban areas.[11] Currently, the majority energy demand in non-grid connected rural areas is satisfied through firewood, placing significant pressure on vegetation use.[12] The rate of rural electrification was only 18 per cent in 1995, but rose steadily to 96.8 per cent by the end of 2010.[11] Solar power is being targeted as a secure form of energy and as a national way to minimize the problem of electricity access.[13]

Small hydropower sector overview and potential

A century rainfall data analysis shows that the climate of Morocco is principally characterized by drought.[14] Nationally, spring rainfall has declined by over 40 per cent since 1960s. Drought seems to become more persistent over time. The maximum dry spell length is increasing during the rainy season. During the period end of February to April 2012 it has increased by 15 days compared to the same period in the 1960s, placing pressure on drinking water supplies and hydropower. The annual mean of rainfall varies from more than 1,000 mm per year in the mountains zones in the North to less than 300 mm in the East and the South basins of the country.[15]

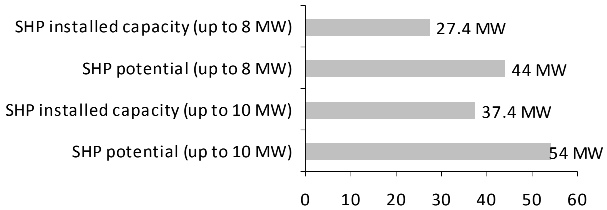

Figure 2 **Small hydropower capacities in Morocco**
Source: Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique[16], Comité Maghrébin de l'Electricité[19]

The wind/hydro component of the Integrated Wind/Hydro Programme, run by ONE and supported by the African Development Bank (AfDB) is designed to maximize wind exploitation, using excess wind energy to store water for the later production of hydropower, and supply water to generate hydropower during the dry season. The project, with completion envisioned for 2017, is expected to support new transmission infrastructure and water storage facilities.[17] The hydropower component specifically comprises two sub-projects: the Abdelmoumen Pumped Power Transfer Station Project (STEP) and the Mdez El Menzel Hydropower Complex, which is designed with a nominal capacity of 125 MW.[18]

Morocco, in particular, was highlighted by the United Nations in September 2012 as having a particular potential for micro- and mini-hydropower plants.[8] In 2010, the total installed small hydropower capacity in Morocco was 0.633 MW spread over 10 plants, with many of them needing renovation (table 1).[16] Furthermore, ONE identified some 200 sites which could make an improved contribution to the energy needs of isolated areas.[8] However, in quantitative terms, the total small hydropower potential of 18 MW means that its input in the energy balance will remain limited.[16]

Table 1
Micro- and mini-hydropower in Morocco

Past and current small hydropower	*1990*	*2000*	*2010*
Total installed capacity (operating) (MW)	0.162	0.216	0.633*
Annual production (GWh/yr)	..	..	..
Number of plants			10
Average age of plants (years)			23
Percentage of private owners (%)			9
Small hydropower potential	*2015*	*2020*	
Additional capacity to be completed in the future (MW)	2	4	
Annual estimated production (GWh/yr)	18	46	
Existing master plan for small hydropower	Yes		
EIA required for small hydropower	Yes		
Evaluation of small hydropower potential (undefined) in 2011	18 MW, 126 GWh/yr		

Source: Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique[16]

Table 2
Examples of micro-hydropower in Morocco

Station name	*Installed capacity (kW)*	*Operating since*	*Benefit*
Askaw (Province d'Agadir)	200	May 2002	30 villages in township of IGUIDI close to Agar (593 homes)
Oum –Rbaî [a]	220	December 2004	556 homes and administrative buildings belonging to the municipality Oum Er Rbia, in the province of Khénifra.

Note: a. isolated network.

Table 3
Installed small hydropower capacity up to 10 MW in Morocco

Plant name	*Installed capacity (MW)*	*Commissioning date (Year)*
Ait Messaoud	6.4	2003
Kasba Zidania	7.1	1935 and 1936
Mansour Eddahbi	10.0	1973
Bou Areg	6.4	1969
Taurart	2.0	1951
12 others	4.9	-

Source: Comité Maghrébin de l'Electricité[19]

Renewable energy policy

Technical and financial support provided by the AfDB should ensure that the goal of increasing installed renewable energy capacity to 42 per cent by 2020 (accounting for approximately 6,000 MW of additional renewable energy) is realized.[20] Out of the 42 per cent solar energy, wind energy and hydropower will each represent 14 per cent.[21]

Morocco has among the highest levels of sun radiation in the world.[22] In recognition of Morroco's emergence as an early leader in developing low carbon, sustainable energy on a large scale, AfDB approved loans in May 2012 for the first phase of the Concentrated Solar Power (CSP) plant at Ouarzazate which is proposed to generate 120 MW to 160 MW of electricity in its first phase and 500 MW at full capacity, making it the largest CSP plant in the world.[17 23]

In June 2012, AfDB approved its largest project to date for 2012 with a loan of €359 million and a US$125 million funding from the Clean Technology Fund for Morocco's Integrated Wind/Hydro and Rural Electrification Programme.[18] Implemented by ONE, these initiatives aim to increase national wind power capacity by 1,070 MW and expand rural electrification to 79,436 households in 24 of Morocco's most isolated and vulnerable districts.[17]

Decentralized renewables have not yet been deployed in Morocco due to pending adoption of the necessary legal and regulatory framework and further development of the low- and medium-voltage infrastructure. The introduction of smart metering as part of ONE's initiative (as of September 2012, it was still awaiting approval from the Board) will pave the way for the deployment of decentralized renewable generation.[24]

Barriers to small hydropower development

The strong financial support provided by AfDB amongst others is a positive sign and reward for Morocco's proactive approach. However, decreasing rainfall as well as water quality and availability remain the key issues, hindering small hydropower development in Morocco.

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1.2.4 Sudan

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Key facts

Population	34,206,710[1]
Area	2,376,000 km[2]
Climate	The prevalent climate is hot and dry and there is an arid desert.
Topography	Generally flat, with featureless plains and desert dominating the north
Rain Pattern	The rainy season varies by region from April to November.[1]

Electricity sector overview

Energy power infrastructure is at the moment developed only around selected urban centres and strongly associated with hydropower with limited thermal generation capacity. The national grid reaches a half million households, less than 10 per cent of the population; major and minor local grids serve another 5 per cent. As a result, only 30 per cent of the population has access to electricity.[2] The National Electricity Utility (NEC) transmits electricity through two inter-connected electrical grids: the Blue Nile Grid and the Western Grid. The supply of electricity in off-grid zones is often based on small diesel-fired generators for power.[2]

The authors believed that there was a scope for extending the national electricity transmission and distribution capabilities, and that Sudan has the potential to engage in cooperative electricity transmission projects with neighbouring Ethiopia.[3] Power generation capacity tripled in just a few years, rising from around 800 MW in 2005 to 2,687 MW in 2007, with a shift toward hydropower (figure 1).[4]

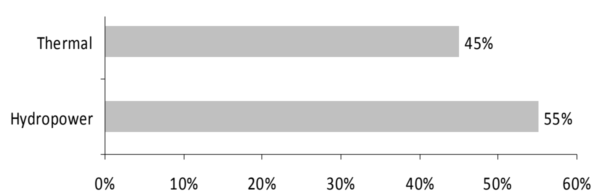

Figure 1 **Electricity generation in Sudan**
Source: Ranganathan and Briceño- Garmenda[4]

The 2000 Energy Law opened doors to private investors in electricity generation, transportation and distribution. The 2001 Investment Law also did the same for foreign investments, inviting such cooperation in particular from China.[2]

Small hydropower overview and potential

Before independence was granted to South Sudan, Sudan had the highest hydropower capacity in the North African region.[5] There are six hydropower plants in operation, with one of them being a small hydropower plant (below-10 MW installed capacity) (figure 2 and table). Sennar dam is the oldest dam in the country.[6]

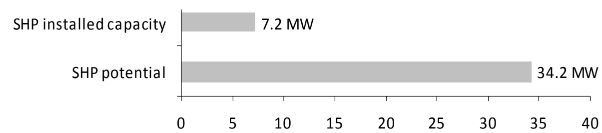

Figure 2 **Small hydropower capacities in Sudan**
Note: A country-wide study has not been carried out.

Installed hydropower capacity in Sudan

Station	*Year*	*Unit capacity (MW)*	*Units (Number)*	*Total capacity (MW)*
Sennar	1962	7.5	2	15.0
Roseires	1972/1989	40	7	280.0
Girba 1	1964	5.3	2	10.6
Girba 2	1964	2.4	3	7.2
Jabal Aulia	2003	3.6	8	30.4
Merowe	2009/2010	125	10	1250.0

Source: Abuaglla[7]

There have been two agricultural projects, one in Eljazeera and one in Elmanagil, estimating the power generation potential for some irrigation structures. The Elzajeera project focused on the assessment of four different sites with a total estimated potential of 14.3 MW. The Elmanagil project focused on the assessment of eight different sites with a total estimated potential of 12.66 MW. Potential sites for small hydropower plants are on existing irrigation dams and canals, as well as on seasonal rivers.[7]

The government is currently heightening the Roseires Dam by 10 metres, which will allow additional storage of 4 billion m^3 of water. This water will be used to irrigate about 1.5 million hectares of land in the eastern part of the country which includes two schemes of Kenana and Rahad canals. Rough estimations indicate that each canal may provide 20 MW of small hydropower capacity.

At the same time, two new dams are currently under construction at Upper Atbara and Setatit in eastern Sudan with a total capacity of 320 MW. The dams will also irrigate over one million hectares of land downstream and for that two giant canals will be constructed, each with one small hydropower plant with a capacity of 15 MW. Two Chinese companies, China Three Gorges Corporation (CTGC) and China Water and Electric Corporation (CWE), were contracted for the construction and the project will be commissioned in 2014.[8] A number of prospective areas have been identified by surveys, and studies are being carried out to explore mini hydropower resources. The current flow of the Nile could be used to run in-stream turbines; water could then be pumped to riverside farms. There are more than 200 suitable sites for the use of in-stream turbines along the Blue Nile and the main Nile. The total potential of energy generation from mini hydropower can be considered to be 67 000 MWh/year for the southern region, with 3,785 MWh/year in the Jebel Marra mountains, and 44,895 MWh/year in El Gezira and El Managil canals. About 8.5 MW of hydropower capacity is planned at the three plants.

Renewable energy policy

The Sudan Renewable Energy Master Plan from 2005 promoted the use of renewable sources, particularly photovoltaic and biomass with the aim to eliminate the dependency on conventional energy.[2] The major state stakeholders in shaping renewable policies in the country include the Ministry of Science and Technology, the Energy Research Institute, which develops renewable energy pilot projects; and Forestry Research Institute covering biomass energy technologies.

Barriers to small hydropower development

Small hydropower appears to be an attractive option for the country. However, certain barriers need to be addressed if the objectives are to be fully achieved. These include the following:

- Continuing social tensions and unstable security situation in some areas: Sudan has suffered from two prolonged civil wars rooted in economic, political, and social division
- Low level of public awareness on the economic/ environmental benefits of hydropower and small hydropower plants;
- Weak institutional capacity of the various energy research institutes and the lack of clear policy.

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1.3.5 Tunisia

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Key facts

Population	10,732,900[1]
Area	155 360 km^2
Climate	The prevalent climate is temperate in the north with mild, rainy winters and hot, dry summers.[1]
Topography	Mountainous in the north; a hot, dry central plain and a semi-arid south that merges into the Sahara
Rain Pattern	The annual average precipitation in Tunisia amounts to about 1,580 mm in the Atlas mountains in the north-west, down to well below 50 mm in the south.[3]

Electricity sector overview

The electricity sector is fed predominately by gas-fired power plants from both natural gas from the country's own reserves and imports from Algeria. More than 90 per cent of electricity generation comes from gas. The total installed capacity from all energy sources is 3,559 MW, generating 11,569 GWh/year.[2]

The majority of the electricity used in Tunisia is produced locally by the Societé Tunisienne d'Électricité et du Gaz (STEG), the national electric utility that is responsible for electricity generation, transmission, and distribution, as well as natural gas transport and distribution.[4] Electricity consumption in Tunisia has been increasing steadily for the past 30 years. From 1976 to 2006 the registered annual growth rate was approximately 7.4 per cent.[5] It is expected to reach to about 32,000 GWh per year by 2030.[1]

The state utility company has operated a monopoly for many years and continues to demonstrate some resistance to private investment in the sector. The legal framework allows independent power projects (auto-producers)with the possibility of selling up to 30 per cent excess back to the grid of STEG. The Independent Power Producers (IPPs) for direct sale to STEG are permitted only on a case-by-case basis. The share of power of STEG's equipment is around 85 per cent (2,846 MW). The remaining 15 per cent represents two IPP power plants, Rades II and El Bibane, managed respectively by: Carthage Power Company (with a combined cycle of 471 MW putting into operation in 2002) and El Bibane (two gas turbines of a total capacity 27 MW put into operation in 2003).[6]

A subsidiary, STEG Énergies Renouvelables, was established in May 2010 as a private law company with the main objective to contribute to the leadership and the development of Tunisian Solar Plan (TSP). It aims to promote the national renewable energy policy through the development of public-private partnerships in renewable energy and energy efficiency, and to conduct feasibility studies, construction, operation and maintenance of renewable energy and cogeneration power plants.[7] In early 2012, the Tunisian government indicated that it will revise existing legislation to allow IPPs in renewable energy. Furthermore, tax incentives are in place for energy conservation and renewable energy projects, such as exemption of VAT on different products used for renewable energy technologies.[8]

The national electrification rate is 99.5 per cent: 100 per cent in urban and 99 per cent in rural areas.[2]

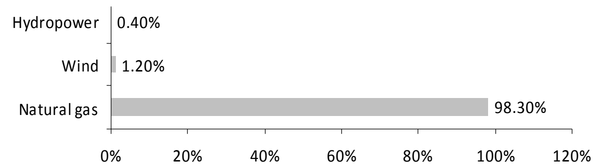

Figure 1 **Electricity production in Tunisia**
Source: Tunisian Company of Electricity and Gas[9]
Note: Only includes STEG electricity production, not IPPs.

Small hydropower sector overview and potential

Tunisia has a modest technically developable hydropower potential. An important constituent, which has been developed for electricity production, can be found in the northern part of the country. The hydropower stations are in El Aroussia, Nebeur, Fernana, Kasseb, Sidi Salem, Bouhertma and Sejnane (their capacities are presented in table 2). Such installations are permitted in this region due the dominance of a Mediterranean climate, with hot and dry summers and mild and relatively rainy winters.[4]

Table 1 and figure 1 provide an overview of small hydropower capacities in Tunisia. In 2010, the installed 67 MW capacity of hydropower generated 50 GWh, which represented only 0.3 per cent of the total national generation. This share will decrease steadily as the country will continue to depend on natural gas for power generation and developing other renewable energy resources such as solar and wind.[10] The total small hydropower installed capacity (2010) was 29 MW, generating about 34 GWh of electricity (figure 2).

Table 1
Small hydropower in Tunisia

Past and current small hydropower	*1990*	*2000*	*2010*
Total operating installed capacity (MW)	..	27.5	29
Annual production (GWh/yr)	38	42	34
Number of plants (under 10MW)	..	..	4
Average age of plants (years)	..	..	50
Percentage of small hydropower generating capacity owned by private owners	..	..	0
Planned small hydropower	*2015*	*2020*	
Additional capacity to be completed in the future (MW)	300 (pump storage)	300 (pump storage)	
Current capacity to be closed	0	0	
Annual estimated production (GWh/yr)	260	260	
Existing master plan for small hydropower	no		
EIA required for small hydropower	no		

Source: Chokri[2]
Note: Data from 2011.

Table 2
Installed small hydropower capacity in Tunisia

Station name	*Type of plant*	*Type of turbine*	*Head (m)*	*Average annual production (GWh)*	*Installed capacity (MW)*	*Start date (Year)*
El-Aroussia	Run-of river	Francis	11.0	3	4.80	1956
Fernana (downstream)	Run-of river	Francis	152.8	10	8.50	1958
Fernanan (upstream)	Run-of river	Francis	26.6	3	1.20	1962
Kasseb	Run-of river	Francis	51.0	2	0.66	1969
Bouhertma[a]	Run-of river	Francis	37.0	3	1.20	1976 , 2003
Mellègue	Dam - Multiple Gates, Capacity 300 x 106 m^3	..	-	-	6.50	1956
Ben Metir	Dam Capacity 73 x 106 m^3	..	-	-	8.50	1958
Kasseb	Spillway dam Capacity 92 x 106 m^3	..	-	-	0.66	1959
Sidi Elbarrak Sejnane	Earth fill dam Capacity 264 x 106 m^3	..	-	4	0.60	2003

Source: Chokri[2]
Notes:
a. Conflict of data, start for Bouhertma also given as 1976
b. STEG mentions eight hydro plants, including El-Arrousia, Fernana, Kasseb, Bouherthma and Sejnene.

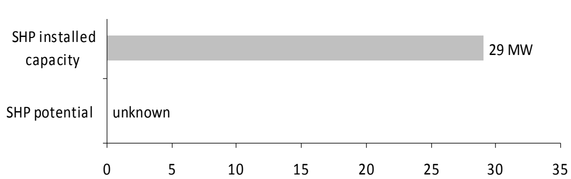

Figure 2 **Small hydropower capacities in Tunisia**

For the definition of small hydropower in Tunisia, see an overview of installed run-of-river plants and dams which use small hydropower in Tunisia. Within its policy of development and rational use of renewable energies, STEG launched a project of renewing the hydro stations in order to extend their life span.

Renewable energy policy

The African Development Bank (2012) commended Tunisia's proactive policy with regard to the management of energy as well as new and renewable energies (wind, solar, sludge from treatment plants).[11] The Law No 2004-72 and its modification in 2009, Law No. 2009-7, emphasizes the rational use of energy and defines the sensible use of energy as a national priority and the most important element of a sustainable development policy. It states three principal goals: energy saving, promotion of renewable energy and substitution of the energy forms used previously, wherever this offers technical, economic and ecological benefits. Article 14 lists four areas in the field of renewable energy, which are to be treated as priority areas of a national promotion programme:

1. Expansion of wind power for electricity generation;
2. Introduction of incentives for the use of solar thermal energy;
3. Use of solar energy for further electrification of rural areas, irrigation and seawater desalination;
4. Encouragement of the greater use of production residues for energy generation and of geothermal sources and small-scale hydropower plants.

As of October 2012, less than one per cent of the Tunisian energy comes from renewable sources. Through the completion of wind turbine installations such as Bizerte Wind farm stage B with 70 MW, the total installed capacity of wind is expected to be 244 MW by the end of 2012, which equates to 5.5 per cent of the national energy production. Solar energy is also expected to play a bigger role in the future with a 10-MW photovoltaic plant planned to be in operation by 2014 while a 50-MW concentrated solar power plant is planned to be in operation in 2015. Hydropower in the form of pumped storage systems will also be part of the mix, with a feasibility study underway for 400-500 MW capacity.[12]

The Government has planned a total capacity of 16 per cent renewable energies by 2016. This means that 12 per cent of the electricity will be coming from renewable energy sources such as hydropower and wind, with an installed capacity of 1,000 MW. Small hydropower should provide 4 per cent of the produced electricity. By 2030, 25 per cent should come from renewable energy sources with an installed capacity of 4,700 MW.

Barriers to small hydropower development

Hydropower generally faces the typical challenges found across the Maghreb region: water scarcity and over-exploitation of groundwater resources.[13] In addition, the following obstacles are to be addressed:

- Administration and planning constraints: the need of approval from the Ministry of Agriculture before a small hydropower plant can be operated;[2]
- Financing: the post-revolution effect has hurt the economy with two key sources of income experiencing deep decline, namely tourism revenue and declining foreign investment. The capacity of the external financial system to support funding for projects and Tunisian companies was generally (including renewable energy projects) undermined by the increase in financial risk. Also, political tensions in Libya make investments in Tunisia uncertain and technological innovation and recovery all more difficult.[11]

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1.4 Southern Africa

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Introduction to the region

The Southern African region comprises five countries, of which Lesotho, Namibia, Swaziland and South Africa use small hydropower, with Namibia currently having a very limited use of this technology. Botswana does not possess any hydropower plants.

The region has various climatic conditions, from tropical to temperate, semi-arid to desert. A high percentage of the population lives in rural areas and national electrification rates are generally very low with the exception of South Africa (table 1). Lesotho, Namibia, and Swaziland produce all or a majority of their electricity from hydropower, while South Africa is mostly coal dependent. All countries are members of the Southern African Power Pool (SAPP)[i]; Lesotho, Namibia and Swaziland are net importers of electricity. Lesotho has a very small electricity sector, thus recognizes the benefits of renewable energies. By 2020 the target for Lesotho is that 35 per cent of its electricity for rural electrification should come from renewables.[1]

Table 1

Overview of countries in Southern Africa

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electricity capacity (MW)*	*Electricity generation (GWh/year)*	*Installed hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Lesotho [a b e]	1.930	73	16	76	200	75.7	200
Namibia [a b e h]	2.165	62	34	393	1 430	249.0	1 171
South Africa [a b f]	48.810	38	75	44 175	218 591	700.0	1 082
Swaziland [a c e g]	1.386	79	27	150	470	60.1	124
Total	**54.291**	**-**	**-**	**44 794**	**220 691**	**1 084.8**	**1 577**

Sources:
a. Central Intelligence Agency[2]
b. International Energy Agency[3]
c. Swaziland Country Report[4]
d. Clean Energy Portal - Reegle[5]
e. The International Journal on Hydropower & Dams[6]
f. South Africa Country Report[7]
g. Swaziland Energy Regulation Authority[8]
h. NamPower[10]

Small hydropower definition

South Africa de-facto defines small hydropower as below 10 MW because that is the upper limit of hydropower plants in the current bidding process. Other Southern African countries do not have their own definition of small hydropower.

Regional overview

Four countries in the region have adopted small hydropower.

Lesotho will very soon be able to support projects including small hydropower with its National Rural Electrification Fund.[11] It is to be seen, when the National Integrated Resource Plan for Namibia's electric power system is published in 2013, how small hydropower will be included. South Africa has an Integrated Resource Plan which has given small hydropower an allocation. The South African Government has implemented a bidding process for grid connected renewable energy technologies, which resulted in an allocation of 75 MW for small hydropower. According to *Green Jobs* by the Development Bank of South Africa, it is estimated that the total net direct employment potential for micro and small hydropower in South Africa in the short term will be 300 jobs in construction, in the medium term there will be 120 jobs in construction and 95 jobs in operation and maintenance. In the long-term 100 jobs will be created in operation and maintenance.[12]

Swaziland has relatively low small hydropower potential compared to other countries in the region. Several small hydropower plants are operational. Due to an expected increase in electricity prices, there is interest in refurbishing old defunct small hydro plants.

The installed small hydropower capacity, defined as up to 10 MW, in the Southern African region is 43.12 MW, with a small hydropower potential of 383.5 MW, (table 2). South Africa dominates the region in terms of both installed small hydropower capacity and available potential. Its potential includes the novel development of harnessing hydropower using existing infrastructure such as water distribution channels.[12]

Climate change poses a constraint on potential. Namibia´s desert climate is not very suitable for hydropower in general, even though the country has a hydropower master plan.[12] South Africa has an annual rainfall of about 500mm, coupled with occasional droughts or floods and seasonal river flows.

Table 2
Small hydropower in Southern Africa
(Megawatts)

Country	*Potential (MW)*	*Installed capacity (MW)*
Lesotho	20.0	3.82
Namibia	108.5	0.50
South Africa	247.0	38.00
Swaziland	8.0	0.80
Total	**383.5**	**43.12**

Sources: See country reports.

Note

i. Please note that Mozambique, Zambia, Malawi and Zimbabwe which are in the UN region, of Eastern Africa, are also members of SAPP.

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1.4.1 Lesotho

Wim Jonker Klunne, Council for Scientific and Industrial Research, South Africa

Key facts

Population	1,930,493[1]
Area	30,300 km[2]
Climate	Temperate; cool to cold, dry winters; hot, wet summers
Topography	Of the total land mass, 1/4 in the west is lowland country, the remaining 3/4 are highlands[2]
Rain Pattern	The lowest average annual precipitation occurs in the Senqu River Valley (450 mm) and the highest in the northeastern mountains zones (1,300 mm). The amount of precipitation received is highly variable in both time and space resulting in regular occurrences of droughts and floods. High intensity rainfall often leads to flash floods that accelerate soil erosion causing high sediment loads in rivers. Snowfall occurs annually over the mountain tops and once every three years in the lowlands.

Electricity sector overview

Lesotho does not have any known indigenous sources of oil, coal or natural gas. About three quarters of its total energy demand is met by biomass fuels in the forms of wood, shrubs, animals manure and agricultural residues. The only other fuels consumed in significant quantities are mineral coal and paraffin.

The electricity sector is thus relatively small (3 per cent of total energy consumed) with an installed capacity of only 76 MW, mainly from the Muela hydropower plant linked to and managed by the Lesotho Highlands Development Authority water scheme to provide water to South Africa. As the Muela hydropower plant is connected to the South African Eskom (Electricity Supply Commission in South Africa) grid and not to the main Lesotho electricity grid, the country is highly dependent on Eskom and it’s a net importer of electricity (figure 1). Maximum peak load in the system stands at around 125 MW.

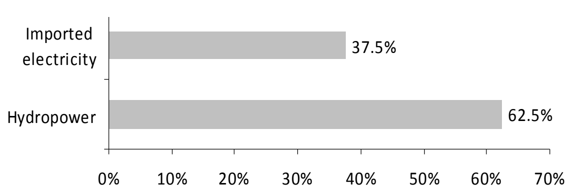

Figure 1 **Electricity generation in Lesotho**

Note: Imported electricity from Eskom South Africa

In 2011, only about 22 per cent of households had access to electricity, with most of these being in urban areas.[3] The Government has set a goal of increasing electrification rate to 35 per cent of total households by 2015 and 40 per cent by 2020.

The Electricity Supply Industry in Lesotho is regulated by the Lesotho Electricity Authority (LEA). LEA is an independent regulator responsible for issuing licences, approving electricity tariffs, setting and monitoring quality of supply and service standards, and resolving disputes between suppliers and customers. LEA has the authority to regulate all aspects of the industry, including the generation, transmission, distribution, supply, import and export of electricity.[4]

Lesotho currently trades exclusively with Eskom. As a member of the Southern African Power Pool (SAPP) Independent Power Producer- in Lesotho are, in theory, allowed, to sell to other buyers of electricity as well.[4]

Electricity is supplied to customers by the Lesotho Electricity Company (LEC). The LEC is a parastatal entity established under the Electricity Act 7 of 1969, and is empowered to distribute, transmit and supply electricity. The Lesotho Highlands Water Development Authority (LHWDA) is the agency responsible for the generation of hydropower from the Muela hydropower station. The roles and responsibilities of these two bodies are set out in the 1993 Policy on the LHWDA/LEC interface.[3]

Small hydropower sector overview and potential

All locally generated electricity in Lesotho is hydropower based, with the 72 MW Muela plant providing most of it. Currently only augmented by two mini hydropower plants. The Lesotho Highlands Water project does offer opportunities for more hydropower developments and several studies have been conducted on possible pumped-storage plants as well.

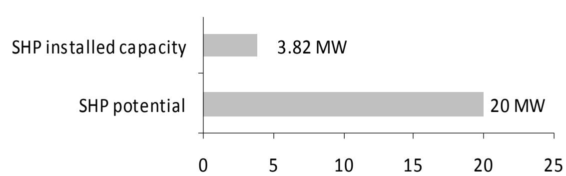

Figure 2 **Small hydropower capacities in Lesotho**

Sources: Clean Energy Portal – Reegle[3], Taele, Mokhutšoane and Hapazari[5]

It is estimated that the large-scale hydropower generation potential for Lesotho is approximately 450 MW. The potential for small-scale hydropower plants in Lesotho has been investigated in a number of studies. By 1990 a total capacity of 20 MW had been identified at 22 sites for both mini- and micro-hydropower (figure 2).[5] French company Sogreah (now it is part of Artelia) has studied nine potential sites in the range of 100 kW to 1,000 kW and completed feasibility studies on three preferred sites: Tlokoeng, Motete and Qacha's Nek. In the micro range of hydropower, it is estimated that a potential of 20-40 feasible sites exist in the country with an average capacity of 25 kW.[6]

Examples of small hydro projects:
Commissioned in the early 1990s, the Tsoelike small hydropower plant is a 400-kW run-of-river installation that was constructed to serve the town of Qacha's Nek in the south of Lesotho, near the border of South Africa. This hydropower station was built as part of the French development assistance to Lesotho. The Tsoelike plant consists of the two Francis hydropower turbines supplemented by a 200-kVA diesel generator set located on a ledge next to the power station, and a 320-kVA set at the town of Qacha's Nek. Previously an isolated system, Qacha's Nek has been connected to the South African Eskom grid in 1997. This cross-border connection enabled LEC to decommission Tsoelike as it was developing serious technical and siltation problems.

Tlokoeng is a 670-kW hydropower station built with the French development aid to serve the town of Mokhotlong. The station has two Francis turbines of 460 kW and 210 kW capacity, augmented by two diesel generator sets as back up (one at the power station with 200 kVA and another one at Mokhotlong town with 500 kVA). The station was commissioned in February 1990. During its operation, the plant met an average of 27 per cent of Mokhotlong's electricity demand.[7] The station was decommissioned in November 2002 when the 33 kV transmission line from the Letseng diamond mine reached the town of Mokhotlong. The difficult access situation and limited availability of spare parts for the French-origin equipment have inhibited refurbishment of the site.

The Katse Dam, a concrete arch dam on the Malibamat'so River in Lesotho, is Africa's second largest dam. It is also part of the Lesotho Highlands Water Project, which will eventually include five large dams in the remote rural areas. Although the main purpose of Katse dam is water storage and diversion, and contained a 570-kW mini hydropower plant. It is located in gallery K (123 metres below the spillway level) of the dam. The plant consists of a horizontal Francis turbine and an 800-KVA synchronous generator as the main component, together with associated equipment. Since its commissioning in August 2000, the plant has been running in an isolated mode from the LEC grid, the main power source to Katse Dam. The intention is to link the plant to the LEC grid and have it operating continuously at an average 500 kW power output.[8]

The Mantsony'ane hydropower plant (2 MW) was financed by a grant from Norway and handed over to LEC in February 1989. The power station is located on the Mantsony'ane River in central Lesotho and is feeding the LEC grid through Mantsony'ane Substation on the 33-kV Mazenod-Taba Tseka line. The station can operate on an isolated network when required, but the main operational strategy has been the daily peak lopping[i]. The station is equipped with two Francis turbines of 1,500 kW and 500 kW, together with a 1,900-KVA and a 650-KVA generator. The station features a storage dam on the river and an unlined 655-metre long tunnel from the intake to the rock cavern power house. The design head is 35.5 metre.

Figure 3 **Powerhouse of the Mantsony'ane hydropower plant in Lesotho**
© Wim Jonker Klunne

The power station was flooded at the beginning of November 2006 and was out of operation since then.[9] In 2011, LEC was in the process of rehabilitating the power station as part of the African Development Bank's Lesotho Electricity Supply Project. A tender process for the station was started in the second half of 2011.[10]

The Semonkong project currently has an installed capacity of 180-kW hydropower, supplemented by a 120-kW diesel generator. The plant supplies an isolated community of approximately 25 customers, with the potential of adding a further 50 customers in the future. It contains space for two 190-kW hydropower generation units, one stand-by peak load 120 kW diesel unit, control room, switch gear room and an office/shop/storage room. The scheme comprises intake structure, headrace and penstock piping, powerhouse and power generating equipment. The intake structure consists of a 100-metre long concrete weir, a headrace inlet with trash rack and a simple pipe with a light steel gate for flushing of sediment in front of the intake. The low pressure headrace is a 290-metre long concrete pipe and the penstock is a 150-metre long fiberglass-polyester pipe.[11]

Renewable energy policy

Lesotho has identified wind, solar and hydropower as potential renewable energy sources. Wind power potential of a few hundred MW has been identified, and there are currently three sites being investigated.

The Government of Lesotho and UNDP/GEF have worked together to increase electricity access in their rural electrification programme. The main objective is the promotion of renewable energy for the reduction of carbon dioxide emissions by the substitution of paraffin and diesel with clean technology.[12] A key target, for example, was the installation of 5,000 solar home systems by the end of 2012. Some 1,537 homes have been installed with the system. Another project with 500 solar units will be installed independently as a result of its influence. From January to April 2011, an average of 15 households per village in more than 10 villages had been electrified by independent installers.[13]

Barriers to small hydropower development

In order to boost small hydropower electricity production, viable business models for the development of small hydropower in Lesotho need to be found. Barriers to small hydropower development are the difficulties to access some sites and the lack of availability of spare parts in the local market.

Note

i. Peak lopping is a technical term for storing energy during low demand periods for use during high demand periods.

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1.4.2 Namibia

Kai Whiting and Lara Esser, International Center on Small Hydro Power

Key facts

Population	2,165,828[1]
Area	824,292 km[2]
Climate	Hot and dry desert climate with sparse and erratic rainfall[1]
Topography	Mostly high plateau; Namib Desert along coast; Kalahari Desert in east.
Rain Pattern	Namibia is the driest country of sub-Saharan Africa. Rainfall is particularly scarce and unpredictable, aggravated by an extremely high rate of evaporation[2]

Electricity sector overview

Namibia is a part of the Southern African Power Pool (SAPP), it contributes roughly one per cent to the total peak demand of SAPP.[3] In the past, Namibia imported more than 60 per cent of its electricity requirements from South Africa, Zimbabwe and Zambia (figure 1). The vast majority of electricity in Namibia has always been produced by hydropower and since 2001 there has been a small, stable share of coal and oil.[3] Namibia is also the world's fourth largest producer of uranium.[1]

The total installed electricity generation capacity in Namibia is 393 MW. With the recent expansion in June 2012, Namibia´s largest hydro plant is pushed up to 330 MW. The Government states that even with other sources in the country, the total generation still falls short of Namibia's 550 MW demand.[4]

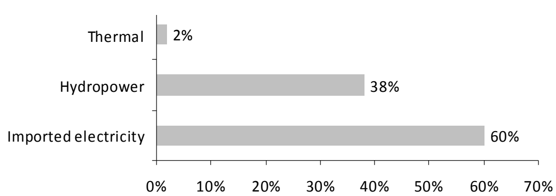

Figure 1 **Electricity generation in Namibia**
Source: Graduate School of Cape Town[5]

Some 62 per cent of the Namibian population lives in rural areas. Dispersion over large parts of the country often makes grid extension unviable. The national electricity access level is 34 per cent.[6] All of Namibia's 17 municipalities and 19 towns are currently served by grid electricity. While urban access levels to electricity are at 75 per cent, rural access is much lower at 12 per cent.[3]

The Government supports two energy initiatives that help speed up the electrification process. A Regional Energy Distribution Master Plan (REDMP) that will connect a large number of rural settlements to Namibia's main distribution grid over the next 20 years, but it is not economically feasible or technically possible to electrify all off-grid settlements. Approximately 1,543 rural communities will be electrified over the next 20 years by the REDMP as outlined by the Ministry of Mines and Energy. It is expected that 4,315 communities will remain un-electrified. For those settlements, there is the Off-grid Electricity Management Plan, which, however, does not include a hydropower option.[7]

The largest hydropower station, Ruacana, increased its capacity to 330 MW in 2012.[4] The downstream area of Ruacana has as much as 2,000 MW of hydropower potential according to the Ministry of Mines and Energy.[8] The country is considering a 500-MW hydropower project that would be located at Epupa Falls.[8]

The country has a Hydropower Masterplan (2008), with a study performed on all perennial rivers, none of which arise from within its borders. The aim of the study was to identify and estimate the cost and production of all potential sites in the lower Kunene, Kavango and lower Orange Rivers.[7] None of the identified sites have a capacity of less than 10 MW, thus none falls into the generally accepted small hydropower definition.

Small hydropower sector and overview and potential

Currently no official small hydropower definition exists in Namibia. It has only an installed capacity of 0.5 MW small hydropower, with a potential of 108 MW (figure 2).[9] The IRENA country profile says that 26 MW of its small hydropower capacity additions have been announced (three projects), however no further information was mentioned.[10] The National Investment Brief (2008) mentions that there are hundreds of small farm dams scattered around the ephemeral river basins, where small hydropower potential could be developed.[11]

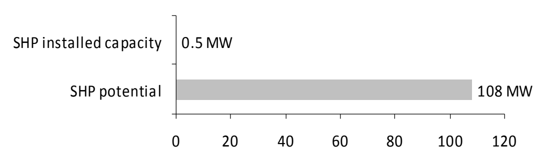

Figure 2 **Small hydropower capacities in Namibia**
Source: The International Journal on Hydropower and Dams[9]

Renewable energy policy

The Namibian constitution, Article 95 (l) is explicit in the legality of the "Maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future". Should the situation warrant, the constitution also provides judiciary powers to the ombudsman in order to ensure environmental protection.[23] Thus even if policies were not previously explicit or absent in their calls for renewable energy, there has been, since the establishment of Namibia as a country, a founding ideology which favours environmentally sensitive and considerate development.

In 2003 the Namibian government established the Namibian Renewable Energy Programme (NAMREP). A Renewable Energy Action Plan followed in 2006 on the basis of six principles:

- Capacity building.
- Removal of institutional barriers.
- Public awareness and social acceptability.
- Removal of financial barriers.
- Removal of technical barriers.
- Demonstrations and pilots.

UNDP Namibia (2007) reiterated the need for a long-term energy policy and vision for sustainable development, which looked to support environmentally sustainable technologies and to attain greater energy security through a steady increase of electricity production in Namibia using energy sources that are available.[13]

A cabinet directive has made solar water heaters mandatory for all public and semi-public buildings. It was issued as a logical step, given that the country has one of the highest solar radiation regimes in the world.[14] The *White Paper of Energy Policy* (1998), which has set the priorities of the energy agenda for the last decade and a half, was under review in 2012 as were its energy regulatory frameworks dealing with renewable energy procurement mechanism and tendering. A National Integrated Resource Plan was also underway in 2012.

Barriers to small hydropower development

The scarcity of water and dependency on neighbours for water supply does little to encourage foreign direct investment due to the huge effect of precipitation on the potential for financial return from small hydropower projects. Arguably, the Government needs to be more active in its carbon cutting policy. For example, as of 2012 there were no clean development mechanism projects connected to renewable energy in Namibia.

Meanwhile, the continuation of internal land use conflicts with indigenous people who were concerned about the hydropower industry and its impact on their way of life did little to promote the technology.[8] Thus, it is important that any development is not only harmonized with the long-term aims and objectives of the financial investors, but also the affected communities, including nomadic ones. Raising awareness and education is a major challenge which needs to be tackled in order to overcome the social barriers and disapproval of the stakeholders.

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1.4.3 South Africa

Wim Jonker Klunne, Council for Scientific and Industrial Research, South Africa

Key facts

Population	48,810,427[1]
Area	1,219,090 km[2]
Climate	Mostly semi-arid; subtropical along east coast; sunny days, cool nights[1]
Topography	Vast interior plateau rimmed by rugged hills and narrow coastal plain[1]
Rain Pattern	Mean annual rainfall of approximately 450 mm. Wide regional variation in annual rainfall, from <50 mm in the Richtersveld on the border with Namibia, to >3,000 mm in the mountains of the south western Cape. However, only 28% of the country receives more than 600 mm. Core of rainy season is December to February.[2]

Electricity sector overview

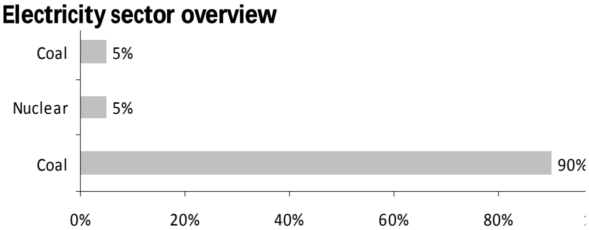

Figure 1 **Electricity generation in South Africa**
Source: Department of Energy[3]
Notes: Data from 2010.

South Africa has a total electricity generation capacity of about 45,000 MW. Nearly 90 per cent of electricity is generated in coal-fired power stations (figure 1). Koeberg, a large nuclear station near Cape Town, provides about five per cent of capacity, while the remaining five per cent is provided by hydropower and pumped storage schemes. Currently about 700 MW[i] of installed hydropower capacity exists in the country.[3]

Electricity generation is dominated by Eskom, the state-owned utility. Eskom also owns and operates the national electricity grid. It supplies about 95 per cent of South Africa's electricity and is one of the world’s top seven energy producer in terms of generating capacity; one of the world’s top nine in terms of sales, and it has one of the world's biggest dry-cooled power stations - Matimba Power Station (coal-fired; installed capacity 3,990 MW). South Africa, which for many years operated with overcapacity, has begun to experience a power crisis induced by rapid growth in electricity demand, coupled with prolonged underinvestment in new generation capacity.[4]

Since the end of the apartheid rule, South Africa has gone from an overall 36 per cent electrification rate in 1993 to 80 per cent in 2007 and a further 81 per cent by 2012. Rural electrification, specifically, stands at 63 per cent.[5]

Small hydropower sector overview and potential

Currently no official small hydropower definition exists in South Africa, although the upper limit of 10 MW was used in the current renewable energy bidding process, de-facto limits small hydropower to 10 MW. Though not very well documented, small scale hydropower used to play an important role in the provision of energy to urban and rural areas of South Africa. The first provision of electricity to cities like Cape Town and Pretoria was based on small hydropower, while other smaller towns started local distribution of electricity through isolated grids powered by small hydropower stations. With the expansion of the national electricity grid and the increasingly cheap, coal-generated power supplied through it, a large number of such systems were decommissioned. A typical example is the Sabie Gorge hydropower station, with three 450-kW turbines, commissioned in 1928 to serve the town of Sabie in Mpumalanga and later closed in 1964, after the area was connected to the national Eskom grid.[6]

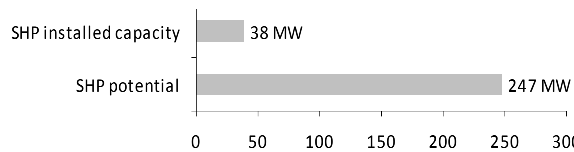

Figure 2 **Small hydropower capacities in South Africa**
Source: Barta[7]

After nearly 30 years of neglecting the hydropower potential of the country, the first new small hydropower station was commissioned in November 2009 at the Sol Plaatje Municipality (Free State province), and a few other stations are currently in different stages of development.

The South African Renewable Energy Database, as developed by the Council for Scientific and Industrial Research (CSIR), Eskom and the Department of Minerals and Energy, investigated the available renewable energy resources in the country, including the potential for hydropower.[8] As follow-up, the resources available for the Eastern Cape region was detailed as part of a three-year investigative project entitled ‘Renewable energy sources for rural electrification in South Africa’. The primary objective of the latter project was to identify the commercially viable opportunities for rural electrification in the Eastern Cape Province of South Africa using wind-, hydro- and biomass-powered energy systems. The maps in figures 3 and 4 present the outcomes of these two studies with respect to the potential for small

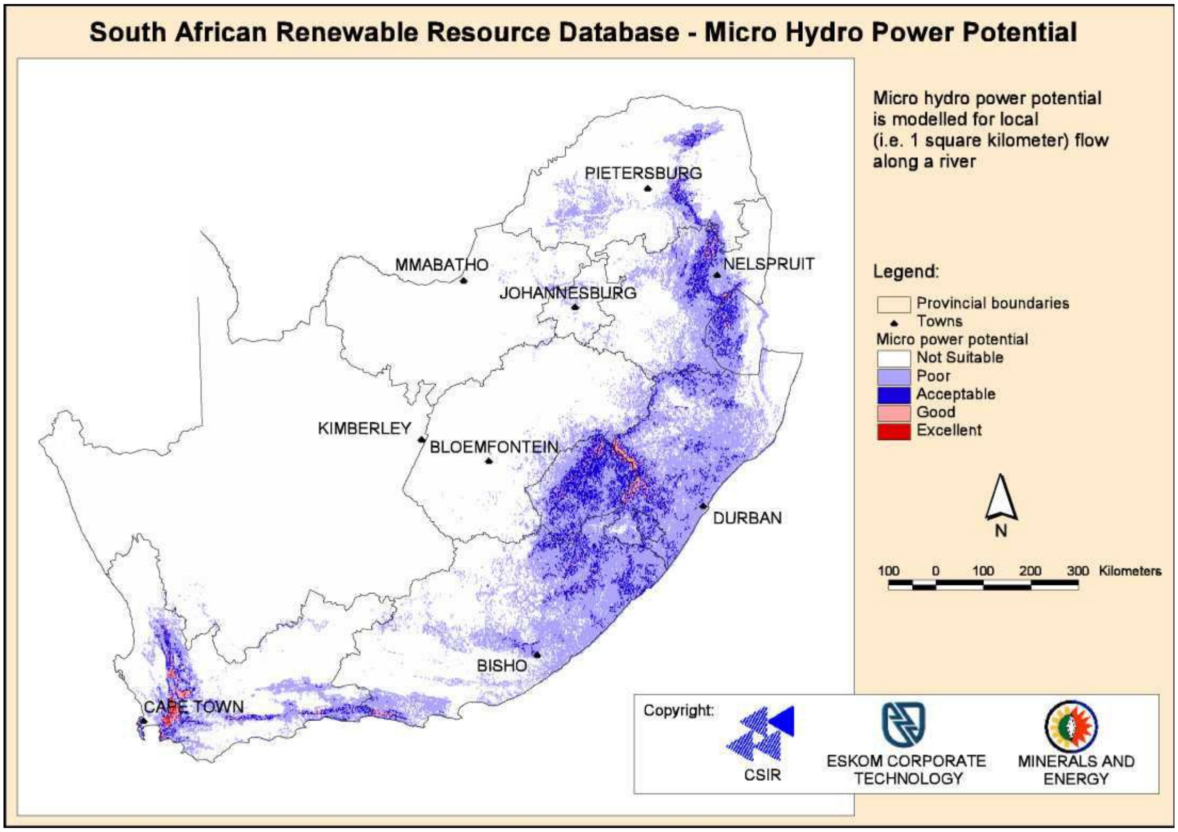

Figure 3 **Micro hydropower potential in South Africa**
Source: Muller[8]

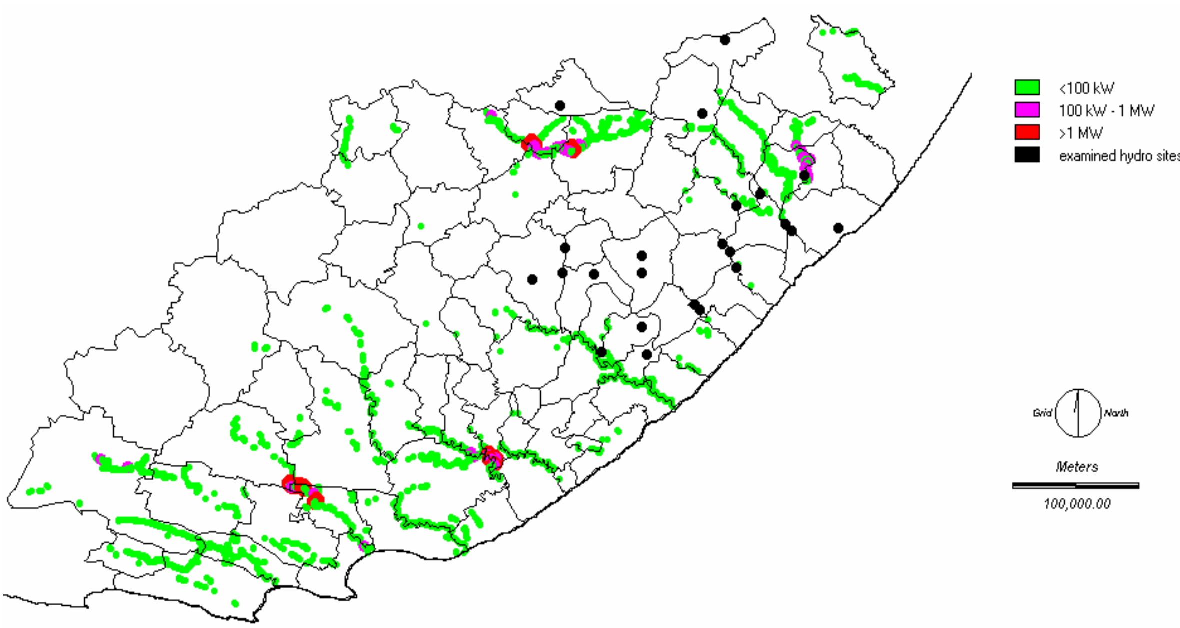

Figure 4 **Small hydropower potential in the Eastern Cape of South Africa**
Source: Szewczuk, Fellows, and van der Linden[9]

hydropower in South Africa and the Eastern Cape respectively.

Installed hydropower capacity under 10 MW has the potential to be further developed in the rural areas of the Eastern Cape, Free State, KwaZulu Natal and Mpumalanga.[7] A later publication by Barta (2011) includes new insights regarding the potential of small hydropower in South Africa by including the hydropower potential of water transfer systems and gravity-fed water systems, and mentions a total potential of 247 MW of which 38 MW have been developed (figure 2).

At the moment Eskom is operating two small hydropower stations: First Falls (6 MW) and Ncora (1.6 MW). Municipalities operate another three grid-connected small hydropower stations, while companies in the private sector run another two, both grid-connected. There is a substantial number of micro hydropower systems that are in operation, mainly in the KwaZulu Natal and Eastern Cape region, supplying primarily individual farmers.

There are a few small-scale hydropower installations currently not in operation, which could be refurbished to working order, like the ones at Belvedere (2.2 MW), Hartbeespoort (37 kW) and others.[3]

Figure 5 **Interior of the decommissioned Hartbeespoort plant in South Africa**
Source: Author
Note: The plant was in operation between 1924 and the mid-1960s, and could be rehabilitated/upgraded.

With the main economic hubs located in areas suffering from water scarcity, the South African economy is heavily reliant on water transfer systems. Several water distribution companies are currently looking into the possibility of using in-flow hydropower turbines for electricity generation. As part of the research project by University of Pretoria, a 16-kW pilot system has been installed at the Pierre van Ryneveld reservoir in Pretoria, with preparations ongoing for more systems nationwide.[7]

Below are examples of small hydro projects:
The First Falls small hydropower station has two 3-MW units, with provision for a future third machine. Water is conveyed to the powerhouse through a 27-metre long penstock with a 2.7-metre diameter steel pipe. The water for the station is discharged at $6m^3$/sec from Mthatha dam, down the river to First Falls. The Ncora small hydropower station has a single 1.6 MW unit supplied by a 260-metre by 1.6 metre diameter penstock operating at 4 bar. The water is released from the main Ncora dam via a canal to the holding dam.[10]

On the Dorps River, north of the town of Lydenburg, the Thaba Chweu Local Municipality owns a small hydropower station since 1982 called Lydenburg. It has a Gilkes Pelton turbine of 2.6 MW capacity. The system is privately operated by MBB Consulting Engineers of Nelspruit, under a contract with the local municipality.[11]

In the early months in 1926 and in 1953, the town of Ceres commissioned its first and second small hydropower schemes, with capacities of 95 kW and 1 MW respectively.[12] Unfortunately, this scheme is no longer operational, although rehabilitation could be considered.

The Friedenheim station consists of two Sulzer Francis turbines of 1 MW each. Water for the station is taken from approximately 5.5 km upstream from the Krokodil River, and is transported to the power house site where a head of 64 metre is available.[13] The station has been running since 1987. It sells bulk of the generated electricity through a Power Purchase Agreement (PPA) to the local Mbombela Municipality. It is owned by the members of Friedenheim Irrigation Board (FIB) and is operated on behalf of the MBB Consulting Engineers. The plant provides power for water pumping to FIB, but 93 per cent of the power generated is sold to the municipality through a PPA that sets the tariff at 12 per cent below the price at which it buys power from Eskom (its bulk electricity provider).[14]

Bethlehem Hydro Pty Ltd owns two small hydropower stations that are normally referred to as ‘Bethlehem Hydro’. These were the first addition of hydropower generation capacity for the last three decades. The system consists of:

- The 3 MW Sol Plaatje Power Station near the town of Bethlehem. This station was commissioned in November 2009 and has a generating head of approximately 11 metre and a maximum flow of 30 m^3/s. One 2.1 metre-diameter Kaplan turbine, attached to a generator, is installed at the power station.

- The 4 MW Merino Power Station is close to the town of Clarens. The project consists of a diversion weir with a semi-circular spillway in the Ash River, a 700-metre long canal to transfer the water to the power station, a small fore-bay and a power station situated in a sandstone bank from where the water is returned to the Ash River. The generating head is approximately 14 metre and a single Kaplan turbine and a generator are installed in the power station.[11]

The Bakenkop small hydropower plant was commissioned in 1950 to supply the town of Piet Retief with electricity before it was connected to the national grid. After 60 years of operation, it is still providing power to the town. The installed capacity is 800 kW. The system operates intermittently depending on water availability. At present it provides electricity at an average cost which is half that of the rate the town pays to Eskom for its power.[14]

The future for small hydropower in South Africa will see two main parallel tracks: grid-connected projects that will feed into the national grid and small scale systems for private use (not feeding into the grid, irrespective of whether a grid connection is available or not). These tracks can be supplemented by a third category of isolated systems for rural electrification purposes. The grid-tied systems future is closely linked to the national government's policy on renewable energy development. The utilization of small scale systems for private use is expected to grow based on the foreseen rise in electricity prices, coupled with the reduced reliability of the grid. Off-grid electrification by means of small hydropower could fall under the 'Working for Energy' programme, as it is currently under development by the South African National Energy Development Institute (SANEDI). It could also be supported by the renewed focus of the Department of Energy in the off-grid electrification processes.

Renewable energy policy

In 2010, the Department of Energy presented the Integrated Resource Plan (IRP), outlining the electricity generation mixes for the period up to 2030.[3] According to the policy, the adjusted development plan will see 17.8 GW of renewable energy as part of the energy mix in 2030. The main source of hydropower in the IRP will come from imported electricity (approximately 5.2 GW by 2030), while local, small hydropower shares an allocation of 125 MW alongside landfill gas electricity.[15]

In March 2009 the energy regulator National Energy Regulator of South Africa (NERSA) announced the Renewable Energy Feed-In Tariffs (REFIT) for a selected number of renewable energy technologies. Small hydropower (between 1-10 MW) qualified for a REFIT of ZAR 0.94/kWh (approximately € 0.074 or US$0.096).[16] However the unclear legal status of REFIT and the would-be buyers of that electricity prevented power-purchase agreements (PPAs) from being signed for this tariff. The REFIT review in 2011 did see adjustments in the REFIT-based on inflation, capital costs and other assumptions. The REFIT for small hydropower was revised downwards by over 28 per cent, to ZAR 0.671/kWh (about €0.065 or US$0.089).[17]

Concurrent to the REFIT review, the South African Government announced its intention to start a competitive bidding process for electricity from renewable sources. The Request for Proposals was issued in August 2011. As the bids would be evaluated in a two-stage procurement evaluation process that includes qualifying criteria based on economic development requirements, as well as price, the REFIT process was consequently side-tracked.[15]

In the Renewable Energy Independent Power Producer Procurement Programme (REIPPP) a total of 3,725 MW is to be procured by the Government, with an allocation of 75 MW for small hydropower (up to 10 MW).[18] The bidding process will see a number of bidding rounds, of which the first has been concluded with allocation of 1,415 MW to 28 bidders, none of which involves hydropower.[19] The second round of REIPPP provided two hydro developers with preferred bidder status: the Neusberg plant of Kakamas Hydro Electric Power and the Stortemelk plant of NuPlanet (4.47 MW). Although the Neusberg site has a potential of 12.57 MW, only 10 MW will be developed in order for it to qualify under the REIPPP.

Barriers to small hydropower development

The main barrier for development of hydropower in South Africa has long been the unclear policy framework from both electricity as well as a water use perspective. With REIPPP, the policy framework is much clearer, although effectively limiting options as development of grid feeding hydro schemes outside the REIPPP has become virtually impossible.

Note

i. This 700 MW refers to traditional hydro schemes only and excludes imported hydropower from Mozambique and pumped storage.

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1.4.4 Swaziland

Wim Jonker Klunne, Council for Scientific and Industrial Research, South Africa

Key facts

Population	1,386,914[1]
Area	17,364 km^2
Climate	The climate is temperate in the west, but may reach 40°C in summer in Lowveld region.
Topography	The western half is mountainous, descending to Lowveld region to the east. The eastern border with Mozambique and South Africa is dominated by the escarpment of the Lebombo Mountains.
Rain Pattern	Rainfall occurs mainly in the summer and may reach up to 2,000 mm in the west.

Electricity sector overview

Power in Swaziland is supplied and distributed by the Swaziland Electricity Company (SEC), which was established in 2007 by the Swaziland Electricity Company Act. SEC currently has a monopoly on the import, distribution and supply of electricity via the national power grid. The SEC also owns a majority of the country's power stations. There are five other private power stations. A substantial amount (nearly 25 per cent) of energy used in Swaziland has been self-supplied.

The SEC operates four grid connected hydropower plants: Edwaleni (15 MW), Ezulwini (20 MW), Maguduza (5.6 MW) and Maguga (19.2 MW) installations. In December 2010, the SEC decommissioned the small-scale 500 kW Mbabane station, built in 1954, due to unprofitability.

A reform of the energy sector has been undertaken recently to reduce the monopoly of the utility (it changed from a board to a company in 2007), to establish a regulatory body and to preserve the state company as a more disciplined corporate entity.[2]

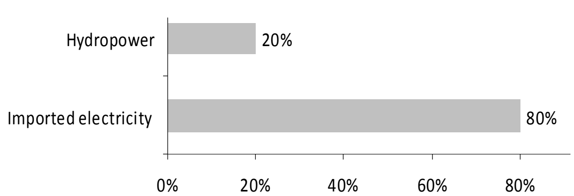

Figure 1 **Electricity generation in Swaziland**
Source: Clean Energy Portal – Reegle[2]
Note: Data from 2007.

The overall electrification rate is 27 per cent, with an estimated 40 per cent access in urban and 4 per cent access in rural areas.[2]

Approximately 80 per cent of Swaziland's electricity is imported from South Africa through the SAPP. The remaining 20 per cent of the electricity requirement is generated by hydropower (figure 1). Biomass, especially wood fuel, constitutes about 90 per cent of the total energy consumed and is still dominant for use in cooking and heating in rural areas. Not only biomass is the major fuel used by households, but it's also the major source of electricity self-generation in the sugar, pulp and saw mill industries.

Small hydropower sector overview and potential

Currently, no official small hydropower definition exists in Swaziland. The first electric lighting system to light up at night in Swaziland was installed at Mlilwane with a 42-kW small hydropower turbine operated by James Weighton Reilly. Since then several public and private hydropower plants have been installed in the country, as well as hydraulic ram pumps to provide water for steam locomotives at the Ngwenya mine.

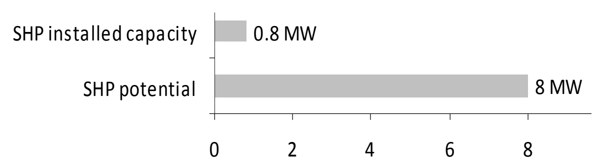

Figure 2 **Small hydropower capacities in Swaziland**
Source: Knight Piésold Consulting[3]

Several studies have been conducted to estimate the hydropower potential of Swaziland. In 1970, the UNDP financed a study which identified 21 possible sites for hydropower schemes.[4] Based on existing information, the Environmental Centre for Swaziland comes to a gross theoretical potential of 440 MW and a technically feasible potential of 110 MW, of which 61 MW are economically viable.[5]

The latest full study on hydropower potential in Swaziland showed that there are a number of potential micro (<0.1 MW), mini (0.1–2.0 MW) and small (2–10 MW) hydropower generating sites along the rivers in the country. The available potential for both micro and mini hydropower is about 8 MW (figure 2).[3]

Examples of small hydropower projects:
The 800 kW small hydropower plant of the Swaziland Plantations company was initially commissioned in 1952 and was later built to satisfy power needs of the town Piggs Peak. The water is taken from the Mkomazana River and stored in a 35 metre high dam, before being fed into a 1.75-metre-diameter, 300-metre long tunnel. It is then connected to the penstock. During summer, when there is an abundance of water, the plant can provide up to 90 per cent of the company's power needs.[6]

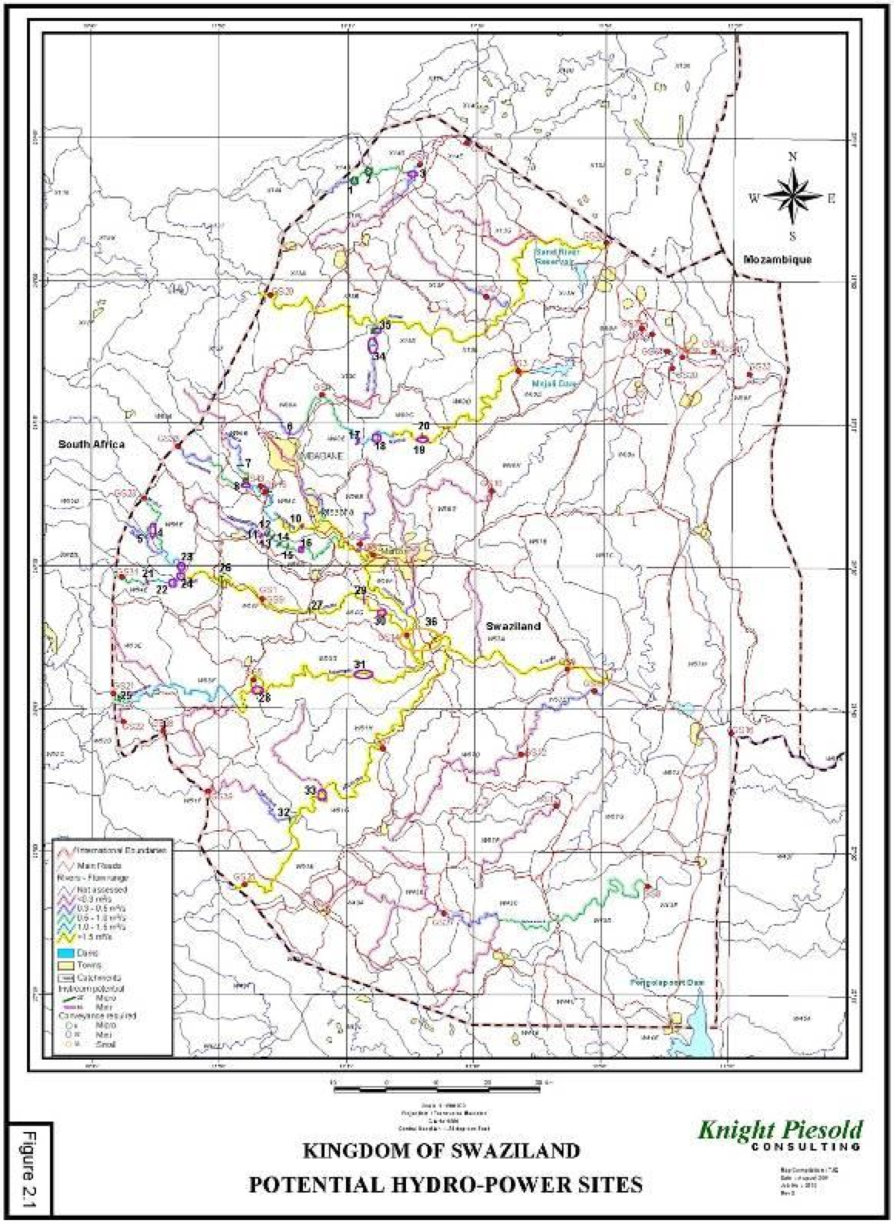

Figure 3 **Map of potential hydropower sites in Swaziland**
Source: Knight Piésold Consulting[3]

Current operations are largely dependent on water availability in winter and dry season production being about a quarter of summer's production.

Renewable energy policy

In 2007, the Ministry of Natural Resources and Energy formulated a strategic framework and action plan with the aims to:[7]

- Establish a centre for demonstration and education on renewable energy and sustainable energy.
- Encourage and enhance, where applicable, topics on renewable energy and energy in general in educational and training curricula.
- Maximize the use of renewable energy technologies wherever they are viable.
- Promote greater understanding and awareness of renewable energy resources and the associated technologies.
- Develop and maintain accurate renewable energy resource data and make it available to all, in order to make informed policy decisions regarding sustainable energy use and supply.
- Develop woodlots in areas where there is an acute fuel wood shortage.

Increasing electricity prices and reduced reliability of the national grid have resulted in increased interest in rehabilitating old defunct hydropower plants. Although no good overview exists on possible sites for refurbishment, it can be expected that a number of sites will be economically feasible to rehabilitate. This will also revive interest by potential investors.

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1.5 Western Africa

A. A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa

Introduction to Region

Western Africa consists of 17 countries, of which 10 have operating small hydropower plants (table 1). Niger has no small hydropower plants, but shows some potential. Senegal has a flat topography, hence limiting its potential in developing small hydropower sites. Other countries in the region, such as Cape Verde, Gambia, Guinea Bissau, and Mauritania do not use small hydropower. All countries in West Africa region, except Mauritania, are part of the Economic Community of Western African States (ECOWAS).

From south to north, there are four climatic zones: the sub-equatorial zone, the Sudanese zone, the Sahelian zone and the Saharan zone. Precipitation is almost non-existent or negligible in the Saharan zone. Precipitation increases in the Sahelian zone (300-600 mm) and the Sudanese zone (600-1,100 mm), reaching 1,800–2,200 mm in the sub-equatorial zone. Strong variation in seasonal and daily temperatures is very pronounced in the Saharan and Sahelian zones (10°C to 45°C) but not nearly so in the southern zones featuring strong rains (22°C to 35°C). The vegetation varies from dense or scattered forest in the sub-equatorial zones to desert plains in the Saharan zones with savannahs featuring trees and shrubs in the Sudanese and Sahelian zones.

About 70 per cent of the 300 million people in West Africa live in rural areas with access to less than 10 per cent of modern energy services. Traditional biomass, in the form of charcoal and fuel wood is the major energy consumed. Access to other energy sources such as kerosene and natural gas are beyond their reach, as a result of their earning power. The absence of modern energy services contributes greatly to for example on-going poverty, illiteracy, health services access and a lack of access to potable water.

Table 1
Overview of countries in Western Africa

Country	*Total population (million)*	*Rural population (%)*	*Electrification access (%)*	*Electrical installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Benin[a]	9.21	57	27.4	97	113	-	1
Burkina Faso[a]	16.30	84	14.6	252	620	32.0	117
Côte d'Ivoire[a]	21.60	49	47.4	1 391	5 877	604.0	1 618
Ghana[a]	24.33	85	72.0	2 170	11 200	1 180.0	6 200
Guinea[ab]	8.76	65	14.0	395	920	125.5	519
Liberia[c]	4.10	80	..	23	..	..	..
Mali[ad]	14.5	80	..	327	1 213	156.5	692
Nigeria[ae]	158.42	64	50.6	8 702	76 231	1 938.0	7 104
Sierra Leone[afg]	5.08	62	..	113	80	56.2	100
Togo[fi]	6.10	80	20.0	213	868	65.0	150
Total	**268.4**	**-**	**-**		**97 122**	**4 157.2**	**16 501**

Sources:
a. World Atlas and Industry Guide[1]
b. Central Intelligence Agency[2]
c. World Bank[3]
d. Mali Direction Nationale de l'Energie)[4]
e. UNIDO Regional Center for Small Hydropower[5]
f. Mansaray[6]
g. ECOWAS Regional Centre for Renewable Energy and Energy Efficiency[7]
h. Togo Ministère des Mines et des l'Énergie/Direction Générale de l'Énergie[8]
i. Togo Energy Planning Department of Ministry of Mines and Energy[9]
Notes: The electrical capacity of Liberia prior to war was 412 MW.

Despite the growing gap and lack of investment capital, energy intensity in the countries remains high while energy is used in an inefficient way throughout all sectors. The estimated technical and commercial electricity losses in the electricity systems reach between 20 to 40 per cent in the West African sub-region. Increasing fossil fuel import dependency, shortages and fluctuating fossil fuel prices are major concerns of the West African countries, requiring a diversification of energy sources.

The Economic Community Of West African States Renewable Energy Policy (EREP) aims to serve 25 per cent of the rural population by decentralized renewable energy solutions in 2030 (mini-grids and stand-alone systems) i.e. 60,000 mini-grid systems by 2020. Part of the mini grids could be powered by small-scale hydropower systems.[9]

Small hydropower definition

Small hydropower is defined as up to 10 MW or up to 30 MW in this region, with the exception of Ghana where it is up to 1 MW (table 2).

Table 2
Classification of small hydropower in Western Africa

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*
Benin[a]	10-30	1-10	10-1000
Ghana[b]	≤ 1		
Mali	1-10	0.1-1	<100
Nigéria	<10	<1	<500
Sierra Leone[c]	1-30	0.1-1	<100
ECOWAS[b]	1-30	0.005-0.1	< 5

Notes:
a. Benin Direction Générale de l'Energie[10]
b. ECREEE Baseline Report[7]
c. Sierra Leone Ministry of Energy and Water Resources[6]

Regional overview

Only 10 out of the 17 countries in the region have adopted small hydropower technology (table 1).

Estimations for the small-scale hydropower potential (up to 30 MW) in the Economic Community of West African States (ECOWAS) regions differ widely, ranging from 1,900-5,700 MW of feasible potential. The lower end takes into account the provided site data by the ECOWAS countries to the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE) inventory during a workshop in April 2012. Applying a definition of up to 10 MW for small hydropower, installed regional capacity is estimated at around 82.5 MW and the approximate feasible potential at 743 MW.

No comprehensive study has been conducted to precisely determine the specific potential of small hydro in Niger. The only comprehensive hydropower study conducted by Lavalin International in the 1980s identified three sites ranging from 30-255 MW. It was noted, that an estimated four sites located on tributaries of the main river Niger, which is the main permanent river, may be of interest for the exploitation of micro hydro. However, this study is more than two decades old, therefore, taking into account all the effects of drought and climate change that occurred in the meantime, the potential of small hydropower resource would have to be re-quantified.[11]

Table 3
Small hydropower in Western Africa
(Megawatts)

Countries	*Potential*	*Installed capacity*
Benin	72.40	2.50
Burkina Faso	138.80	2.00
Côte d'Ivoire	11.90	5.00
Ghana	17.42	0.00
Guinea	60.70	10.31
Liberia	57.31	4.03
Mali	114.74	5.80
Niger	5.00	0.00
Nigeria	75.40	45.00
Sierra Leone	44.85	6.25
Togo	144.00	1.60
Total	**742.52**	**82.49**

Sources: See country reports

Small hydropower development has been slower than expected in the past, however, new initiatives are underway in many countries and the use of small hydropower has recently been increasing, specifically in Nigeria. International funds, such as African Development Bank (AfDB), Bank of Industry (BOI, Nigeria), World Bank, International Finance Corporation (IFC) are engaged. Short, medium and long term targets are being put in place by each country coupled with the removal of barriers, due to an increase in awareness, and with the trend of off-grid and decentralized electricity generation.

The small hydropower future seems promising in the Western Africa region. A sustained effort is required to achieve this position, which includes more feasibility studies where necessary, country level studies with small hydropower plans. Nigeria could be used as leader by virtue of the establishment of the UNIDO Regional Centre for Small Hydro Power in Africa, Abuja, and the success story so far. But the small hydropower developers in the Western Africa sub-region face many challenges.

For example, there is lack of hydrological data in the countries making it difficult to give comprehensive and updated overviews. Inventories established decades ago have never been updated. Gauging stations do not exist anymore. Resource assessments in the 1970s to 1990s were conducted by foreign consultants; therefore, regional expertise in hydro resource assessments is poor.[7]

In response to the challenges, governments of West African countries are already implementing some strategies, such as:

- Trust funds for renewable energy technologies (RET) and specifically for small hydropower projects in Ghana and Nigeria.
- Deregulation of the electricity sub-sector to allow independent power producers in Nigeria
- Establishment of Rural Electrification Agencies in Ghana, Nigeria and Liberia.
- Partnerships between public and private sector, e.g. ECOWAS Renewable Energy Facility
- Formulation of Strategies for RET development.
- Formulation of regulatory frameworks to facilitate feed-in-tariffs from RET to the national grid, e.g. Ghana and Nigeria in 2011.
- Establishment of UNIDO-Regional Center for Small Hydropower in Africa in Nigeria in 2006.
- Establishment of ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in Cape Verde in 2010.

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1.5.1 Benin

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria; Lara Esser, International Center on Small Hydro Power

Key facts

Population	9,598,787[1]
Area	112,622 km²
Climate	Tropical; hot, humid in south; semiarid in north.[1] Three climatic zones: in the South, the sub-equatorial zone with a bimodal rainfall pattern; in the centre the Sudanese Guinean transition zone between the Sudanese and sub-equatorial climates; in the far North the semi-arid Sudanese zone with uni-modal rainfall. Recorded temperatures vary between 27°C and 32°C.
Topography	Mostly flat to undulating plains; some hills and low mountains[1]
Rain Pattern	Two rainy and two dry seasons: principal rainy season April to late July; shorter less intense rainy period late September to November. Main dry season December to April; short cooler dry season late July to early September. Annual rainfall in the coastal area averages 3,600 mm.[2] Average annual rainfall varies between 800 mm and 1,200 mm depending on the year and the village.

Electricity sector overview

The electricity sector in Benin is jointly governed by an international agreement between Benin and Togo and the Benin-Togo Code of Electricity since 1968. This code was revised in December 2003 to reflect the new requirements of development in the sector, especially in terms of openness to independent producers and single buyer status.[3]

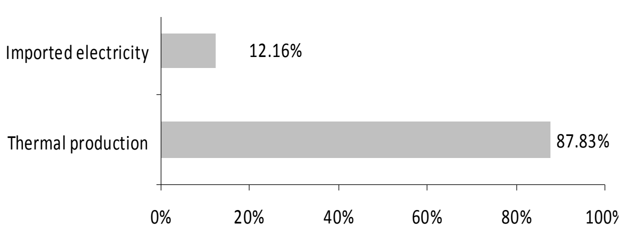

Figure 1 **Electricity generation in Benin**
Source: La direction générale du Trésor[4]

The national electrification rate of Benin was 27.4 per cent in 2010, but only 3.53 per cent in rural areas. Electricity production in Benin is managed by the company Communauté Électrique du Bénin (CEB), which is owned by Benin and Togo. Societé béninoise d'Energie électrique (SBEE) is responsible for electricity distribution. SBEE imports electricity directly from neighbouring countries such as Ghana, Ivory Coast and Nigeria. It also engages in its own electricity production using rented and owned diesel generation (figure 1).[5] In 2010 the country had a self-sufficiency rate of only 10 per cent.[6]

The stakeholder agency responsible for the electrification of rural areas is Agence Béninoise d'Électrification Rurale and de Maîtrise d'Énergie (ABERME).[7] Its electrification efforts are based on usage of hydropower, biomass, solar photovoltaic and wind.[3]

Small hydropower sector overview and potential

By 2009, micro-hydro plants with a total capacity of about 2 MW were completed.[3] The small hydropower plant of Yeripao, an installed capacity of 500 kW, is currently not in operation and requires maintenance.[6]

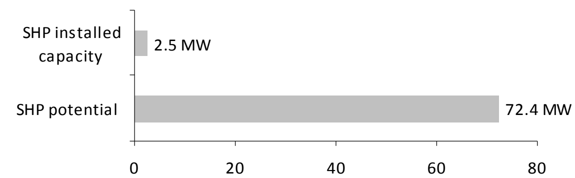

Figure 2 **Small hydropower capacities in Benin**
Source: Innovation Énergie Développement[3], ECOWAS Centre for Renewable Energy and Energy Efficiency[8]

The overall hydropower potential of Benin is not known, several sources indicate different potentials. According to a map issued by the Ministry of Mines, Energy and Water, there are nine sites, with capacities ranging between 2 MW and 9 MW and a total potential capacity of 42 MW, to be constructed.[6] There are three principal lists, two of which include hydropower sites with the capacity ≤10 MW:[8]

- List of 85 micro hydropower sites that includes potential sites <4.4 MW, with a total of almost 50 MW (200 GWh)
- List by ABERME based on work six sites by the Canadian Tecsult in 2009. Out of 20 potential sites, 6 were chosen for feasibility studies. The feasibility studies are available for six micro hydropower sites under 1,000 kW, with a total potential capacity of 1,240 kW.[3 6]

The lists above are summarized in the *Baseline Report on Small-Scale Hydropower* in the Economic Community of West African States (ECOWAS) Region. There is a feasible potential of 305 MW and 99 sites in Benin for small-scale hydropower plants up to 30 MW and 88 sites with an unexplored potential capacity of 69.87 MW (applying up to 10 MW definition).[8]

According to a 2010 analysis for innovative energy development in Benin, there is potential for small hydropower deployment due to an abundant nationwide coverage of rivers, political support, including tax incentives and exemption of customs duties, as well as financing interest of some donors.[3]

Renewable energy policy

The Strategy for the Supply of Energy Necessary for Achieving the MDGs in Benin in 2006 mentioned solar PV, hydropower, biogas and wind as renewable energies available in the country.[9] It also concluded that several problems associated with the sub-sector of renewable energy, such as the lack of national energy policy as basis for developing a renewable energy strategy, lack of operational structures for the promotion of renewable energy and lack of a coherent policy for promoting renewable energy project implementation, especially in remote communities.

In April 2011, Benin's Minister of Energy announced that the Government intended to raise the rural electrification rate with renewable energy, from its present 3 per cent to 50 per cent by 2025.[7] A national agency for the development of renewable energy is under development.[8]

Barriers to small hydropower development

Several barriers to small hydropower development exist in Benin, including a lack of local hydropower equipment supply and an absence of local manufacturers. There is, however, potential for the establishment of a local hydropower manufacturing and reparation industry. It would need, however, institutional and regulatory framework that facilitates licenses, permits, authorizations and a buyback tariff.

In conjunction with the hydropower potential, problems of low flow and drying up of rivers need to be considered.[9]

While there is a Rural Electrification Fund in place and electricity production has been liberalized, independent power producers have not yet explored the option of small hydropower and there is no feed-in tariff for small hydropower in place.[8]

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1.5.2 Burkina Faso

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria, Lara Esser, International Center on Small Hydro Power

Key facts

Population	17,275,115[1]
Area	274,200 km²
Climate	Primarily tropical climate with two seasons (dry and rainy). There are three climatic areas: the Sudanian zone with extensive rainfalls during the rainy season; the Sudano-Sahelian zone, located in the center; and the Sahelian zone with a very short and moderate rainy season. The climatic situation of Burkina Faso includes long dry periods and therefore causes serious water supply issues.[2]
Topography	Mostly flat to dissected, undulating plains; hills in west and southeast[1]
Rain Pattern	The dry season lasts eight months in the North and six months in the South.[1] Irregular rainfall, 400 –1000 mm/year[3]

Electricity sector overview

The national electricity company Societé Nationale d'Electricité du Burkina Faso (SONABEL) ensures electricity generation as the main vertically-integrated operator, with a national monopoly on the generation and distribution in the country's urban centres. Generation is based upon 24 thermal (diesel) plants and 4 hydropower plants (32 MW).[4] Forty-five per cent of the electricity is imported from neighbouring countries, especially Ivory Coast (figure 1).

The national electrification rate of Burkina Faso is 14.6 per cent.[5] Coopératives d'électricité (COOPEL) works with the rural electrification fund Fonds de développement de l'électrification (FDE) under the Electricity for All Programme. Local cooperatives produce and distribute electricity and are part of an umbrella organization, the National Union of Electric Cooperatives in Burkina Faso (Uncoopel / B).[6]

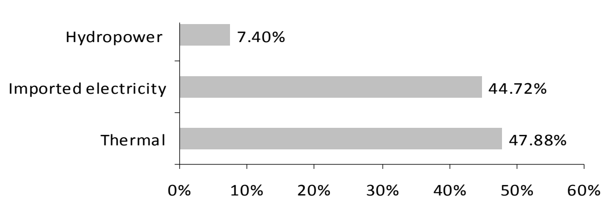

Figure 1 **Electricity generation in Burkina Faso**

Note: Data from 2012. The numbers do not include self-generation by private industrial companies (total capacity of 13.45 MW), mainly from thermal sources.[4]

Small hydropower sector overview and potential

In 1999, nine small hydropower sites with 36 MW were identified.[3] [7] Currently, two small hydropower plants exist: Tourni (0.5 MW) and Niofila (1.5 MW), which together produce about 1 GWh/year.[7] Both plants were built in 1996. Furthermore, there is a 2.5 MW small hydropower scheme to be implemented at Samendeni Dam which will produce 25 GWh/year, and two additional mini hydropower plants are planned, including Bonvale.[8]

A survey of hydropower sites was carried out within the Électricité de France SONABEL, National Centre of Hydraulic Equipment (Centre National d'Equipement Hydraulique). The study covers large-scale hydropower sites as well as small-scale installations. The capacities range between 65 kW and 550 kW, and 550 to 1,700 kW. The hydropower potential of rural areas is sufficient for decentralized electricity production. Some identified sites have estimated production costs between CFAF[i] 100 and 175 per kWh, several other sites have estimated costs of at least CFAF 200 per kWh.[2]

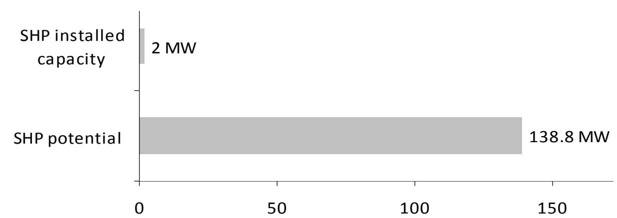

Figure 2 **Small hydropower capacities in Burkina Faso**
Source: Burkina Faso Ministere des Mines, des Carrieres et de l'Énergie[7]

All in all, 70 potential small hydropower sites have been identified with a total potential capacity of 138.8 MW (figure 2).[9]

Renewable energy policy

The Strategy for Rural Electrification supports solar energy for the electrification of rural areas currently lacking connection to the SONABEL grid. There are currently no policies or strategic directions for the use of renewable energy.[10]

Barriers to small hydropower development

Barriers to renewable energy include lack of local technical expertise and lack of financing, especially for capital-intensive technologies.[2] Apart from that, irregular rainfall pattern (400–1000 mm/year), the remoteness of the small hydropower sites to the sites of consumption, as well as cost depreciation for rural small hydropower projects hinder development.[3]

Note

i. CFA stands for Communauté Financière d'Afrique (Financial Community of Africa) or Communauté Financière Africaine (African Financial Community). In several central African states, the Central African CFA franc, which is of equal value to the West African CFA franc, is in circulation. They are both the CFA franc.

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1.5.3 Côte d'Ivoire

A.A. Esan, UNIDO Regional Centre for Small Hydro Power in Africa, Nigeria; Lara Esser, International Center on Small Hydro Power

Key Facts

Population	21,952,093[1]
Area	322,462 km^2
Climate	Four major climate zones, i.e. equatorial, semi-damp tropical, dry tropical and wet tropical/mountain climate.[2] Two air masses are influential: the Monsoon, a moist equatorial air mass, and the Harmattan, a dry tropical air mass coming along with a drying wind, with a saturation of 65-90%.
Topography	Mostly flat to undulating plains in the south; plateaus in the center, hills or hill chains with a height of 200-500m in the North, mountains in northwest.[1 2]
Rain pattern	Varying rainfall regimes exist, uni-modal and bi-modal. The annual mean rainfall lies between a minimum of 900 mm and a maximum of 2,250 mm.[3]

Electricity sector overview

The Electricity access rate is 47.3 per cent.[4] Table 1 shows energy sector objectives from the Poverty Strategy Paper (2009).[5]

Table 1
Energy sector objectives in Côte d'Ivoire
(Percentage)

Indicator	2008	2013	2015
Proportion of electrified localities	31	43	50
Proportion of households with access to electricity	17	35	55
Proportion of share of new and renewable energies in the national energy consumption (excluding biomass)	0	3	5

Source: Poverty Strategy Paper[5]

Electricity is exported from Côte d'Ivoire to Benin, Burkina Faso, Ghana, Mali and Togo.[6] Additional capacity development in the thermal and hydropower sector is planned.

Agence Nationale de Régulation (ANARE) is the National Regulatory Agency of the electricity sector. The Ivorian Electricity Company Compagnie Ivoirienne d'Electricité (CIE) has been granted concession and exploits electricity generation, conveyance and distribution facilities.[1]

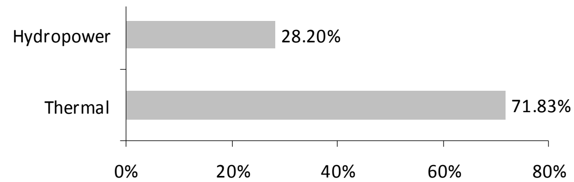

Figure 1 **Electricity generation in Côte d'Ivoire**
Sources: BIOVEA[7] and Ministry of Mines, Petroleum and Energy[10]
Note: Data from 2010.

Some 28 per cent of the electricity is derived from hydropower in Cote d'Ivoire.[9]

Table 2
Installed hydropower capacities in Côte d'Ivoire

Name	Installed capacity (MW)	Year constructed
Ayamé	20	1959
Ayamé	30	1961
Kossou	174	1972
Taabo	210	1979
Buyo	165	1980
Grah	5	1983
Total	**604**	

Source: German Agency for Technical Cooperation[1] and Koffi[9]

The economic potential of hydropower is 12 TWh. Hydropower sites with a potential of more than 1,300 MW were assessed by Électricité de France in the 1980s. Four large hydropower sites ranging from 5 MW to 290 MW have yet to be built, as well as several small hydropower sites with potentials up to 5 MW each.[1]

Small hydropower sector overview and potential

There is no specific classification for hydropower plants (small, micro, mini).[10] There is one existing small hydropower plant, Grah (5 MW), which was put into service in 1983 (figure 2).[10] Three small hydropower schemes are planned in the long term: Drou (1.6 MW, 2021), Aboissobia (5 MW, 2016) and Agnéby (0.3 MW, 2016).

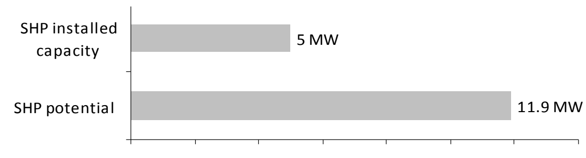

Figure 2 **Small hydropower capacities in Cote d'Ivoire**

Renewable energy policy

Société d'Opération Ivoirienne d'Électricité supervises the provision of facilities with focus on the implementation of the rural electrification programme.

Sustainable energy through developing renewable and other new energy sources is one of the areas of activities of the 2011-2030 Strategic Development Plan of the Republic of Côte d'Ivoire.[8] The private sector should play an important role through investments. An assessment of national renewable energy potential is also planned. Furthermore, an increase in production capacities, both thermal and hydropower, is planned to match increasing electricity demand.

Barriers to small hydropower development

With the support of UNIDO and ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), Côte d'Ivoire plans to concentrate on the following activities to remove barriers preventing small hydropower development in the country:[10]

- Update old small hydropower studies.
- Establish a regulatory framework for the purchase of electricity.
- Adapt regulations on the use of waterways to avoid conflict between agriculture, fishing and electricity consumption.
- Provide training session for mapping.

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1.5.4. Ghana

Lara Esser, International Center on Small Hydro Power

Key Facts

Population	24,652,402[1]
Area	238,535 km[2]
Climate	Tropical climate. Temperature is generally between 21°C and 32°C.
Topography	Mostly low plains with dissected plateau in south-central area[1]
Rain Pattern	Annual rainfall in the south averages 2,030 mm but varies greatly throughout the country, with the heaviest rainfall in the south western part. Two rainy seasons: March to July and September to October, separated by a short cool dry season in August and a relatively long dry season in the south from mid-October to March.

Electricity sector overview

In 1989, the Ministry of Energy instituted the national electrification scheme (NES) as a principal policy to reach all parts of the country between 1990 and 2020. In 2010-2011, the national electricity access was 72 per cent and was expected to continue to increase.[2] Another report said that electricity access increased from 25 per cent in 1989 to 66 per cent in 2011, while rural access has increased from 5-40 per cent.[3]

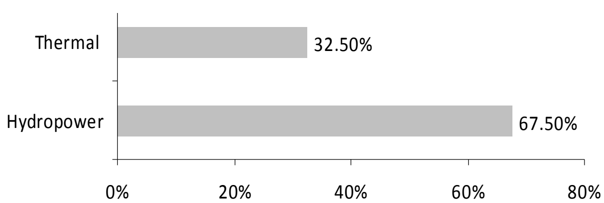

Figure 1 **Electricity generation in Ghana**
Source: Ghana Energy Commission[4]

In 2011, the total grid or public electricity generated in the country was 11,200 GWh. Two-third of electricity generated in Ghana comes from hydropower (figure 1).[5] There are two main large hydropower plants, Akosombo (1,020 MW) and Kpong (160 MW). For its dual-fuelled thermal plants, Ghana imports natural gas via the West Africa Gas Pipeline, for example, from Nigeria.[4]

The Energy Commission in 2006 published the Strategic National Energy Plan for Ghana (SNEP) for the period of 2006-2020. The Commission has been preparing annual energy demand and supply forecasts to provide a guide to the energy sector operators and potential investors.[4]

Small hydropower sector overview and potential

Ghana's definition of small-scale hydro is up to 1 MW, medium scale lies in the range of 1 MW to 10 MW and large-scale is 10 MW to 100 MW. There are no existing small hydropower plants in Ghana. The *Baseline Report for Small-Scale Hydropower* in the Economic Community of West *African States Region* reports a total of 85 potential sites of up to 30 MW, with a total potential capacity of 110 MW.[6] When considering only those up to 10 MW capacity, the 17.42 MW small hydropower potential comprises two sources: the Hydrological Service Department of Ministry of Works and Housing points out that this includes 69 sites (< 2MW) with a total potential of about 15.18 MW; and by the Energy Foundation, 12 sites (<1 MW) with a total potential of 2.24 MW.[6,7]

The feasibility study of the Randall Falls site (160 kW potential capacity) has been completed.[8] The Energy Commission has initiated actions to develop the country's renewable energy resources; particularly mini hydropower (table 2). The Energy Policy mentions that the mini hydropower potential is limited – 21 potential sites with generating capacities ranging between 4 kW and 325 kW.[8]

The Government has recognized the advantages of a more sustainable approach to agriculture, as a result, it created a policy to develop small hydropower and small scale irrigation facilities in order to boost agriculture in the rural areas. There are numerous rivers which have the potential for small hydropower development which could generate electricity with an installed capacity of between 4.5 MW to 42 MW (e.g. River Ankobra, Pra and Oti).[9]

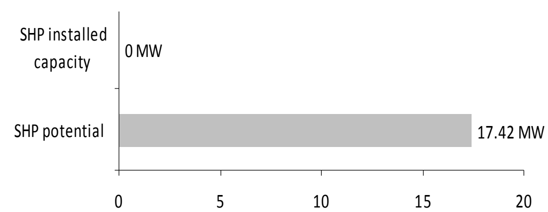

Figure 2 **Small hydropower capacities in Ghana**

Renewable energy policy

Ghana is endowed with abundant renewable energy resources such as solar energy, biomass, wind and small hydro. Therefore, it has a huge potential for electricity generation from these sources.[5] The Ghana Energy Commission has the mandate to ensure the adequate development and use of the country's indigenous energy sources. Since 2011, Ghana has a Renewable Energy Law, Act 832, which should create an enabling environment for the private sector to invest in renewable energies.[4] The 2010 Energy Policy mentions mini hydropower in its policy direction and cites actions i.e. to create an appropriate fiscal and regulatory framework and to provide pricing incentives for small hydropower projects.[10]

Barriers to small hydropower development

Large hydropower plants are seen as cheap energy generators in Ghana. Most communities within the proximity of potential small hydropower sites are grid connected and therefore small hydropower deployment is not cost competitive. This is especially due to high capital costs (US$0.5million to US$2.0 million). Inadequate financing of civil works has already proven to lead to project abandonment (e.g. Likpe-Kukrantumi) which increases investment risks, especially in the case of unfavourable flow duration curves. In some cases, a particular site could be used to stimulate socio-economic activities other than power generation, for example irrigation, tourism, ecological education, religion which would avoid the displacement of people, animals and flooding.[11]

Another key issue is the absence of a regulatory and legal framework for development and use of renewable energy sources with little or no economic incentives in place to attract investors to small hydropower, although feed-in tariffs for renewables have been planned for 2013.[12] Another barrier is the limited local technical expertise.

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1.5.5 Guinea

Susanne Hughes, International Center on Small Hydropower

Key facts

Population	10,884,958[1]
Area	245,857 km[2]
Climate	Generally hot and humid
Topography	Generally flat coastal plain, hilly to mountainous interior[1]
Rain pattern	Average annual precipitation is 4,418.5 mm. There are 160 days annually on which precipitation greater than 0.1 mm occur. Monsoonal-type rainy season: June to November (with southwesterly winds). Dry season: December to May (with northeastern Harmattan winds).[1] Driest month is February with 0.5 mm. Wettest month is July with 1,327 mm.[2]

Electricity sector overview

The national electrification rate of Guinea is around 17 per cent, with 14 per cent of the population with access to electricity living in urban areas and 3 per cent in rural areas.[3] Another source reported that only about 10 per cent of the population in the capital, Conakry, and other small urban areas have access to electricity and water.[4] Hydropower accounts for 95 per cent of the total renewable electricity production, at 36 per cent (figure 1). Out of the total electricity generation, 90 per cent is consumed by 25 per cent of the country's population living in Conakry.[4] The provided electricity supply in Conakry and other urban areas remains insufficient.[4]

The Guinea Electrical Company (EDG), under the administration of the Ministry of Energy and Hydraulic, manages an installed power capacity of 150 MW.[4] About 50 per cent of all electricity generation is now privately owned.[5] The electricity is distributed via three interconnected grid-systems (Samou, Garafiri and Kinkon).

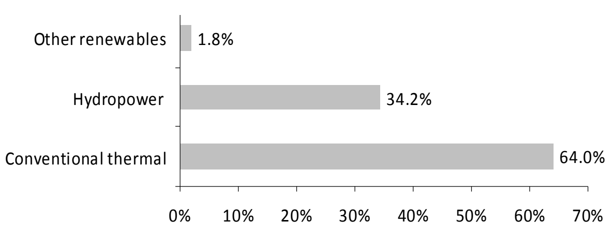

Figure 1 **Electricity generation in Guinea**
Source: World Atlas and Industry Guide[5]

A rural electrification project, partly financed by the African Development Bank, is being implemented (between 2011 and 2014), covering 31 localities, along the national interconnected grid. The Government has set an objective of raising the country's electrification rate to 36 per cent by the end of 2015.[6] It is estimated that electricity demand will increase by 10 per cent annually over the next decade.[5]

In 2010, the Kouroussa Corporation made a commitment to fight poverty through the construction of a hydropower dam on the Cogon River, supplying the villages of Boke, Kamsar and Sangaredi with electricity. This hydropower plant is estimated to add a power capacity of 80 MW within five years.[7] In 2011, the Prime Minister of the Guinean Government announced the news about the construction of a large hydropower plant at the Konkoure River (240.6 MW, 942 GWh) by the Chinese company China Water and Electric (CWE).[8] Once the citizens of Guinea are supplied with the required electricity, the Government plans to export this precious resource to the neighbouring countries through inter-connected electrical grids. CWE has proceeded with the construction of the dam as well as promised to achieve 70 km of paved roads, to supply two villages with electricity and to create an electricity transmission line of 147 km.[9]

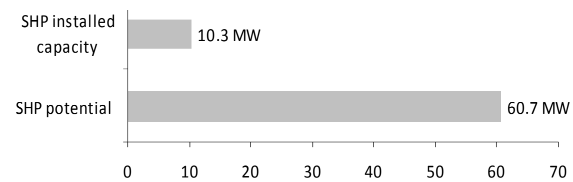

Figure 2 **Small hydropower capacities in Guinea**

Small hydropower sector overview and potential

There are seven small hydro plants with a total capacity of 10.31 MW in Guinea (figure 2). All of them need refurbishment. The following were recently reported to be operational: Kinkon (3.2 MW), Tinkisso (1.5 MW, 1967-1968) and Loffa (120 kW).[9] There were plans to upgrade the Loffa plant to 2.8 MW.[10]

In a recent report by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the total hydropower potential (≤ 30 MW) is 107 MW (in 18 sites).[10] Out of those listed, 11 sites are < 10 MW and constitute a verifiable potential capacity of 24.668 MW.

Table 2
Micro hydropower sites in Guinea

Number	*Site*	*River*	*Prefecture*	*Installed capacity (kW)*	*Energy production Gwh/year*
1	Tolo	Tolo	Mamou	20	0.80
2	Djoundé	Bouroundou	Boké	30	1.80
3	Goléya	Soguisogui	Kindia	30	0.75
4	Moussayah	Kassogny	Forécariah	50	1.00
5	Tamagaly	Konkoure	Mamou	10	0.25
6	Pike	Pike	Dalaba	10	0.60
7	Kansagui	Sonki	Telimele	10	0.80
8	Sagalé	Tominé	Lélouma	10	0.30
9	Kassira	Kassira	Mali	60	0.36
10	Nimbéli	Koela	Koubia	60	0.38
11	Nongoa	Mafissa	Gueckedou	60	3.00
12	Wantaguala	Kondékhouré	Dinguiraye	28	1.68
13	Dabadou	Konowa	Kérouané	50	0.32
14	Para-Marela	Mongo	Faranah	20	0.14
15	Kamba	Kouliyire	Forecariyah	30	1.80
16	Kabiéta	Huwoya	N'Zérékoré	20	0.48
17	Ouin ouin	Loffa	Macenta	37	0.52
18	Sonofilako	Kourayé	Beyla	40	2.94
19	Guibaya	Makona	Macenta	30	1.00
20	Tabouna	Santa	Kindia	80	1.20
21	Tonon	Gouan	Lola	10	0.08
22	Donghol	Petedji	Labe	40	0.24
23	Nila	Labatou	Pita	10	0.06
24	Souessou 2	Souessou	Beyla	10	0.08
25	Lokoua	Loffa	N`Zerekore	50	0.50
26	Djounde	Bouroudou	Boke	30	0.18
27	Bossere	Doutou	Telimele	50	0.36
28	Banko	Bindibar	Dabola	60	0.50
29	Gountou	Gountouwol	Tougue	80	0.48
30	Pita	Lalia	Bambeta	60	0.36

Source: N'Faly and Barry[11]

According to N'Faly and Barry (2006), there are 136 sites with potential capacities between 0.1 to 3 MW (total capacity 60.69 MW, 269.69 GWh). The priority lies with the small hydropower plants below 3 MW.[11]

Global Environmental Facility (GEF) is financing a project called Promoting Development of Multi-purpose Mini Hydropower Systems (2012-2016) that addresses existing barriers to renewable energy and plans to establish a total of 800 kW hydropower generation capacities. Three small hydropower sites have been identified and selected by the Ministry of Energy, i.e. Touba (Gaoual), Seredou (Macenta) and Keno. More detailed feasibility studies are needed, but due to budget limitations, it is likely that only one of the plants will be built as a pilot demonstration site.[12]

Renewable energy policy

There is no policy on the promotion and development of renewable energy projects in Guinea. It targets a renewable energy penetration rate of 2 to 6 per cent in 2013 and 8 to25 per cent in the long term (until 2019).[13]

Legislation on small hydropower

There is no established small hydropower legislation. In 1993, there was a regulating law initiative based on the Built Operate and Transfer (BOT) to favour the participation of private operators in the development of energy and hydropower, and a law established in 1998 to authorize private participation in financing, construction, development, maintenance and structural development in the energy and power sector.[4 5]

Barriers to small hydropower development

Small and large hydropower plants have been an important part of the electricity sector, justified by the importance of the development of the industry and mine sector. Guinea has a wide range of hydropower resources which can be developed in a sustainable manner to provide grid connected and non-connected areas with all the needed electricity supplies.[4] However, improvement must be made in areas as follows:

- Capacity building: The lack of adequate infrastructure for research and training of staff and supervisors of maintenance services of renewable energy technologies in general and small hydropower in particular.[3]

- Developing the country's hydropower resources, in particular by promoting synergies between the mining and energy sectors, and continuing regional integration.[5]
- Upgrading the electricity grid to expand electricity access.
- Development of suitable and adapted legislation promoting the use of renewable energies including small hydropower as well as related implementation and creation of incentives.
- Further reforms in the electricity sector, with a view to achieving greater efficiency and encouraging private sector investment.[5]
- Financial mechanisms: Lack of financial resources due to the complex permitting and licensing process for renewable energy projects, with negative impact on the indices of development of renewable energy and on technology transfer.[3]

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1.5.6 Liberia

Lara Esser, International Center on Small Hydropower

Key Facts

Population	3,887,886[1]
Area	111,370 km[2]
Climate	West African monsoon climate - tropical; hot and humid. Dry winters with hot days and cool to cold nights; Wet, cloudy summers with frequent heavy showers. Seasons are determined by the prevailing moisture-laden monsoon winds that come from the southwest. November to March, the dust-laden Harmattan wind blows in from the northwest producing a chilly and dry climate[2]
Topography	Four distinct relief zones: the coastal belt, rolling hills, plateaus and northern highlands
Rain Pattern	Dry Season: November to March. Rainy season: April to October. Average rainfall ranges between 4,770 mm along the coast and 2,030 mm in the interior.[2]

Electricity sector overview

The Liberia Electricity Corporation is the state utility, with the mandate to provide adequate and reliable power to the nation at a reasonable tariff. All of its facilities (both hydropower and thermal plants) were looted and vandalized during the 14-year civil war from 1989 to 2003. Prior to the war, the total installed capacity was 412 MW (of which 200 MW operated by mining companies). A state-owned hydropower plant Mount Coffee (64 MW) was in operation at that time and is now being restored and expanded to 100 MW.

The installed capacity is approximately 24.6 MW and an Emergency Power Programme (EPP) including several diesel power plants is in operation. The estimated total electricity demand for 2010 was 36 - 37 MW.[3] More recent electricity production data is not available.

According to the Poverty Reduction Strategy (PRS), about 10 per cent of urban residents and less than 2 per cent of rural residents have electricity access. Liberia's rate of access to publicly provided electricity is close to zero.[3] Furthermore, an urban access rate can only be derived for the capital of Monrovia. Some 1,217 of an estimated 210,619 households are supplied with public electricity (as of late 2010), corresponding to 0.58 per cent of the capital's population. With the exception of a very limited municipal mini-grid in Gbarnga, Bong County, no publicly-supplied electricity service is available outside of the capital.[4] The remainder of the population depends on costly, inefficient and polluting resources such as small gasoline and diesel generators, firewood, charcoal, candles, kerosene and palm oil.[3]

In May 2010, the Rural and Renewable Energy Agency (RREA) started a number of pilot activities, including a pilot micro-hydropower project in Lofa county, and swapping kerosene lanterns with solar lanterns under Lighting One Million Lives in Liberia with the help of the Rural Energy Fund.[5]

A World Bank report estimates that by 2015, the electricity demand based on a slow-growth scenario will be 111.84 MW (36 MW on-grid, 75.84 MW off-grid) and by 2020 the demand will be 301.75 MW (103.49 MW on-grid, 198.26 MW off-grid).[3]

Small hydropower sector overview and potential

Liberia has an assessed hydropower potential of 2,000 MW. Prior to the war, there were 23 small hydropower plants. Now, only one privately-owned small hydropower plant (4 MW) is in operation.[6] Two small hydropower plants were damaged during the civil war and are in need of repair.[6,7]

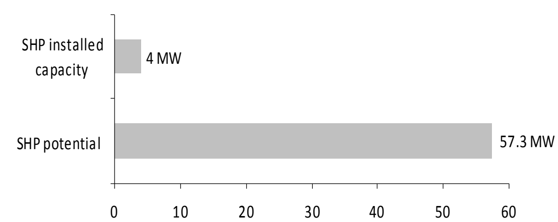

Figure 1 **Small hydropower capacities in Liberia**

A 30 kW small hydropower plant with an isolated grid was successfully operated and managed by the Yandohun community (Lofa county) in the 1980s. However, it was destroyed during the 14-year civil war. It was redesigned to 60 kW in 2009 through funding from the World Bank's Africa Renewable Energy Access Program. The rehabilitation works started in June 2011.[3,9]

Proposed small hydropower plants

	Proposed plant	*Potential capacity (MW)*
1	Lofa River Mini Hydro Plant	2.5
2	Zeliba River Mini Hydro Plant	1.5
3	St. John River Mini Hydro	7.5
4	Dougbe River Mini Hydro Plant	0.6
5	St. Paul Mini Hydro Plant	5.5
6	Ya Creek Mini Hydro Plant	1.5
	Total	**19.1**

Sources: Sow[4], ECREEE[8]

The Baseline Report by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) indicates total potential of approximately 86 MW in Liberia based on two lists that combine 30 potential small hydro sites up to 30 MW each.[8] When considering sites up to 10 MW only, the 28 sites identified have a combined potential capacity of 57.31 MW (figure 1).

Renewable energy policy

Liberia has significant renewable energy resources including biomass, hydropower and solar energy. A draft Renewable Energy and Energy Efficiency Policy and Action Plan of the Ministry of Lands, Mines and Energy was published in 2007. Liberia has targeted to raise its share of renewable energy to 30 per cent of electricity production and 10 per cent of overall energy consumption by 2015.[10] A World Bank report *Options for the Development of Liberia's Energy Sector* considers various scenarios including renewable energy options in detail.[3] [10] A draft for the integrated water resource management is in process.[8]

Barriers to small hydropower development

Studies to assess Liberia's hydropower potential were conducted between 1976 and 1983, thus there is a great need to update these findings.[3] Higher education institutions do not have a small hydropower curriculum. An energy policy and a legal framework for the promotion of hydropower are not yet established (i.e. no policy, feed-in tariff or standard PPA).[8]

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1.5.7 Mali

Oumar Sidibe, Direction Nationale de l'Énergie, Mali

Key facts

Population	15,494,466[1]
Area	1,240,192 km[2]
Climate	Subtropical to arid; hot and dry (February to June); rainy, humid, and mild (June to November); cool and dry (November to February)[1]
Topography	Mostly flat to rolling northern plains covered by sand; savannah in south, rugged hills in northeast[1]
Rain Pattern	Highly variable climate characterized by a long dry season and a rainy season averaging one month in the North (Timbuktu region) to five months in the South (Sikasso region). Rainfall ranging from 1,200 mm/year in the Sudano-Guinean zone to 200 mm/year in the Saharan zone[2]

Electricity overview

The rate of access to electricity is 55.27 per cent in urban areas and 14.89 per cent in rural areas, leading to a national average of 27.08 per cent.

Some private sector operators provide the public service of electricity, the most important of which is the company Energy of Mali (Énergie du Mali EDM) as a contract-holder.

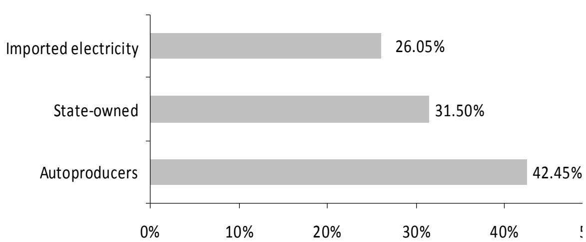

Figure 1 **Electricity generation in Mali**
Source: Mali Direction de l'Energy[3]

On the inter-connected grid, 57.3 per cent of the electricity is generated by hydropower plants and 42.7 per cent by thermal plants. The share of hydropower in the grid decreased from 80 per cent in 2004 to 57 per cent in 2010, because the constructions of key regional/national hydropower plants and regional interconnections were delayed, the Government had to increase costly thermal power supply in the short term.[2]

The total installed electricity generation capacity in Mali is 326.8 MW (excluding self-generation), distributed between hydropower (71.6 per cent) and thermal (28.4 per cent) power plants. About 20 hydropower sites of medium and large capacity with a total capacity of about 1,150 MW (an electricity production of about 5,600 GWh) were identified throughout the national territory. Only four of these sites are fitted out at the moment (representing approximately 25 per cent of the national potential), namely: Félou (0.6 MW, about 3 GWh/year), Sotuba (5.2 MW, about 40 GWh/year), Sélingué (44 MW, about 200 GWh/year) and Manantali (200 MW, about 800 GWh/year).

Small hydropower sector overview and potential

Since 1927, the inauguration year of the hydropower power station in Félou (600 kW, 3 GWh/year), no other small hydropower projects have been put into operation, except for one pico-hydropower station at Siraorobougou of 3 kW in 2008.

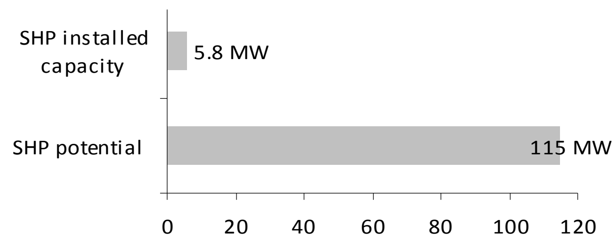

Figure 2 **Small hydropower capacities in Mali**

The country has a small hydropower potential, as demonstrated by the 1988 study of the German Technical Cooperation (GTZ), which inventoried and estimated briefly the sites of Farako (50- 250 kW), Kéniéba or Doundi (180-250 kW), Nimbougou (10-50 kW), Paparah (50-60 kW) and Missira. Other potential sites are identified in the regions of Kayes and Sikasso (at Sirakorobougou; 3 kW). Of all those sites, only Sirakorobougou is currently operational and Farako is part of a feasibility study, with technical and financial support from UNIDO.

Seven priority sites have been identified: three sites at Farako (Farako I, Farako II, Farako III), two sites at Waromi (Woroni I, Woroni II), Nimbougou and Doundi. The evaluation of a further 10 additional micro hydropower sites is planned within the framework of the Master Plan Study for Rural Electrification financed by the African Development Bank (AfDB).

Renewable energy policy

Mali's renewable energy penetration target for 2015 is 25 per cent.[4] [i] Renewable energies (solar, wind, micro/mini hydropower, etc.) are currently used at an insignificant level. The Government's vision and targets have been formulated in key policy papers, including the National Energy Policy (2006), the National Strategy for the Development of Renewable Energies (2006), the National Strategy for the Development of Biofuels (2006) and the National Energy Sector Policy Letter (2009-2012).

Mali has been selected as one of the six countries to benefit from the Scaling-Up Renewable Energy Program in Low Income Countries (SREP), funded by the AfDB. The main objective is to demonstrate the economic, social and environmental viability of a low-carbon development path in selected countries, with a view to increasing energy access, by using renewable energy and creating new economic opportunities.

The SREP Mali Investment Plan has been prepared under the leadership of the Government of Mali, represented by the Ministry of Energy and Water, and by different specialized national agencies. It is therefore a country-led programme, in line with key strategies of the national energy sector, as well as with the main principles of its Growth and Poverty Reduction Strategy and the National Climate Change Strategy.

Barriers for small hydropower development

The main barriers in Mali for small hydropower are geo-climatic factors (see key facts above) as well as lack of financial resources to implement projects.

A legal and regulatory framework is needed in order to facilitate the construction of small hydropower plants in rural communities and in order to remove the barriers that small hydropower promoters in local communities and in the private sector encounter.

Tools are missing to build up local capacity for the design and implementation of mini- and micro-hydropower plants.[5] Lacking capacities in metal processing and manufacturing of key parts of small hydropower plants also pose a challenge.

Note

i. Another source reports the target of renewable energy contribution of 10 per cent of the total energy production by 2022.[5]

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1.5.8 Nigeria

Basheer Adekunle Kadejo, Nigeria; Kai Whiting and Lara Esser, International Center on Small Hydro Power

Key facts

Population	170,123,740[1]
Area	923,766 km[2]
Climate	Varying climate; equatorial in south, tropical in center, arid in north[1]
Topography	Southern lowlands merge into central hills and plateaus; mountains in south-east, plains in north. The river Niger enters the country in the northwest and flows southward through tropical rain forests and swamps to its delta in the Gulf of Guinea.[1]
Rain Pattern	Rainfall has decreased from 1,350 mm (1941–1970) to 1,276 mm (1970–2002) annually. However, the coastal area is experiencing a light increase. Apart from the general southward shift in rainfall patterns, the intensity of rainy days has also decreased from 80-360 mm (year 1941 to 1970) to 40-280 mm (year 1970 to 2002).

Electricity sector overview

The dominant sources of power generation in Nigeria are natural gas and hydropower. The estimated installed electricity generation capacity is 8,644 MW, while available capacity is approximately 3,200 MW.[2] With an estimated technically exploitable potential of 20,000 MW, the hydropower potential of Nigeria is high and hydropower currently accounts for about 32 per cent of the total installed commercial electrical power capacity.

Despite the country's abundance of petroleum and other natural resources, more than 60 per cent of the country's population has no access to electricity. The annual electricity consumption per capita of the remaining 40 per cent is about 109 kWh due to frequent power interruptions, load shedding and poor electricity infrastructure. This instability of the electricity system is seen as one of the causes for poor health services and poor economic growth.[3 4 5]

Electrification access stands at 50.6 per cent. As of 2009, only 10 per cent of rural inhabitants, which makes up 50 per cent of the total population, are connected to the national grid.[6]

The transmission network is overloaded with a wheeling capacity of less than 4,000 MW and has a poor voltage profile in most parts of the network, especially in the north part of the country where there is inadequate dispatch and control infrastructure, radial and fragile grid networks, frequent system collapses and exceedingly high transmission losses. Indeed, 40 per cent of the electricity generation is lost during transmission to the national grid.[7] According to Llugbo (2012), vandalism and theft of cables and other vital equipment are frequent, as well as accidental destruction of distribution lines and illegal connections, what often results in over-loading of the distribution lines, unannounced load shedding, and prolonged and intermittent outages. Consequently, many industrial outfits have resorted to generating their own off-grid electricity.[8] The African Development Bank (2009) has reported that instability in electricity supply is by far the most binding constraint to doing business in the country.

Small hydropower sector overview and potential

Nigeria adheres to the internationally accepted small hydropower definition (10 MW capacity limit). Plants with capacities up to 1 MW are considered mini hydropower in Nigeria, and those with capacity up to 500 kW are considered as micro hydropower.

With the set-up of the UNIDO Regional Centre for Small Hydro Power in Abuja in 2006, Nigeria is considered as one of the few places for systematic capacity development in small hydropower technology in Africa. It should serve not only for domestic needs but also for giving guidance to other countries in Africa.[9] Nigeria has a short term target of installing 100 MW of small hydropower capacity, and a medium target of 760 MW based on the renewable energy master plan (2006).[10] Please see following discussion on small hydropower potential.

There are various installed small hydropower plants reported for Nigeria. In 2011, it was reported that five small hydropower plants (up to 10 MW definition) exist in Nigeria (23.35 MW and 204.55 GWh/yr).[11] However, the *Baseline Report on Small-Scale Hydropower in the ECOWAS Region* lists 45 MW of existing small hydropower plants (up to 10 MW), 18 MW of which needs to be rehabilitated, as well as an additional 191 kW of micro capacity (figure 1).[12]

There is varying information on the potential of small hydropower in Nigeria. According to UNIDO Regional Centre on Small Hydropower, the gross small hydropower potential (for plants up to 10 MW) is 720 MW, the technically feasible potential is 605 MW and the economically feasible potential is 498.4 MW.[11] A study from 2006 identified 278 yet undeveloped sites for small hydropower production with a total of 734.2 MW (with a definition of up to 30 MW).[13 14]

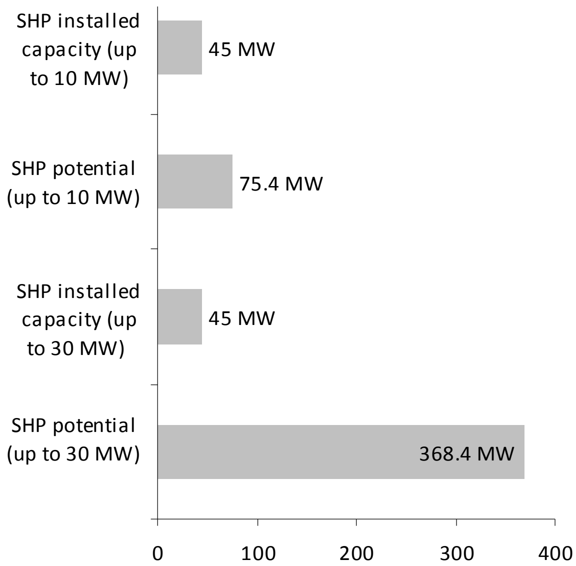

Figure 1 **Small hydropower capacities in Nigeria**
Source: Ecowas Centre for Renewable Energy and Energy Efficiency[12] and authors' calculation

Ongoing small hydropower activities are:

- 2x75 kW Waya Dam, Bauchi State plant completed (United Nations Industrial Development Organisation (UNIDO), Energy Commission of Nigeria (ECN), Bauchi State Government).
- 1x30 kW Ezioha-Mboro Dam small hydropower, Enugu (UNIDO, ECN).
- 2x200 kW Tunga Dam small hydropower, Taraba State (UNIDO)
- Capacity building in hydropower research and development at the National Centre for Hydropower Research and Development (NACHRED), University of ILORIN.

Renewable energy policy

In April 2010, the Federal Ministry of Power established a standing committee to work out ways of developing the country's capacity in the hydropower sector as part of its strategy to tackle its endemic problems.[9] So far there is no feed-in-tariff regulation in place.

Nigeria has a National Energy Policy that has been approved and launched in 2003, as well as a National Energy Master Plan and a Renewable Energy Master Plan in final draft.[15] Main targets are the expansion of electricity supply to 75 per cent of the population by 2025 and a stronger participation of the private sector. It also foresees a promotion of renewable energies and their incorporation in the national energy mix.[9] The goal is to generate 18 per cent of electricity from renewable energies by 2025, and 20 per cent by 2030, with broad objectives as follows:[16]

- To enhance energy security in the nation by diversifying the energy supply mix;
- To increaes energy access especially in the rural and semi-urban areas;
- To facilitate employment creation and empowerment;
- To protect the environment and to mitigate climate change.

Barriers to small hydropower development

As discussed in the previous sections, the issues of vandalism, theft and illegal connections to the grid make investment in electricity infrastructure difficult and limit business opportunities, with many firms struggling or failing to survive as an indirect result of electricity supply problems. However, small hydropower, particularly in its micro and pico forms, offers the possibility of energy security to rural areas. Due to the difficulties in the electricity infrastructure both people and businesses are ready to embrace small hydropower and other mini-grid solutions.[8] This provides a good springboard for small hydropower if it can overcome capacity building and technical barriers such as:

- Lack of small hydropower skills and information of the potential sites;
- Lack of feasibility studies;
- Need of information and awareness raising in rural areas;
- Energy infrastructure financing difficulties;
- Lack of energy service companies which can efficiently develop and operate the sites;
- Absence of local small hydropower research and development and small hydropower equipment manufacturing.[9]

Overlapping mandates and conflicts over responsibilities in Nigeria, including disagreements between the agencies responsible for water resources and those for power generation and distribution also affect small hydropower development.[10]

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1.5.9 Sierra Leone

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key Facts

Population	5,485,998[1]
Area	71,740 km[2]
Climate	Tropical climate with two seasons: rainy season (May to October), and dry season (November to April). Humidity is high, about 85 per cent.
Topography	Mountainous range in the north-east which slopes down to the coastal swamps through an undulating grassland plain. The relief is drained by a system of rivers flowing through cataracts and waterfalls ideal for hydropower development, and providing water for the rural communities.
Rain Pattern	Average annual rainfall: 2,746 mm.[2] Three climatic belts: coast to 80 km inland (rainfall greater than 3,300 mm per annum), 80 to 190 km inland (average annual rainfall between 2,500 mm and 3,300 mm), 190 km to border areas (average annual rainfall between 1,900 mm and 2,500 mm).[3]

Electricity sector overview

Sierra Leone is endowed with abundant energy resources, these include hydropower (estimated at 1,200 MW), solar, biomass, biogas/bagasse. However, these are not sufficiently developed yet to meet energy needs in the country. Most of the energy needs are met by petroleum products (e.g. petrol, diesel, kerosene), and traditional sources such as firewood, charcoal and other agricultural products. Only about 4.7 per cent of the hydropower potential in the country has been tapped so far.[4] Until the Bumbuna I hydropower station (50 MW) came on stream in 2010, generation relied mainly on costly fuel-based thermal generation (figure 1).[5]

The nation is still recovering from war and the electricity generation, transmission and distribution infrastructure is still poor. There is currently no national grid.

The national electrification rate is 10 per cent.[5] While Freetown has a relatively acceptable degree of electricity access, the rest of the towns are virtually in perpetual darkness, with only 1 per cent having access to an electric grid supply. In order to restore power to these areas, the Government has in principle repealed the act of parliament that empowers the National Power Authority (NPA) as the sole monopolist of electricity supply and now encourages private participation in electricity generation.[4] With the completion of the Bumbuna I hydropower facility in 2010, the country jumped from 13 MW to 63 MW of installed electricity generation capacity.[5]

The estimated hydropower potential in Sierra Leone is more than enough to supply Freetown and to export excess electricity to the neighbouring countries.[5]

Sierra Leone is part of the West African Power Pool (WAPP), a regional organization dedicated to fostering greater co-operation in the region's power sectors and interconnection between countries to enhance energy security. Currently Sierra Leone does not import electricity. By joining the WAPP, Sierra Leone has the potential to become both an importer and exporter of electricity and to compensate for seasonal variations in hydropower generation.[6]

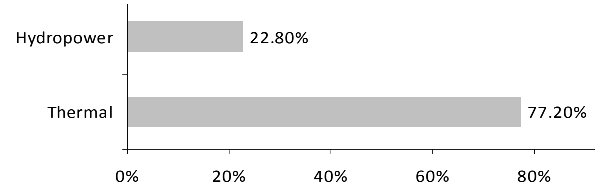

Figure 1 **Electricity generation in Sierra Leone**
Source: African Development Bank[7]
Note: Data from 2010.

Small hydropower sector overview and potential

Sierra Leone has a very high potential for small- and medium-hydropower generation. The new vision of the Sierra Leone Government is to develop all of its hydropower potentials, and to install thermal generation to complement the envisaged hydropower stations.[8] Nearly all the districts have one or more waterfalls which could be developed to generate small and/or medium hydropower.

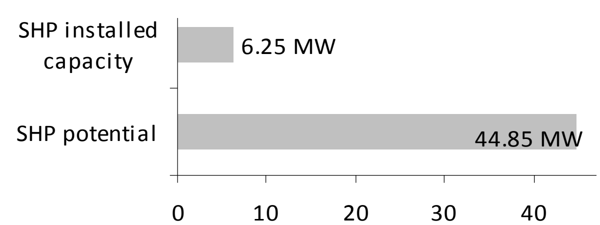

Figure 2 **Small hydropower capacities in Sierra Leone**
Source: ECOWAS Centre for Renewable Energy and Energy Efficiency[9]

The *Baseline Report on Small-Scale Hydropower in the ECOWAS Region* identified six potential small hydropower sites with a potential capacity of 38 MW.[9]

The only small hydropower station in the country is Dodo, with 6 MW capacity following a refurbishment.[4] A mini hydropower plant exists in Yele/Makali, with a total operating capacity of 250 kW in the northern part of Sierra Leone (figure 2).[9]

Since 2012, UNIDO has been working on a feasibility study for a 10-MW hydropower project linked to Njala University at the Moyamba district. Following an initial feasibility study, there are also further developments for a 1-MW mini hydropower scheme on River Banaksoka.[10]

Studies have been carried out in Charlotte, Freetown, with the aim to develop a 2.2-MW small hydropower plant. There has been limited information on the project, however the project is set to commence according to Kamara.[11]

Further possible development at Moyamba in the south of Sierra Leone (10 MW) still awaits contractual confirmation.[99] The project is proposed to receive Global Environmental Facility financing.[9]

Renewable energy policy

The main target of 2010 Energy Policy on electricity is to provide access to 35 per cent of the Sierra Leone population by 2015. There is no proposed contribution from renewable energy under the policy.[8]

The main objective of the national energy policy is to develop energy supply infrastructure countrywide, judiciously developing alternative sources of energy without adverse effect to the five pillars of the 25-year Development Plan, i.e. an environment for economic and social development, good governance, improvement of national security, employment creation, and poverty alleviation.

For the second and third stages of the energy expansion plan (by 2020 and 2025, respectively), two per cent renewable energy (non-hydro) is planned. For example, the target for 2020 is to reach a total installed capacity of 800 MW and an electricity production of 7,000 GWh per year.[8] Part of future renewable energy plans is grid-connected solar PV, solar thermal electricity production, generation from urban wastes and crop residues as well as low speed off-shore wind parks. However, feasibility studies are still required. Sierra Leone also aims to develop a rural electrification policy and strategy. The dominant institutional solutions considered are the establishment of a Rural Electrification Agency and the active deployment of off-grid technologies that make use of small-scale renewable energy sources, such as mini- or pico-hydro schemes, or solar technology.[5]

Barriers to small hydropower development

Eleven years of war has caused enormous damage to the national economy and severe destruction to the infrastructure. The country's electricity industry lags behind and needs upgrading. Barriers specific to small hydropower development are:

- Lack of local production of turbines and spare parts;[9]
- Lack of local consultancy capacity;[9]
- Lack of hydrology departments at universities and/or training institutes. However, a network of gauging stations for regular water level and runoff measurements and hydrological data collection is available at hydrological stations;[9]
- Lack of funding, which hinders the implementation of small hydropower projects.

There are also specific challenges in the electricity sector which hinder development. According to AfDB (2011) the country has one of the highest electricity tariffs in West Africa. There is also a lack of utility infrastructure and equipment. Capacity building for strategic planning, operation and maintenance of facilities is lacking, as are the financial means.[5]

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1.5.10 Togo

Lara Esser, International Center on Small Hydro Power

Key facts

Population	5,858,673[1]
Area	5,017,000 km[2]
Climate	Tropical; hot, humid in south; semi-arid in north
Topography	Gently rolling savannah in north; central hills; southern plateau; low coastal plain with extensive lagoons and marshes[2]
Rain Pattern	In the North: one wet season (May to November) and one dry season (December to March, when the Harmattan wind blows north easterly). The South has two wet seasons: from March to July and a shorter wet season from September to November.[3] The northern and central regions receive 200-300 mm rain per month in the peak months of the wet season (July to September). Average annual rainfall in coastal areas is 950 mm.[4]

Electricity sector overview

The national electrification rate in the Togolese Republic (Togo) is 22 per cent, with 18 per cent access in urban areas and 4 per cent access in rural areas.[5] An appropriate energy policy was previously lacking but is underway.

Electricity is supplied by two companies: the Compagnie Énergie Électrique du Togo (CEET), which has had a monopoly of electricity distribution and supply to end users since 2006; and the Communauté Électrique du Bénin (CEB), a joint venture with Benin for the purpose of purchasing electricity from the Volta River Authority hydropower facilities in Ghana. Togo depends on foreign sources for its electricity supply and is affected by multiple brownouts (an intentional or unintentional drop in voltage in an electrical power supply system).[1] According to the Clean Energy Portal-Reegle, 70 per cent of the electricity in Togo is imported (figure 1).

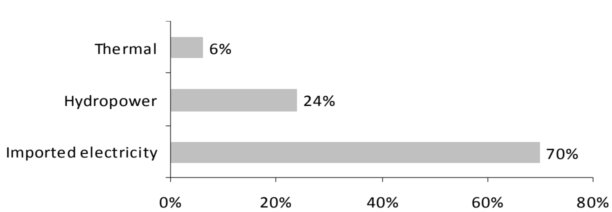

Figure 1 **Electricity generation in the Togolese Republic**
Source: Clean Energy Portal- Reegle[6]

Small hydropower sector overview and potential

There is a 48-year old small hydropower plant in the country, but it needs renovation. Its installed capacity is 1.6 MW, generating around 2.6 GWh/year. By 2015, up to 58 MW (more than 850 GWh/year) of small hydropower could be installed, however, funding is a major problem.[5]

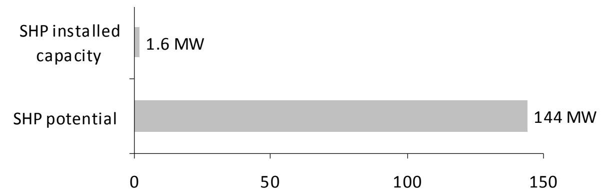

Figure 2 **Small hydropower capacities in Togolese Republic**
Source: Authors calculation based on Ecowas Centre for Renewable Energy and Energy Efficiency[8]

The last hydropower resource evaluation was conducted in 1984. It assessed a total technical potential of 224 MW (more than 850 GWh/year) on over 40 sites.[5] Fifteen of these 40 sites have potential capacities of up to 10 MW and a total potential of 81 MW (table).[7] The *Baseline Report on Small Hydropower in the ECOWAS Region* reports that the feasible potential of small-scale hydropower (defined as up to 30 MW) is 206 MW.[8] When applying 10 MW as the definition, the feasible potential in Togo is 144 MW, based on 35 sites (figure 2).

Potential small hydropower sites in Togo

River	*Village of site*	*Plant*	
		Potential capacity (MW)	*Estimated annual electricity generation (GWh)*
Amou	Gléï	2	5
Amou	Amou Oblo	3	8
Kara	Landa kpozanda	5	13
Mô	Banga (Bassar)	6	16
Domi	Tomégbé Akloa	8	21
Mono	kpéssi	8	21
Sin Sin	Route Atakpame-Badou	2	5
Kpaza	Parc Fazao	3	7
Assou Koko	Langabou	5	13
Keran	Route Kande-Mago	5	13
Mono	Dotecope	9	24
Mono	Sagada/Kpeteta	8	21
Koroon	Seregba	9	24
Gban Houn2	Danye Konda	5	13
Mono	Landa Mono	3	8
Total		**81**	**199**

The African Development Bank (2011) mentions a need for diversification of energy supply sources by developing the country's hydropower potential.[1]

Renewable energy policy

One of the priority areas in the 2006-2008 Poverty Reduction Strategy of Togo is to develop infrastructure needed for growth, by developing energy resources. The priority measures include the decision and implementation of an energy policy, establishment of a national rural electrification agency, a rural electrification fund and a legislative and regulatory framework for developing renewable energies. However, due to the lack of financing, none of the objectives have been achieved.[9]

Barriers to small hydropower development

The hydro potential of small hydropower in Togo is highly seasonal and varies regionally.[8] Lack of funding is the principal barrier to developing small hydropower projects.[5] In addition, there is no feed-in-tariff for small hydropower.[8]

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2 Americas
2.1 Caribbean

Sven Homscheid, Caribbean Renewable Energy Development Programme, St. Lucia, West Indies

Introduction

The Caribbean comprises 28 countries/ territories and can be divided into the Greater and the Lesser Antilles. The Lesser Antilles (also known as the Caribbees, 20 countries) and the Greater Antilles (five countries) are part of the West Indies along with the Bahamas, the Cayman Islands, and the Turks and Caicos Islands.

Table 1
Overview of countries in the Caribbean

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Installed electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
The Greater Antilles							
Cuba[abd]	11.252	25.0	97.0	6 240	17 387	64.0	>80
Dominican Rep.[ah]	9.927	31.0	..	3 394	14 580	540.0	1 383
Guadeloupe[fg]	0.503	1.8	..	..	..	9.5	21
Haiti[abc]	9.993	48.0	38.5	267	687	61.0	300
Jamaica[abj]	2.889	48.0	92.0	872	5 001	22.0	152
Puerto Rico[ahi]	3.690	1.0	100.0	5 840	22 558	100.0	133
The Lesser Antilles (as considered in this report)							
Dominica[ae]	0.073	33.0	95.0	27	89	6.4	32
St. Lucia[al]	0.175	72.0	98.0	76	341	0	0
Grenada[abk]	0.112	61.0	..	49	224	0	0
St. Vincent and the Grenadines[an]	0.121	51.0	..	49	139	5.6	17
Total	**38.735**	**-**	**-**	**16 814**	**61 006**	**718.5**	**2 118**

Sources:
[a] Central Intelligence Agency[1]
[b] Organización Latinoamericana de Energía Organización Latinoamericana de Energía[2]
[c] International Energy Agency[3]
[d] Cuba, Oficina Nacional de Estadística[4]
[e] Dominica Electricity Services[5]
[f] Worldstat[6]
[g] EDF and Direction des Systèmes Energétiques Insulaires[7]
[h] International Journal on Hydropower and Dams[8]
[i] Puerto Rico Electricity Services[9]
[j] Jamaica Public Service Company Limited[10]
[k] Grenada Electricity Services[11]
[l] St. Lucia, Energy Unit[12]
Note: Please note in the case of Haiti, in order to provide a full set of information on electricity, prior to earthquake information is reported.

The Lesser Antilles are a sub-region of the Caribbean Islands and are located in between the Caribbean Sea and the Atlantic Ocean. This report (see respective country reports) takes into consideration the countries of the Lesser Antilles which are mentioned in table 1. The total population of the Lesser Antilles is estimated to be three million living on multiple islands. Common to all islands, maybe with the exception of Trinidad, is their small area size, which generally constrains the use of small hydropower to a certain extent. Most of the islands under consideration were formed through the subduction of the Oceanic Crust of the North American Plate under the Caribbean Plate and hence are of volcanic origin resulting in mountainous terrain. The zone is tectonically active and experiences frequent earthquakes, mostly of a lesser magnitude. The islands of Barbados and Trinidad and Tobago are not volcanic.

The general climate of the Lesser Antilles is characterized as tropical with a distinct dry season and a wet season, whose duration varies according to the island's location. The mean annual temperature is around 26°C for all islands. The region shows various micro-climates, which differ significantly depending on the island's latitude. Maximum annual precipitation is generally high, ranging from 1,900 mm in Barbados to 9,000 mm in Dominica. The high evaporation rate causes high average relative humidity beyond 70 per cent.

The electricity sector of all the islands under consideration, are governed by monopolistic, vertically integrated utilities that are either entirely owned by government or by a mix of public and private shareholders. In terms of other renewable energy sources, it is worth mentioning that the geothermal plant of La Boulliante in Guadeloupe has a nearly 16 MW installed capacity that provides about 10 per cent of the island's electricity. The islands of Martinique, Guadeloupe and Nevis operate small grid-connected wind farms. On various islands decentralized electricity generation from renewable sources by and for private households and small entrepreneurs has commenced in the recent past.

The topic of renewable energy is discussed in general at a political level. One of the region's priorities is securing energy supply and becoming increasingly independent from fossil fuel imports. Several countries have passed respective energy policies with mixed outcomes. At a regional level, there are several initiatives that promote the use of renewable energy, such as the Caribbean Renewable Energy Development Programme (CREDP), which is an initiative of the Caribbean Community (CARICOM). Beneficial for the promotion of renewable energy is the installation of energy units at national and regional levels, such as the CARICOM Energy Program, the Organisation of Eastern Caribbean States (OECS) Energy Department or the Energy Unit of St. Vincent and the Grenadines, for example. These institutions serve as entry points for potential renewable energy developers in the region.

The Greater Antilles are a sub-region of the Caribbean Islands and comprise Cuba, Jamaica, Hispaniola (containing the nations of Haiti and the Dominican Republic), and Puerto Rico, all of which use small hydropower. Together, the Greater Antilles constitute almost 90 per cent of the land mass of the entire West Indies.

The climate of the Greater Antilles is generally characterized as warm and tropical with dry winters. Hurricanes are more frequent in the Greater Antilles than in any other group of islands. Hydropower development has been very active in Cuba, since special attention is given to renewable energy in order to avoid oil imports and to reduce environmental pollution.

Small hydropower definition

The list of classifications for the various scales of hydropower is not available as most of the countries and islands do not adhere to any classification of small, mini, micro or large hydropower. Thus during the compilation of this report these classifications were indistinguishable.

Regional overview

Within the Lesser Antilles, no new small hydropower development could be observed within the last 15 years. The contribution of renewable energy to the electricity supply is marginal on most islands. Only in Dominica, Guadeloupe and Saint Vincent and the Grenadines does small hydropower contribute to the electricity supply, with hydropower in Dominica contributing to a third of the island's electricity supply.

The Greater Antilles differ in this retrospect to the Lesser Antilles and thus, experience a more mature small hydropower sector, the majority of the small hydropower plants are located in Puerto Rico and Cuba, followed by Jamaica. In the Dominican Republic, small and micro hydropower plants are planned or under construction. Grenada used to have hydro wheels to operate mills, but none of the early power stations are now in operation and its National Energy Policy does not mention hydropower explicitly. In the future, Cuba is looking into the possibility of assembling necessary hydropower equipment within Cuba and study experiences of hybrid solutions such as pico-turbines, small wind turbines and solar panels. Both Cuba and St. Vincent and the Grenadines are planning to upgrade their old hydropower plants.

The whole Caribbean Region has about 124 MW installed small hydropower capacity and a known small hydropower potential of around 252 MW (table 2). Cuba is planning to increase its hydropower capacity by 30.5 MW between 2011 and 2015, through the development of 14 new projects and 4 refurbishments (see Cuba report). Small hydropower development activities are also ongoing in the Dominican Republic and Jamaica.

Table 2
Small hydropower in the Caribbean
(Megawatts)

Country	*Potential*	*Installed capacity*
Greater Antilles		
Cuba	62.0	21.90
Dominican Republic	15.4	15.40
Guadeloupe	46.0	8.70
Haiti	..	..
Jamaica	63.0	24.00
Puerto Rico	44.8	41.80
Lesser Antilles		
Dominica	6.4	6.40
Saint Lucia	0.4	0.24
Grenada	7.0	0.00
Saint Vincent and the Grenadines	7.4	5.65
Total	**252.4**	**124.09**

Sources: See country reports.
Note: The potential is not known for many countries, therefore the potential is an estimate based on installed capacity and planned capacities where available.

In early 2013, a study on the small hydropower potential of Saint Lucia was completed, and the Dominica report is expected to be available soon. While both countries currently have no plans for new small hydropower projects, it is expected that, once the potential is known, interest in its development will grow.

The general tone of the region suggests that the renewable energy sector will expand in the future with the help of improved information access and strengthened regulatory frameworks. In addition, rural potential for small hydropower provides a promising growth of small hydropower use within the region, despite the fact that some locations will be hindered by natural calamities.

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2.1.1 Cuba

Daniel López and Manuel Álvarez, Cubaenergía, Cuba

Key facts

Population	11,075,244[1]
Area	109,886 km^2
Climate	Tropical climate moderated by trade winds[1]
Topography	Mostly flat to rolling plains, with rugged hills and mountains in the southeast[1]
Rain pattern	Rainy season from May to October; dry season from November to April

Electricity sector overview

The electrification level throughout Cuba is 95 per cent. As of 2011, a total capacity of 6,240 MW is installed in the country for electricity generation, of which only 64 MW are hydropower plants.[2] Fossil fuels (oil and gas) play a major role in electricity generation (figure 1). Renewable energies contribute only 0.63 per cent to the gross electricity generation (data of 2011).

The country has embarked on an extensive programme of modernizing existing power plants to update them with advanced technologies, to achieve higher availability in their operation and to decrease specific fuel consumption as well as to increase use of domestic crude oil.

Among other possible sources of electricity generation are biomass and waste from sugar mills, using sugarcane bagasse and straw.

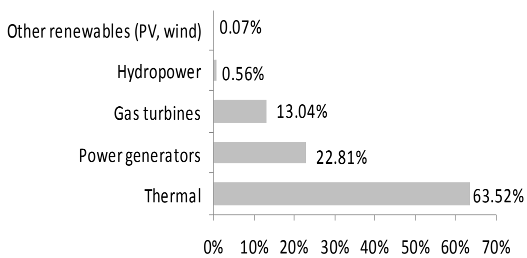

Figure 1 **Electricity generation in Cuba**
Source: Oficina Nacional de Estadística[3]

Small hydropower sector overview and potential

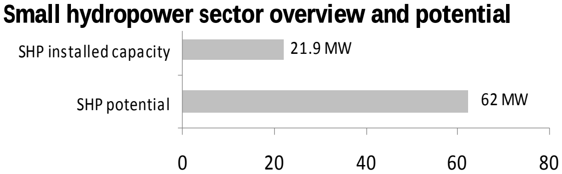

Figure 2 **Small hydropower capacities in Cuba**

Cuba has one large hydropower plant (Hanabanilla, 43 MW) and 168 small hydropower plants with a total capacity of 21.9 MW (figure 2). Of the 168 small hydropower plants, 30 are connected to the national power grid and 138 are off-grid plants located in isolated mountainous areas.

The National Hydraulic Resources Institute has worked for several years to identify the technical hydropower potential of the country, studying the main rivers of Cuba and conducting feasibility studies of hydropower utilization at existing dams. The estimated total hydropower potential is 848 MW, including a small hydropower potential of 62 MW.

Renewable energy policy

In 2005/2006 a series of programmes called the Energy Revolution was initiated focusing on: energy saving and efficiency, increased availability of electric services (deployment of distributed generation and rehabilitation of networks), use of renewable energies, increased exploration and production of oil and gas and international collaboration.

Some of the initiatives envisaged for the future are:

1. To evaluate the possibility of assembling necessary hydropower equipment within Cuba.
2. To study the Chinese experiences of hybrid solutions (small hydropower, small wind turbines and solar panels) for the provision of electricity to 60,000 households in rural areas.
3. To study the Chinese experiences of implementing micro-systems and technologies that decrease civil construction.
4. To reassess the country's hydropower potential.
5. To continue the automation of most of the small hydropower plants.
6. To refurbish old hydropower plants by introducing new technologies.
7. To start operation of the small hydropower plants currently under construction.

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2.1.2 Dominica

Sven Homscheidt, Caribbean Renewable Energy Development Programme, St. Lucia

Key facts

Population	73,126[1]
Area	750 km[2]
Climate	Marine tropical climate, with very little seasonal variation
Topography	Rugged mountains of volcanic origin (highest point: Mount Diablotins, 1,447 m)[1]
Rain pattern	December to April: 50-160 mm. May to November: 90-350 mm (maximum and minimum monthly rainfall averages)

Electricity sector overview

The electricity supply coverage of Dominica is above 95 per cent. With the population being dispersed in the supplied area, energy supply is very expensive resulting in a domestic electricity rate of more than US$0.36 kWh.

Dominica Electricity Services Limited (DOMLEC) is Dominica's sole vertically integrated electric utility. Although there are smaller independent power producers, such as the 275 kW Rosalie wind turbine and a 9-kW photovoltaic plant, DOMLEC has the 'de facto' monopoly for transmission and distribution of electricity.

DOMLEC is 20 per cent government-owned and 80 per cent owned by private investors and other shareholders. Since June 2007, the Independent Regulatory Commission acts as regulatory body.

Dominica's electricity market is completely liberalized and anyone is free to apply for a generation, transmission, distribution or sales of licence for electricity. However, besides DOMLEC's licence, to date only one licence was issued to an independent power producer for a 275-kW wind turbine. DOMLEC's licence will expire in 2015, 10 years earlier than stipulated in the original contract. This change was enforced by the energy sector reform in 2006. Since 2005, Dominica is a member of the Petrocaribe (an Energy Cooperation Agreement based on solidarity support proposed by the Bolivarian Government of Venezuela intended to overcome asymmetries with regard to access to energy resources. This agreement aims at establishing a new favorable, equal and just exchange scheme between the counties of the Caribbean region, most of them without a State-controlled supply of these resources).[2]

To supply Dominica's peak demand of currently some 17.5 MW, DOMLEC provides a total installed capacity of some 26.5 MW, of which 6.4 MW are small hydropower plants and the remaining 20.1 MW originate from its diesel plants (figure 1).

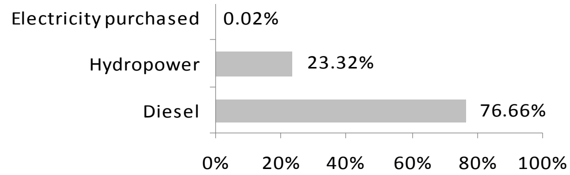

Figure 1 **Electricity generation in Dominica**
Source: Dominica Electricity Services[3]

Small hydropower sector overview and potential

Water wheels were used in Dominica for processing sugar cane and other agricultural produce. Hydropower development in Dominica for electricity generation started during English Colonial times in 1951 with the installation of 2x 320 kW Pelton units at the Old Trafalgar plant. The New Trafalgar hydropower station replaced it in 1991 with 2x 1.761 MW Pelton turbines.

The current hydropower infrastructure in Dominica belongs entirely to DOMLEC and consists of three small hydropower plants with a total capacity of 6.4 MW, individual capacities ranging from 1.88 MW up to 3.50 MW (figure 2). Due to the high elevation of the terrain, the used turbines are Turgo in one plant and Pelton in the others.

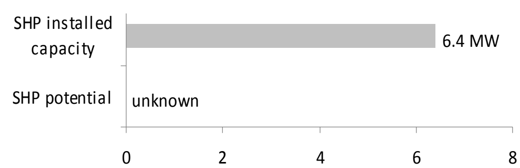

Figure 2 **Small Hydropower capacities in Dominica**

Dominica is an island with frequent volcanic activity as well as frequent landslides that remodel the topography after heavy rain events. The owner of an eco-resort at the Rosalie River attempted to install a small hydropower turbine to provide electricity for his small cottage hotel. Unfortunately, the infrastructure was washed away by a major flood event and ever since the project activities have stopped.

The many waterfalls existing on the island are indications of the vast hydropower potential in Dominica. The Caribbean Renewable Energy Development Programme (CREDP-GIZ) has proposed and studied a 200-kW small hydropower project to be installed at the end of an existing bulk water pipeline, owned by the water utility Dominica Water and Sewerage Corporation. Generated electricity would be fed into the public grid. Although both the water utility and the electric utility have expressed their interest in the project, its implementation has not commenced.

The future outlook for hydropower development in

Dominica is positive. The available potential as well as the Government's commitment to renewable energy development encourages the exploration of new hydropower projects. Although no concrete plans have been produced for further hydropower projects, the CREDP-GIZ is elaborating a study on the small hydropower potential of the island.

In 2011 drilling works have started at three sites for the exploration of geothermal power in Dominica, aimed to export excess electricity to the French neighbouring islands of Guadeloupe and Martinique via submarine cables. This partly EU-financed project looks promising and could supply Dominica's base load if realized. This, on the one hand, limits the potential market for new hydropower investors in Dominica. On the other hand, the submarine cable opens many opportunities for the sale of electricity to the French territories – also from small hydropower.

Legislation on small hydropower

Regulations for the development of new small hydropower projects are very vague to non-existent. The Independent Regulatory Commission has not yet defined standard procedures for the development of new projects. Also, to date, no systematic regulation has been passed for the obligation to leave a minimum flow of water in the rivers when abstracting water for any purposes. However, all new projects will have to provide a comprehensive Environmental Impact Assessment, in which the minimum residual flow is one aspect to be analysed. Dominica's government is very conscious to maintaining environmental standards when developing infrastructure projects as ecotourism is one of the major sources of income.

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2.1.3 Dominican Republic

Lara Esser, International Center on Small Hydro Power

Key facts

Population	10,088,598[1]
Area	48,670 km[2]
Climate	Tropical maritime; little seasonal temperature variation[1]
Topography	Rugged highlands and mountains with fertile valleys interspersed (highest point: Pico Duarte, 3,175 m)
Rain pattern	December to April: 43-76 mm. May to November: 112-178 mm (maximum and minimum monthly rainfall averages)[2]

Electricity sector overview

As of 2009, the installed electricity generation capacity of the Dominican Republic was 2,993 MW.[3] The electrification rate of the country is 95.9 per cent. The installed generation capacity by fuel type can be seen in the figure below.

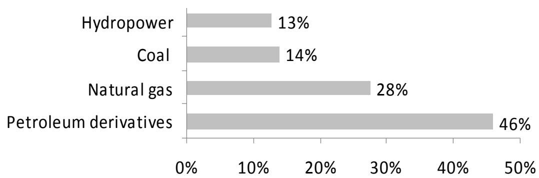

Figure 1 **Electricity generation in the Dominican Republic**
Source: Comisión Nacional de Energía[3]

Small hydropower sector overview and potential

In 2010, there were 26 small hydropower plants (< 5 MW) in the Dominican Republic, with a total capacity of 15.4 MW (figure 2).[4] No information on small hydropower potential in Dominican Republic is available so far.

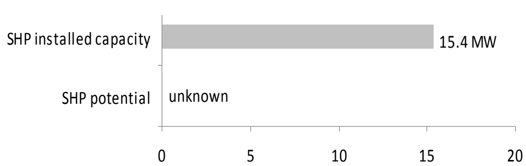

Figure 2 **Small hydropower capacities in the Dominican Republic**
Source: Comisión Nacional de Energía[4]

Renewable energy policy

In 2009, the Government started a four-year rural electrification programme with financial support from UNDP. The goals of this programme are:

- To promote nationwide access and use of renewable energy sources in marginal rural communities.
- To support community enterprise development based on sustainable use of renewable energy.
- To strengthen links between communities, local governments and government bodies in charge of the management of electricity.

This initiative is active in 55 rural communities located in mountainous areas, whose inhabitants live below the poverty line. It plans to install a total of 31 micro-hydro plants (5-150 kW) and one wind turbine that will generate an average availability of 200 Wh per household (in 10 per cent of the communities the average will be 600 Wh) with an estimated generation costs of between €0.02 and €0.035 per kWh. The programme also works on the integrated use of renewable sources (biofuels and solar energy). With regard to the micro-hydro systems, it will not be necessary to build dams. Pelton turbines are used in 90 per cent of cases, requiring a head of 90 metres. The remaining 10 per cent will be equipped with Francis or cross-flow turbines, due to limited head and water availability. More than nine micro-hydro plants have been built within the past two years, benefiting more than 4,000 families and 10 schools. In the end, more than 15,300 people will benefit and 665 kW micro-hydro plants will have been installed.

In 2007 a low-carbon policy was implemented by the Government, with the goal of establishing a 10-per cent renewable energy requirement by 2015 and a 25 per cent requirement by 2020.[5]

Legislation on small hydropower

Law No. 57-07 on Incentives for Development of Renewable Sources of Energy and its Special Regimes (Ley No. 57-07 sobre Incentivo al Desarrollo de Fuentes Renovables de Energía y de sus Regímenes Especiales) includes small (mini and micro) hydropower up to 5 MW, as well wind, photovoltaic, concentrated solar power (up to 120 MW per core); biomass, bio-fuels (bio-refineries and distilleries), ocean energy utilization (waves, currents, temperature differences in ocean water etc.). An exemption from all import taxes is granted on imports of equipment, machinery and necessary accessories for the production of energy from renewable sources (Paragraph II). Exemption from income tax for a period of 10 years from the beginning of its operations, and with maximum force until 2020, is also granted. According to Article 11, a reduction to a fixed 5 per cent on the tax over foreign financed interest payments is also foreseen (modifying Art. 306 of the Dominican Tax Code, for the beneficiaries of this new law).[6]

The General Law on Environment and Natural Resources (Law 64-00) regulates the environmental control of hydropower projects.[7]

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2.1.4 Grenada

Sven Homscheidt, Caribbean Renewable Energy Development Programme, St. Lucia

Key facts

Population	109,011[1]
Area	345 km[2]
Climate	Tropical; tempered by northeast trade winds[1]
Topography	Volcanic origin. Narrow coastal plains, mountains in the interior (highest point: Mount Saint Catherine, 840m)[1]
Rain pattern	Average annual precipitation: 1,500 mm. Dry season: December to May. Rainy (hurricane) season: June to November.

Electricity sector overview

Grenada has an electrification rate of around 95 per cent. The sole electricity utility is Grenada Electricity Services (GRENLEC), a vertically integrated monopolistic company with licence until 2073. By the end of 2011 the country's peak electricity demand of some 30 MW was satisfied mainly by diesel generators (installed capacity 33 MW) plus 300 kW distributed and mainly privately-owned photovoltaic (PV) systems (figure 1). Other renewables are currently not contributing to the energy mix. There are plans for Carriacou to build a diesel and wind hybrid system to power the island with studies on going.

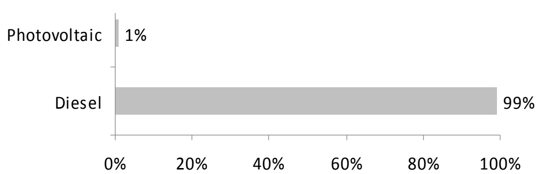

Figure 1 **Electricity generation in Grenada**
Source: Grenada Electricity Services[2]

Small hydropower sector overview and potential

In the past, sugar cane estates used hydropower to operate mills. However, today none of these power stations are in operation. Several studies exist in various depths about potential hydropower projects (figure 2). A hydropower potential analysis conducted in 1981 by the French firm SCET concluded that Grenada has a total potential of at least 7 MW. In 1984, a total of six potential hydropower projects were analysed in a pre-feasibility study at the three rivers: Great River, Marquis River and St. Mark's River. In 1991, the British consulting firm MRM Partnership confirmed the hydropower potential of the Great River Upper Basin, and in particular the 720 kW Birchgrove and the 380 kW Belvidere hydropower projects. To date, none of the projects have been realized.

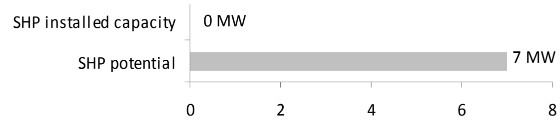

Figure 2 **Small hydropower capacities in Grenada**

Renewable energy policy

The Government of Grenada has passed a National Energy Policy in March 2011 that encourages the use of renewable energy sources and names geothermal energy as focus resource. Hydropower is not mentioned explicitly. Apart from the net-metering agreements applied for the in-total 300 kWp PV, no feed-in or other grid connection contract exists between GRENLEC and any independent power producer (IPP). However, GRENLEC and the Government of Grenada are currently in discussion about a net billing scheme for small IPPs. Currently, GRENLEC is also investigating options for wind power development and geothermal energy involvement.

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2.1.5 Guadeloupe

Lara Esser, International Center on Small Hydro Power

Key facts

Population	503,000
Area	1,710 km^2
Climate	Tropical
Topography	Basse-Terre island: mountainous (highest point Soufriere volcano, 1,467 m). Grande-Terre island: limestone, without much relief
Rain pattern	Mean annual precipitation: 1,730 mm. Dry season: December to May. Rainy (hurricane) season: June to November[1]

Electricity sector overview

The installed electricity generation capacity in Guadeloupe amounts to 490 MW, 382 MW of which are thermal power plants.[1] Figure 1 shows the different sources contributing to the electricity production.

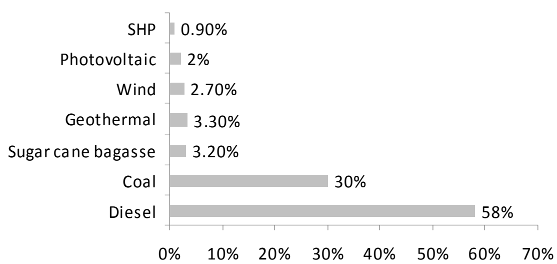

Figure 1 **Electricity generation in Guadeloupe**
Source: Électricité de France and Direction des Systèmes Energétiques Insulaires[2]

In the long-term, an Eastern Caribbean Gas Pipeline project has been proposed to stretch 970 km from north Tobago to St. Lucia, Dominica, Martinique and Guadeloupe.[3] There is also the idea to build a pipeline to import 100 MW of geothermal power from Dominica via submarine cables.[4]

Small hydropower sector overview and potential

In 2011, 14 small hydropower plants with a total capacity of 8.7 MW were in operation in Guadeloupe, with individual installed capacities ranging from 0.1 MW to 3.5 MW (figure 2). These contributed in 2010 to an electricity production of 15 GWh.[2]

Rivière du Galion, a 1.5-MW small hydropower project, should be completed by 2013. Another 3.5 MW small hydropower project might also be developed.[2]

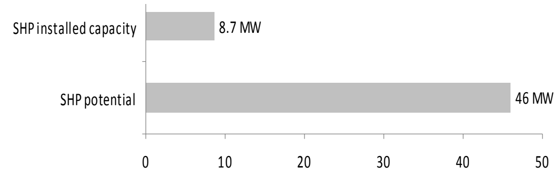

Figure 2 **Small hydropower capacities in Guadeloupe**
Source: EDF and Direction des Systèmes Energétiques Insulaires[2]

The small hydropower resource potential of Guadeloupe is estimated at 80 GWh per year, or an approximate 46 MW.[2]

Renewable energy policy

A ministerial decree, modified on 23 April 2008, fixed the rate of penetration of intermittent renewable energies at a rate of 30 per cent to preserve the stability of the system.[2] For the year 2020 the objective is to generate 50 per cent of the electricity from renewable energy sources, with geothermal and biomass (sugar cane bagasse) playing the main role.

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2.1.6 Haiti

Lara Esser, International Center on Small Hydro Power

Key facts

Population	9,801,664[1]
Area	27,750 km^2 [1]
Climate	Tropical; semiarid where mountains in east cut off trade winds[1]
Topography	Rough and mountainous (highest point Chaine de la Selle, 2,680 m)[1]
Rain pattern	Mean annual precipitation: 1,461 mm. The southern part of the country has two rainy seasons: March to early June, August to October. The central part has one rainy season: April to October. The northern part has one rainy season: September to June with a maximum peak in November to December.[2] Extreme phenomena such as droughts, severe storms or floods are not uncommon.

Electricity sector overview

Haiti has one of the highest population densities in the world. It is also one of the poorest countries in the Western Hemisphere. According to the *World Energy Outlook 2011*, the national electrification rate is 38.5 per cent (based on 2009 electricity access data), which means that 6.2 million people lack access to electricity.[3] However, a massive earthquake struck Haiti in January 2010 with the epicenter just south of the capital, Port-au Prince. This earthquake was assessed as the worst in this region over the last 200 years. National infrastructure was decimated by the earthquake and its recovery has proved so far to be a complex process. During the post-disaster, it is believed that the electrification rate has further fallen to a mere 12-per cent causing significant implications to Haiti's electricity sector. Hence, total installed capacity is estimated to have dropped from about 155 MW to 107 MW.[4]

Most of the information available was from the period prior to the 2010 earthquake. The State-owned utility Eléctricité d'Haïti (EDH) holds the monopoly for electricity generation, transmission and distribution, while the main authority of energy still remains the Ministry of Public Works, Transportation and Communications.[4 5] EDH grid consists of five isolated areas, of which the metropolitan including Port au Prince is by far the largest, with 80 per cent of total demand. Generation, transmission, and distribution facilities are old and need rehabilitation.[6] EDH owns and operates the only large 54 MW Peligre hydropower plant, which already needed refurbishment prior to the earthquake in 2010.[5] In 2011 Haiti received US$20 million to help improve the conditions of Peligre, from the Inter-American Development Bank, followed by donations of turbines in 2012 by French corporation Alstom for restoration of its small hydropower plant to full capacity.[4] Independent power producers provide electricity to EDH generated from an available capacity of 76 MW (diesel or fuel-oil generators).[5]

In 2006, existing grids mainly supplied power to the main cities such as Port au Prince and Jacmel, while rural energy supply in Haiti mainly consisted of woody biomass: wood and charcoal. In addition, there were a handful of isolated mini-grids being powered by diesel generators. However, diesel-based mini-grids are extremely costly in Haiti due to the high cost of diesel.[7]

After the earthquake, Haiti received a total of US$24 milion from various donors in order to develop renewable energy sources within the electricity sector.[4] An Action Plan for National Recovery and Development over an 18-month timescale included actions such as rebuilding basic infrastructure i.e. rainwater drainage, sanitation work, drinking water and the electricity network (see table for more details).[8]

Small hydropower sector overview and potential

To maximize the use of alternative energy sources and reduce fuelwood consumption, the United Nations helped with the construction of two pilot hydropower stations in the South Department.[10]

A feasibility study from 2006 showed that a 100-300 kW mini hydropower plant at the Dufour Plant site, would need 6 km of transmission lines and could supply electricity to nearly 1,000 households and three processing plants in the surrounding area.[7]

A 2010 Caribbean Regional Electricity Generation, Interconnection, and Fuels Supply Strategy Report mentions a minimum small hydropower potential of 50 MW on Haiti, however, it does not mention any source.[6] Thus in general, there is no verifiable information on the small hydropower potential available.

Renewable energy policy

The National Development Plan for the energy sector provides an overview of the energy sector in Haiti, as well as options for development for the period 2007-2032. The country's energy needs are met by about 80 per cent from local biomass and hydropower. The unsustainable use of biomass has led to tremendous deforestation, causing severe soil erosion. The remaining 20 per cent of energy demand is met by imported petroleum products, which consume more than 50 per cent of the country's import capacity and weigh heavily on the Haitian economy.[10] In the field of non-electrical energy, the plan includes the more efficient use of charcoal and firewood, as well as

Electrification priorities in Haiti

Improve technical and commercial efficiency	1.	Short term: Improve the management of the distribution network, including reducing illegal connections and improving network maintenance to reduce technical losses.
	2.	Short term: Review electricity generating costs to balance with different consumer's ability to pay
Improve the legal framework to support a financially viable sector	3.	Short term: Enable public-private partnerships in the energy sector and accelerate the ongoing efforts to modernize the business and investment sectors
Rehabilitate the existing electricity infrastructure	4.	Short term: Repair 8 substations
	5.	Short term: Restore electricity distribution networks (medium and low voltage) in Port-au Prince and other cities
	6.	Rehabilitate transmission lines
	7.	Restore the power plants at Peligre, Sault-Mathurin, Caracol-Nord, Onde Verte, Drouet, and Varreux
Build new capacity to increase access to electricity	8.	Expand power plant at Varreux
	9.	Build the Artibonite C-4 hydropower dam
	10.	Build additional power plants to meet requirements from economic development activity
	11.	Integrate the national transmission network
	12.	Set up various local medium and low voltage networks for the distribution of electrical energy in Port-au-Prince and other cities
	13.	Build Tabare substation

Source: United States Government (2011)[9]
Note: The priorities were set under the Government of Haiti's Action Plan.

alternative energy sources, the planting of forests for energy, conversion to diesel, biodiesel and LPG, financial support to producers of cellulosic briquettes, the promotion of renewable energies (wind, solar, biofuels) through the institutional strengthening and improvement of energy services to the poor.[11] In the electricity sector, efforts are concentrated on improving the service offered by EDH and to promote alternative energy sources to wood energy and renewable energy. Hydropower is not specifically mentioned.[11]

The Growth and Poverty Reduction Strategy Paper (2008-2010) (Document de Strategie Nationale pour la Croissance et pour la Reduction de la Pauvrete, DSNCRP), indicates that on a technical level, stress should be placed on the proven potential of hydropower, wind, solar and even thermal energy. Such opportunities should be seized, and could well result in a significant improvement in the overall situation. DSNCRP is addressing all these issues in a comprehensive manner by laying out a modulated strategy.[12]

Barriers to small hydropower

The country is subject to a broad range of natural threats of a hydrometeorological (hurricanes, droughts) or seismic (earthquakes, tsunamis) origin, and owing to the steepness of its topography, it suffers from particularly intense geodynamics which induce frequent flooding, landslides, and rock slides.[12] Reoccurring natural disasters divert the attention to other emergency issues, such as the food insecurity of 1.5 million people after Hurricane Sandy hit in October 2012.[13]

Other barriers that prevent the growth of the electricity sector (thus apply to the small hydropower sector) are based on the over subsidized EDH which is further burdened by structural constraints. Private sector financing for renewable energy projects is non-existent in Haiti, providing a deficiency of incentives for investors.[4]

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2.1.7 Jamaica

Lara Esser, International Center on Small Hydro Power

Key facts

Population	2,889,187[1]
Area	10,991 km[2]
Climate	Tropical; hot and humid. Temperate in the interior[1]
Topography	Mostly mountainous, with a narrow, discontinuous coastal plain (highest point Blue Mountain Peak: 2,256 m)[1]
Rain pattern	Mean annual precipitation: 1,895 mm. Two wet seasons: May to June and September to November (hurricane season)[2]

Electricity sector overview

Electricity generation in Jamaica is mainly based on heavy fuel oil and diesel generators (figure 1). The total installed capacity of the national electricity grid is 872 MW, which includes 24 MW (8 plants) of run-of-river small hydropower capacity and 38.7 MW of wind capacity.[3] The key player to develop the energy sector is the Jamaica Public Service Company (JPS), a private vertically integrated utility.[4] Jamaica's national electrification rate is estimated to be 92 per cent.

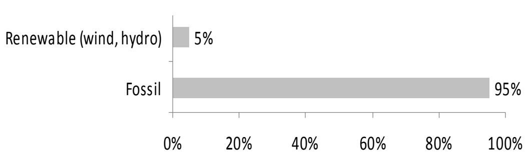

Figure 1 **Electricity generation in Jamaica**
Source: World Watch from Office of Utilities Regulation[5]

Small hydropower sector overview and potential

Due to its hilly terrain and tropical climate Jamaica has various rivers suitable for the development of hydropower. The Water Resources Authority actively monitors about 100 rivers across the island, with the significant number of rivers being on the eastern side where the annual rainfall is the highest.

The total small hydropower capacity of 24 MW (figure 2) is owned and operated by the national power company JPS and provides about 152 GWh per annum of base load electricity to the public grid.[6] Individual power capacities of the eight small hydropower plants in Jamaica range from 0.1 MW to 6.3 MW.

There are two major rain periods in the year. The dry seasons in-between that affect the supply of hydropower. Most of the existing small hydropower plants are fairly old, with the newest ones being commissioned more than 15 years ago.[7]

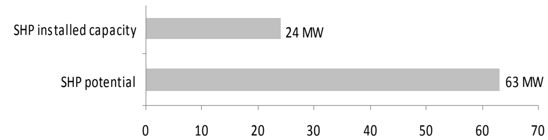

Figure 2 **Small hydropower capacities in Jamaica**

According to Loy and Covello, the total small hydropower potential for Jamaica has been estimated to be more than 63 MW.[7] Great River (8 MW), Back Rio Grande Valley (6 MW) and Laughlands Great (2 MW) small hydropower projects have an anticipated annual power generation of 82 GWh and a planned operating date of July 2014. Until now, the three projects have completed pre-feasibility studies with regard to technical, economic and environmental factors.

Between 2006 and 2010, a total sum of US$100 million was invested in wind and small hydropower projects, significantly aiding the growth of Jamaica's small hydropower sector.[4]

Renewable energy policy

The Ministry of Science, Technology, Energy and Mining in its National Energy Policy (NEP) 2009-2030 has identified fuel diversification and the development of the country's renewable energy sources as two of its main objectives. The request for renewable electrical energy and/or capacity from renewable sources is in line with the Government's vision of having 12.5 per cent electrical energy from renewable energy sources by 2015 according to NEP 2009-2030 and the draft National Renewable Energy Policy 2010-2030.[8]

The Government proposes in its Energy Policy a number of incentives to make investment in grid-connected electricity generation from renewable sources economically attractive. The Government has set a target that 15 per cent of the total generating capacity for the grid will be provided from renewable energy resources by the end of 2015. In addition, a premium of up to 15 per cent above the utility's avoided costs will be allowed for purchases of electricity generated from renewable sources.[9]

Renewable Premium: In order to encourage the development of renewable energy technologies, the Government has determined that renewable plants will be allowed to sell electricity to JPS at a maximum of 15 per cent above the avoided cost of energy.[9]

Legislation on small hydropower

Hydropower is considered both a conventional as well as a renewable technology. The upper limit at which capacity of conventional technology may be added to the grid without going through the competitive tendering process is 15 MW. Plants greater than 100 kW but less than 15 MW are considered medium additions; plants of 100 kW and less are small additions. Small additions of 100 kW and less will be made to the system by way of a Standard Offer Contract issued by JPS.[9] This has been reconfirmed under Condition 18 of the Amended and Restated All Island Electric Licence 2011.[10]

Barriers to small hydropower development

Currently the main hurdle to the development of new small hydropower projects in Jamaica is the need for easier access to information on potential sites, and a corresponding institutional framework and regulatory platform that facilitate and attract private investment. One of the objectives of the ESEE Project is to strengthen the regulatory framework, to improve the institutional capacity and to streamline access to information by private investors interested in small hydropower.

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2.1.8 Puerto Rico[i]

Agustín Irizarry-Rivera, Efraín O'Neill-Carrillo and Edy Jiménez-Toribio, Electrical and Computer Engineering Department, University of Puerto Rico Mayagüez

Key facts

Population	3,690,923[1]
Area	13,790 km^2 (land 8,870 km^2, water 4,920 km^2)[1]
Climate	Humid in the coastal lowlands in the North, semiarid in the lowlands in the South
Topography	Central mountain range from East to West, coastal lowlands (highest point: Cerro de Punta 1,338 m)[1]
Rain pattern	Mean annual precipitation: 1,270 mm Rainy season: May to December Hurricane season: June to November[2]

Electricity sector overview

The Puerto Rico Electric Power Authority (PREPA), a public corporation, is the operator of the only electric power system in Puerto Rico, it operates as a monopoly. During 2009-2010, the total generation of electricity in Puerto Rico was 22,558,967 MWh (figure 1). PREPA generated approximately 70 per cent of this electricity and purchased the remaining 30 per cent from two private generators: EcoEléctrica (liquid natural gas) and AES-Puerto Rico or AES-PR (coal).

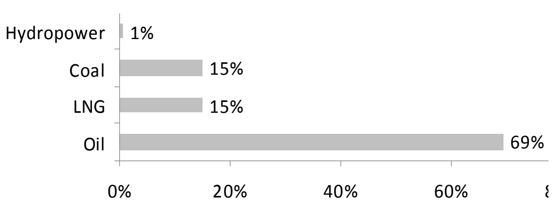

Figure 1 **Electricity generation in Puerto Rico**
Sources: Information collected by the authors and Puerto Rico Electric Power Authority[3]
Note: LNG = liquefied natural gas

The total dependable electricity generating capacity in Puerto Rico at the end of 2010 was 5,840 MW; 507 MW from Ecoeléctrica (liquid natural gas), 454 MW from AES-PR (coal) and 4,879 MW from PREPA (2,892 MW steam-electric capacity (#6 oil), 846 MW combustion-turbine capacity (#2 oil), 1,032 MW combined-cycle capacity, approximately 100 MW hydropower capacity and 9 MW diesel capacity).

In Puerto Rico, 21 hydro generating units, at 11 locations, are operated by the PREPA. These 21 units have an aggregate capacity of approximately 100 MW. In 2011, the hydropower generating units had an aggregate equivalent availability of 89 per cent and generated 149,794 MWh, which was approximately 13 per cent more than they generated during the previous year. The hydropower units had an annualized service factor of 19 per cent.

Small hydropower sector overview and potential

There are eight small hydropower plants in Puerto Rico, with an aggregated capacity of 41.8 MW. Table 1 below briefly describes these plants.

Table 1
Installed small hydropower capacity in Puerto Rico
(Megawatts)

Plant name	*Available capacity*	*Notes*
Toro Negro 1	8.64	3x 1.44 MW units, 1x 4.32 MW unit
Toro Negro 2	1.92	1 unit
Garzas 1	7.20	2x 3.6 MW units
Garzas 2	5.04	1 unit
Yauco 2	9.00	2x 4.5 MW units
Caonillas 2	3.60	1 unit
Río Blanco	5.00	2x 2.5 MW units
Patillas	1.40	1x 0.8 MW unit, 1x 0.6 MW unit
Total	**41.80**	**21 units**

Source: Puerto Rico Electric Power Authority[3]
Note: Only operational plants are listed.

The hydrology of small tropical islands differs from that of temperate continental areas. The precipitation in the Caribbean, the origin of all freshwater resources, is controlled principally by the easterly trade winds, the passage of tropical storms, and orographic effects[ii] in the islands with high relief. The geology, topography, and relative size of the islands determine the degree to which they collect and retain the rainfall that ultimately provides island water supplies.[4]

The water flow in a river is critically affected by annual precipitation in a particular zone. Puerto Rico has 224 rivers. The main rivers drain into the north and south areas. A hydrology analysis indicates that 67 per cent of the superficial drain is from the central mountain ranges to the northern coast (Aguadilla to Fajardo).[4]

The United States Geological Survey divides Puerto Rico into four hydrologic units (HU) as shown in figure 2. In our analysis we considered 44 rivers and define micro hydropower as not exceeding 100 kW in capacity. The U.S. Geological Survey data was analyzed to obtain the average discharge of each river in a period of time. The hydropower generation was determined by water flow and net head. A net head range from 3-120 metres was considered due to variations from river to river or from location to location in the same river.[5]

Table 2 shows our estimate of micro hydropower generation capacity per unit.

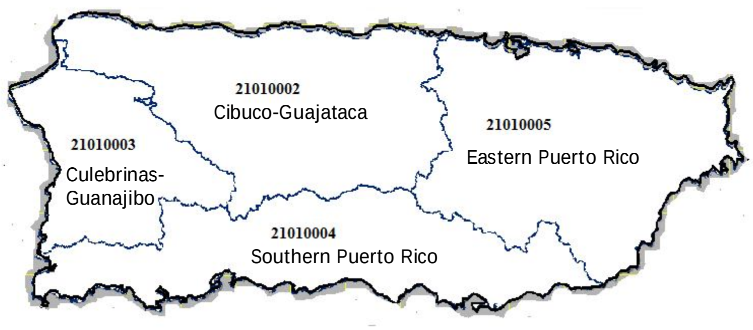

Figure 2 **Map of hydrological units in Puerto Rico**
Source: Adaquino, Zaida, Carlos Figueroa-Álamo and Senén Guzmán-Ríos[4]

Table 2
Estimated micro hydropower capacity in Puerto Rico
(Kilowatts)

Hydrologic Unit	*Available capacity*
21010002, Cibuco-Guajataca	1 067
21010003, Culebrinas-Guanajibo	101
21010004, Southern Puerto Rico	766
21010005, Eastern Puerto Rico	1 148
Total	**3 082**

Note that hydrologic units 21010002 and 21010005, corresponding to the north and draining approximately 67 per cent of superficial water, have the highest micro hydropower potential. The total micro hydropower potential of all hydrologic units is approximately 3.1 MW, a small amount since it is 3 per cent of the total installed hydropower capacity and less than 0.1 per cent of total installed capacity. This is the first methodological estimate of micro hydropower potential, and this is a conservative estimate for such potential for electric power generation in Puerto Rico (figure 3).

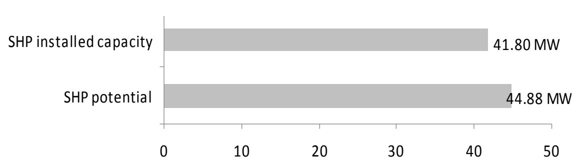

Figure 3 **Small hydropower capacities in Puerto Rico**
Source: Puerto Rico Electric Authority[3] and Caribbean Water Science Center[5]

Renewable energy policy

The first and only Energy Public Policy of Puerto Rico was created via an Executive Order of then Governor Roselló in 1993.[6] It stated that the existing 99 per cent dependence on imported oil was unacceptable as it created a severe economic vulnerability for the Island and proposed the development of alternative and renewable energy sources (excluding nuclear energy) and to foster a more efficient, less vulnerable and environmentally sustainable energy usage in Puerto Rico. The Energy Public Policy presented goals for 5-, 12- and 20-years and focused on electricity, solid waste disposal, transportation, construction, education, research and governmental energy consumption.[7]

The U.S. Energy Policy Acts (EPAct) of 2005 reinforced federal programmes on energy efficiency and renewable energy. It also mandated regulating authorities and unregulated utilities (such as the Puerto Rico Electric Power Authority) to consider distributed generation and adoption of IEEE standard 1547, and net metering. Those entities declining adoption of these measures had to provide valid reasons. It was through EPAct 2005 that PREPA acted and approved interconnection of distributed generation, and net metering by August 2008. PREPA defined restrictions that make distributed generation interconnection a cumbersome process. By the end of 2011, there were about 6 MW of distributed generation in Puerto Rico, most of it PV systems.[8]

Notes

i. This work is based in part on the final report of a project sponsored by the Puerto Rico Energy Affairs Administration under contract 2008-132009.
ii. The orographic is the effect caused by rainfall due to the forced or sudden lifting of an air mass over a mountain. This happens on the windward side of a mountain.

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2.1.9 Saint Lucia

Sven Homscheidt, Caribbean Renewable Energy Development Programme, St. Lucia

Key facts

Population	162,178[1]
Area	620 km[2]
Climate	Tropical maritime climate.
Topography	Interior: rugged and mountainous (highest point: Mount Gimmie 950 m). Coastal and river valleys[2]
Rain pattern	Mean annual precipitation: 1,500-3,700 mm depending on location and elevation. Rainy season: June to December[2]

Electricity sector overview

Saint Lucia's electrification rate is close to 100 per cent, achieved through one diesel power station with an installed capacity of 76 MW to satisfy the peak demand of about 60 MW (figure 1). Less than 10 photovoltaic systems add not more than 40 kWp of energy supply through net-metering arrangements with the public electricity utility Saint Lucia Electricity Services Ltd. (LUCELEC). The vertically fully integrated utility has an exclusive electricity generation licence until 2045.

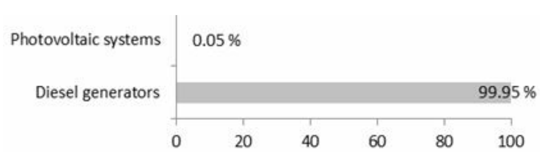

Figure 1 **Electricity generation in Saint Lucia**
Source: Information collected by author[3]

Small hydropower sector overview and potential

Throughout the country, remnants of old sugar cane mills can be found at those had been using hydro wheels for operation. Examples are the Balembouche Estate, the mill at the Stonefield Estate and Mondesir Estate. Currently, only one small Turgo hydropower plant of 240 W is operational, installed by the University of Vermont at the estates at Latille Falls, close to the Mondesir Estate. Another small hydropower plant in its vicinity is currently not operational. No other hydropower plants in operation exist today (figure 2).

In the country's north centre, there is a 30-metre high dam that was built for the drinking water supply north of Saint Lucia. A study done by the Caribbean Renewable Energy Development Programme (CREDP-GIZ) has identified potential for a 160-kW hydropower plant at the dam's toe which would use the spill water of the reservoir and the donation of ecologically required minimum flow. The project could be highly profitable due to low infrastructure costs. The Government-owned water utility WASCO, owner of the dam, has not yet picked up the project. Currently, the reservoir suffers also from excessive sedimentation, a problem that needs urgent attention.

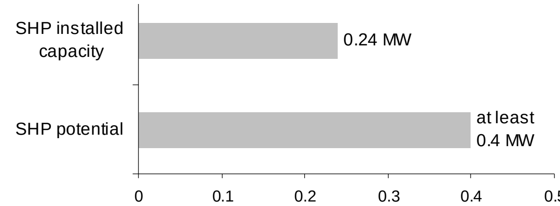

Figure 2 **Small hydropower capacities in Saint Lucia**

WASCO is currently investigating the construction of a further water supply dam in the island's south, and it was recommended to include a hydropower plant into the plans right from the project design.

CREDP-GIZ is currently systematically investigating St. Lucia's hydropower potential with a geographic information system (GIS) based tool which is still being developed. It is expected that, once hydropower potential is identified, the interest to develop it will rise.

Renewable energy policy

In 2010 Saint Lucia's Government passed its National Energy Policy to call for a greater renewable energy share in the energy mix and for the possibility of private and commercial users to feed-in electricity into the utility's grid. This policy, however, is not yet legally binding.

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2.1.10 Saint Vincent and the Grenadines

Sven Homscheidt, Caribbean Renewable Energy Development Programme, St. Lucia

Key facts

Population	103,537[1]
Area	389 km^2 (of these, the main island Saint Vincent has 345 km^2)[1]
Climate	Tropical climate. Little temperature variation throughout the year[1]
Topography	Volcanic, rugged and mountainous, (highest point: La Soufriere, 1,234 m)[1]
Rain pattern	Mean annual precipitation: 1,950 - 4,800 mm depending on location and elevation. Rainy season: May to November[1]

Electricity sector overview

The electrification rate of Saint Vincent and the Grenadines is around 95 per cent. The Government-owned electric utility Saint Vincent Electricity Services Limited (VINLEC) serves the main island and the Grenadines islands of Bequia, Canouan, Union Island and Mayrau. While Mustique's power supply is provided by the private operator of the island, VINLEC is a vertically integrated monopolistic energy utility with a licence until 2033.

VINLEC operates two diesel stations and five hydropower stations on its main island. The diesel capacity amounts to 41.9 MW in the two stations Canehall and Lowman's Bay. The total installed hydropower capacity in Saint Vincent amounts to 5.6 MW. Figure 1 shows the different sources contributing to the electricity production.

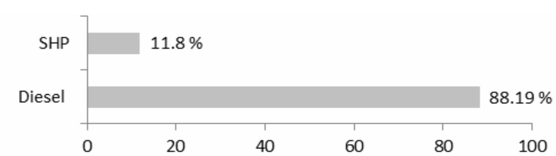

Figure 1 **Electricity generation in Saint Vincent and the Grenadines**
Source: Information collected by author[2]

Small hydropower sector overview and potential

All hydropower plants in St. Vincent and the Grenadines are run-of-river plants with heads around 50-160 metres and no significant storage capacity (see table).

Like in other Caribbean islands the use of hydropower for productive activities has begun with processing of agricultural produce, such as sugar cane, in mills driven by hydro wheels. Today, only the ruins of the old sugar mills can be found, such as the hydro wheel in Fitz-Huges close to the Richmond hydropower station.

Hydropower use for generation of electricity started in 1952 with the inauguration of the South Rivers hydropower plant that was built under the Colonial Development Corporation CDC and is now owned and operated by VINLEC. Today, about 13 per cent of Saint Vincent's electricity originates from hydropower.

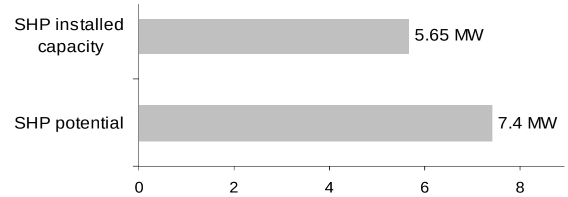

Figure 2 **Small hydropower capacities in Saint Vincent and the Grenadines**

VINLEC plans to upgrade the two oldest hydropower plants, South Rivers and Richmond, and to install new equipment with 1.1 MW and 1.6 MW capacity respectively, resulting in greater electricity output. Works were scheduled to begin in 2012 and will be carried out with VINLEC as project owner. A feasibility study conducted in 2009 has proven the feasibility of a 1 MW hydropower plant downstream of the South Rivers hydropower station. While VINLEC is considering this project, no decision has yet to be made. The above-mentioned projects represent an additional small hydropower potential of 1.73 MW.

There are new, but to date not quantified, hydropower potential in Saint Vincent main island (figure 2). One river to which considerations are given is the Wallibou River on the west side of Saint Vincent just north of the Richmond scheme. Since 2009, Saint Vincent possesses a hydrometric network managed by the hydrometric unit of the local water and sewage company, which systematically collects rainfall and stream flow data. This unit also manages the historical hydrometric data.

Installed small hydropower capacity in Saint Vincent and the Grenadines

Station	*Turbine type*	*Capacity (kW)*	*Year of installation*
South Rivers	3 x Turgo	2 x 275+1 x 320	1952 / 1959
Richmond	2 x Turgo	2 x 550	1962
Cumberland 1 (Grove)	1 x Francis	1 x 1,470	1987
Cumberland 2 (Spring Village)	2 x Francis	2 x 640	1987
Cumberland 3 (Cumberland)	2 x Francis	2 x 465	1987

Note: Only operational plants are listed.

Renewable energy policy

In February 2009 the Government of Saint Vincent and the Grenadines passed its National Energy Policy, which was later adapted into the National Energy Action Plan in April 2010. The policy calls for exploration of existing potential of renewable energy resources for electricity generation and for easier and fair access to the transmission/distribution grid, which will provide the basis for a stronger private sector involvement in electricity generation. To date, no legal right exists for private investors to sell their electricity. Thus far, only a few photovoltaic systems have been connected to the grid by private owners on a net-metering basis, and VINLEC has installed a 10-kWp PV system on their offices as a test and demonstration project.

The Energy Unit of Saint Vincent and the Grenadines is directly subordinated to the Prime Minister and is the prime contact point for all issues related to energy, such as requests from private investors in electricity projects. VINLEC currently investigates the installation of a wind park in Saint Vincent and some of the Grenadines islands and is looking to expand the photovoltaic share in the energy mix.

Legislation on small hydropower

Currently, there are no fixed rules or regulations for Environmental Impact Assessments (EIAs) of hydropower projects, the development control authority will define the scope of an EIA on demand, but it is expected that minimum residual flow requirements will be demanded for new projects. The people of Saint Vincent have a generally positive attitude towards hydropower and accept it as a reality that has been in the country for centuries.

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2.2 Central America

Jose Hermes Junior Landaverde, Ingendehsa, El Salvador

Introduction to the region

Central America comprises eight countries, namely Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and Mexico.

The climate in Central America varies from tropical to subtropical; in some countries it is temperate in the mountainous regions (e.g. Honduras).[1]

Table 1

Overview of countries in Central America

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Belize[abefg]	0.344	48	85.0	144	388	53	250
Costa Rica[abeg]	4.658	36	99.3	3 108	9 704	1 682	7 262
El Salvador[abeg]	6.000	36	86.4	1 312	5 763	472	2 079
Guatemala[abeg]	14.388	51	80.5	1 477	8 147	891	3 752
Honduras[abefg]	7.600	48	70.3	1 722	7 127	531	3 081
Mexico[abd]	113.423	23	97.7	61 155	291 544	11 542	35 796
Nicaragua[abeg]	5.788	43	72.1	895	3 781	105	326
Panama[abeg]	3.516	25	88.1	2 391	7 858	1 351	3 971
Total	**155 .717**	**-**	**-**	**72 204**	**334312**	**16 609**	**56 517**

Sources:

[a] Central Intelligence Agency[1]

[b] Organización Latinoamericana de Energía[2]

[c] International Energy Agency[3]

[d] Instituto Nacional de Estadística y Cartografía[4]

[e] World Bank[5]

[f] International Journal on Hydropower and Dams[6]

[g] Bloomberg New Energy Finance and Multilateral Investment Fund[7]

In order to better integrate the power market across the region and to benefit from economies of scale, the Central American Energy Electrical Interconnection System (SIEPAC) started a construction project in 2006 and it is expected to be completed by August 2014.[8] The SIEPAC network will connect six Central American countries (i.e. Panama, Costa Rica, Nicaragua, Honduras, El Salvador and Guatemala), increasing the capacity of power transfer in the regional market. It will enable the joint operation and development of the regional electricity market, ensuring the safety and quality of electricity supply so that any authorized agent may buy or sell electricity regardless of their geographical location. Globally, this project represents an investment of US$494 million and will link the whole Central America region, from Guatemala to Panama.[8] Some countries, such as Honduras, are net electricity importers.

A transmission line of 103-km at 400 kV linking Mexico and Guatemala started its commercial operation in 2010, increasing the reliability of electric supply, allowing energy transfers to the SIEPAC countries, and promoting investments in new electricity generating plants to serve the regional electric market. It has an initial capacity of 200 MW in the direction towards Guatemala and 70 MW towards the opposite direction. Mexico is connected to Belize with a transmission line of 65 MW capacity. To the North, Mexico has 11 interconnections with Texas and California (USA), with capacities ranging from 36-800 MW.[9]

The Energy and Environment Partnership with Central America (AEA) is an initiative that originated from the framework of the World Summit on Sustainable Development in Johannesburg in 2002. It aims to promote renewable energy in Central America and contribute to sustainable development and climate change mitigation. AEA is supported by the Ministry for Foreign Affairs of Finland, the Central American Integration System (SICA), the Central American Commission for Environment and Development (CCAD) and the Austrian Development Cooperation (ADC). Support is provided to governmental institutions, non-governmental organizations (NGOs) and the private sector for renewable energy projects.

Small hydropower definition

Definition of small hydropower is only available for some countries (table 2).

Table 2
Classification of small hydropower in Central America

Country	*Small (MW)*	*Mini (kW)*	*Micro (kW)*	*Pico (kW)*
Belize	..	..	..	..
Costa Rica	< 20	..	..	..
El Salvador	< 20	..	..	..
Guatemala	..	..	..	..
Honduras	..	..	..	..
Mexico	< 30	< 500	< 100	< 10
Nicaragua	..	..	..	..
Panama	< 10	..	..	..

Regional overview

Hydropower plays an important role in most Central American countries, contributing significantly to the countries' electricity production. The countries considered in this report use small hydropower, albeit to varying degrees. The known installed small hydropower capacity in Central America is 598.5 MW and the known small hydropower potential is 4,025 MW.

Table 3
Small hydropower up to 10 MW in Central America
(Megawatts)

Country	*Potential*	*Installed capacity*
Belize	51.3	7.3
Costa Rica	at least 91.1	91.1
El Salvador	113.9	15.2
Guatemala	at least 62.7	35.6
Honduras	385.0	54.1
Mexico	3 250.0	353.5
Nicaragua	40.0	2.9
Panama	122.3	38.8
Total	**4 116.3**	**598.5**

Sources: See country reports
Notes: El Salvador has a small hydropower potential (up to 20 MW) of 180.8 MW. The small hydropower potential of Mexico has been reported in different publications with a total value close to 3,250 MW, but this broad estimate is based on inferences from international statistics and not on a resource assessment.

Table 3 shows small hydropower potential estimates. Mexico has the largest potential for small hydropower in the region, but it has not been assessed nationwide. The outlook for small hydropower in the region seems positive. The governments take climate change mitigation seriously and encourage small hydropower. For example, in El Salvador, plans to develop renewable energy have been identified in a Master Plan (March 2012). Honduras has a revolving fund to help finance small hydropower plants up to 5 MW (installed capacity) since year 1999.[10] With regard to climate change, Costa Rica has an ambitious National Development Plan that aims to achieve carbon neutrality by 2021. It also aims to reach an electrification rate of 100 per cent using decentralized systems. However, there is limited private sector participation at the moment.[10]

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2.2.1 Belize

Lara Esser, International Center on Small Hydro Power

Key facts

Population	327,719[1]
Area	22,966 km[2]
Climate	Tropical, very hot and humid[1]
Topography	Mostly flat, with swampy coastal plains and low mountains in the South[1]
Rain pattern	Rainy season from May to November. Dry season from February to May. Hurricane season from June to November when coastal flooding, especially in the South, may occur[1]

Electricity sector overview

The Ministry of Energy, Science and Technology and Public Utilities is the main authority on energy in Belize, while the Belize Electricity Limited (BEL) is the main generator, distributor and transmitter of electricity in the country. BEL satisfies 58 per cent of the country's electricity needs.[2] The Canadian utility, Fortis, was the private owner of BEL until 2011 when the Belizean government re-nationalized BEL by expropriating 70 per cent of the Fortis shares.[2]

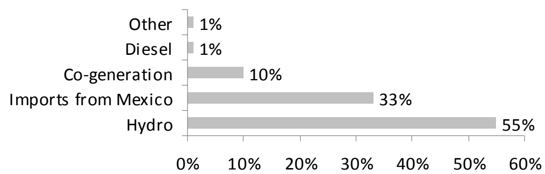


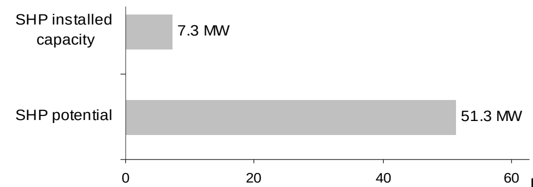
Figure 1 **Electricity generation in Belize**
Source: Belize Electricity Limited[3]
Note: Co-generation includes sugar cane, bagasse and heavy fuel oil.

BEL satisfies the country's peak demand of about 80.6 MW from multiple sources of energy (figure 1). Approximately 65 per cent of the energy distributed by BEL in 2010 was from renewable energy sources.[3] In Belize, 85 per cent of the total households have access to electricity. Electrification is close to 100 per cent in urban areas and almost 50 per cent in rural areas.[4]

Small hydropower sector overview and potential

Belize has no small hydropower definition, therefore information on its installed capacity vary. According to *Climatescope 2012*, small hydropower represents 13 per cent of the total installed capacity of 136 MW, making small hydropower a crucial player in Belize's energy mix.[2] It reported a total small hydropower capacity of 53 MW, of which 22 MW had been commissioned between 2006-2011.[2] The 53 MW has included power plants of up to 25 MW.

Hydro Maya operates small hydropower plants with an annual generation of 7.7 GWh.[5] Belize's estimated small hydro potential is 37.6 GWh per year.[5] The installed capacity of small hydropower up to 10 MW is 7.3 MW (figure 2).



Fig

Figure 2 **Small hydropower capacities in Belize**
Source: International Journal on Hydropower and Dams[5]

Renewable energy policy

The principles of sustainable development are embodied in Belize's national development plan called Horizon 2030. One of the strategic priorities of Horizon 2030 is the promotion of green energy and energy efficiency and conservation, including the creation of an institutional framework for producing a viable energy policy. In February 2012, the Government of Belize endorsed the National Energy Policy and Planning Framework.[6]

The Belize National Sustainable Energy Strategy 2012-2033 aims to institutionalize a countrywide infrastructure to collect data and assess the potential for converting solar, wind and hydro to electricity, in order to identify feasible sites for development. One of its goals, Goal 5, is to increase hydropower up to 70 MW by 2033. It suggests for the revision of in the technical assessments of hydropower resource capacity to identify new sources, to determine the potential and to develop expansion plans.[6]

Belize is a founding member of the Small Island Developing States Sustainable Energy Initiative (SIDS DOCK) that was established in 2009. The initiative is committed to the collective goal of increasing energy efficiency by 25 per cent (2005 baseline), to generate a minimum of 50 per cent of electric power from renewable sources and to a 20-30 per cent decrease in conventional transportation fuel use by 2033.[6]

Barriers to small hydropower development

Renewable energy investment barriers of Belize include the nationalization of the previously vertically integrated BEL. Additionally, political instability that coupled with high sovereign debts of up to 13 per cent and a lack of policy frameworks could further hinder the interest of potential investors.[2]

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2.2.2 Costa Rica

Marcello Hernández and José Pablo Rojas, CEGESTI;
Carlos González, HIDROTECNIA Consultores, Costa Rica

Key facts

Population	4,636,348[1]
Area	51,100 km[2]
Climate	Tropical and sub-tropical[1]
Topography	Mostly flat, with swampy coastal plains and low mountains in the South. Highest point: Cerro Chiripo, 3,810 m[1]
Rain pattern	Rainy season from May to November. Dry season from February to May. Hurricane season from June to November when coastal flooding, especially in the South, may occur.[1]

Electricity sector overview

Costa Rica has almost a complete national rate of electrification: in 2010 it was 99.2 per cent. Approximately 93 per cent of the electricity is obtained from renewable sources, only seven per cent from thermal sources (figure 1).

The Costa Rican Institute of Electricity (Instituto Costarricense de Electricidad, ICE) has acted as a monopoly in the electricity generation sector of the country since its inception in 1949. Subsequently, other public-sector generators and some company-type rural electrification cooperatives were created, which have begun to develop small electricity generation projects.

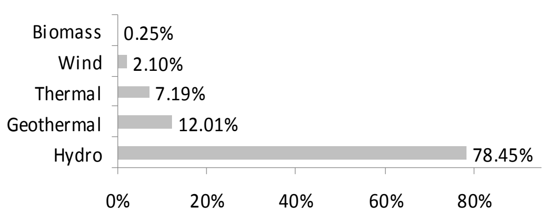

Figure 1 **Electricity generation in Costa Rica**
Source: Grupo Instituto Costarricense de Electricidad[2]

Small hydropower sector overview and potential

As of 2009, the combined capacity of the 18 publicly-owned and the 16 privately-owned small hydropower plants totalled to 91.1 MW, with individual installed capacities ranging from 60 kW to 10.5 MW (figure 2).[2]

According to a study by the Public Services Regulatory Authority (Autoridad Reguladora de los Servicios Públicos, ARESEP), Costa Rica has a hydropower potential of 4,963 MW, which suggests the possibility of reaching quadruple hydropower generation in the country.[3] Yet, the specific small hydro potential has not been identified.

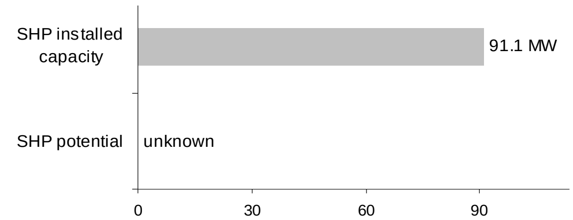

Figure 2 **Small hydropower capacities in Costa Rica**

In Costa Rica, the small hydropower value chain is well developed. [4] On top of that, Clean Development Mechanism projects implemented in the country also include small hydropower projects.

Renewable energy policy

In 1990, Act 7200 was enacted, allowing private-sector participation in electricity generation from renewable energy sources. This law had limited private participation (up to 15 per cent) in the national electric power system and after an amendment by Act 7508, the private-sector participation project limit was raised from 20 MW to up to 50 MW under the Build, Operate, and Transfer (BOT) modality, which must be executed through tenders by ICE. Importantly, under this law, all projects must use renewable energy.

The National Development Plan (Plan Nacional de Desarrollo, PND) 2011-2014 has established the goal to produce 95 per cent of Costa Rica's electricity from renewable energy sources within its priority goals.[5] Hydropower is the main renewable source due to its resource abundance and the vision of the national leaders in the 1950s that recognized the environmental and competitive advantage of having a clean energy mix. The National Development Plan also promotes carbon neutrality, the use of clean energies and generally, the rational use of resources. The goal is to install 334 MW of clean energy with both public and private efforts.

Costa Rica challenges itself by aiming to be carbon-neutral by, the bicentenary of its independence, thus the continuity of policies and actions favouring renewables in the country is essential.

Under the National Rural Electrification Programme with Renewable Resources, ICE has sought to reduce emissions of greenhouse gases, encouraging the use of decentralized renewable energy systems in areas that are isolated from the National Interconnected System. This would enable a nearly 100 per cent electrification rate, while achieving a reduction of more than 210,000 tons of CO_2.[5 6]

Despite the Government's effort to have an electricity mix based on renewable energies, it is clear that the growing electricity demand and the climate variability scenarios bring several uncertainties. The private sector and rural communities will be essential partners in supporting clean power generation.

The Ministry of the Environment, Energy and Technology (MINAET) is the state entity of the country's energy planning by the Energy Sector Management Directorate (DSE) and one of the basic objectives is to diversify the energy mix through the use of renewable energies available at a commercial level.

In various documents such as the National Energy Plan (PNE) from 2008 to 2021, one of the strategic objectives is to promote the use of renewable and indigenous energy for electricity generation. Article 1 of Guideline 14 by MINAET, states that “the institutions of Electricity Sub sector should encourage the development of electricity generation systems on a small scale for personal consumption, using renewable energy sources like solar, wind, biomass and small-scale hydropower...".

Article 2 of Guideline 15 requires "ICE to submit to the Sub-Rector of Energy, within two months, a plan for implementing power generation projects of limited capacity ...”. This objective is reinforced by the General Electricity Law, currently presented by the Executive to the Legislature by the record 17.812, where priority is given to energy planning of the national renewable energy sources and a retail market with renewable projects that are not exceeding 2 MW. Costa Rica offers net-metering and tax-based incentives for renewable energies such as tax relief, thus further encouraging the implementation and growth of the already strong renewable contribution to the energy mix.[7]

Legislation on small hydropower

The Constitution and Water Law are the legislative basis for everything related to private generation of electricity and water resource concessions.

Barriers to small hydropower development

Barriers to small hydropower in Costa Rica are common to barriers encountered by other renewable energy sources. Private developers of electricity generation projects must go through a number of administrative procedures in order to fulfil several documentation requirements of pre-feasibility and feasibility, in addition to obtaining resource use and building permits, and to conclude power purchase agreements, making ICE the only possible buyer. The institutional complexity involved in meeting the above-mentioned requirements creates great barriers to the private sector.

All hydropower projects, small or large scale, are considered to have potentially high environmental impact and therefore require a full environmental impact study, which is the most complex of the currently existing requirements.

Another problem relates to the establishment of rates for Feed-in Tariffs. At present the country lacks accurate methods to set the same, considering the various sources of energy. Costs, rules and tariffs were established in 2002, and stipulated specifically for hydropower plants. Therefore, any technology must adjust to this reality. Both private developers and the different government authorities seem to be aware of this situation, but have still not reached a consensus on how best to fix it.

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2.2.3 El Salvador

Jose Hermes Landaverde Jr., Ingendhesa, El Salvador

Key facts

Population	6,090,646[1]
Area	21,041km[2]
Climate	Tropical on coast; temperate in uplands[1]
Topography	Mostly mountains with narrow coastal belt and central plateau (highest point: Cerro El Pital 2,730 m).[1]
Rain pattern	Rainy season: May to October. Dry season: November to April.

Electricity sector overview

The national electrification rate of El Salvador is 86.4 per cent. Hydropower is produced mostly by the public utility Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL). The rest of the electricity generation is generated by private operators.

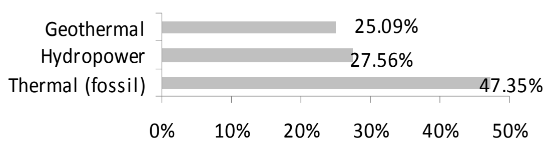

Figure 1 **Electricity generation in El Salvador**
Source: Comisión Económica para Latinoamérica y el Caribe[2]

The main authority on energy is the National Energy Council (CNE). The Transmission Company of El Salvador, SA de CV (ETESAL) is responsible for the maintenance and expansion of the national transmission system, including interconnection lines with Guatemala and Honduras.[3]

Small hydropower sector overview and potential

The small hydropower definition in El Salvador is 20 MW of maximum installed capacity. As of 2011, the combined capacity of the 17 small hydropower plants in operation was 36 MW, with individual installed capacities ranging from 5 kW to 19.8 MW (figure 2).[4]

Several hydropower (large and small) potential, pre-feasibility, feasibility and rehabilitation studies have been conducted between 1988 and 2011, by different national entities.[4] [5] [6] [7] These studies identify86 potential sites for small hydropower projects, with a potential (capacity less than 20 MW) of 158 MW. It is expected that these projects will be developed by private investments.

More recently, the potential to develop hydropower projects has been identified by the Government with technical assistance from Japan International Cooperation Agency in a Master Plan (March 2012). As a result, 209 sites were identified and evaluated in terms of energy and financial indicators, with individual capacity ranging from 3 kW to 17 MW, for a total estimated capacity of 180.8 MW and a potential energy annual generation of 756 GWh.[8]

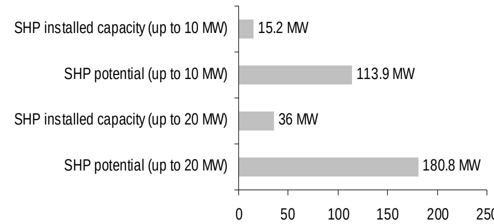

Figure 2 **Small hydropower capacities in El Salvador**
Source: Japan International Cooperation Agency and Comisión Nacional de Energía[8]

Renewable energy policy

The current renewable energy policy framework is mainly dependent on tax incentives to promote existing renewable energy generation (Legislative Decree 462-2007, OJ 238, Volume 377, and Issue 2007). The Fiscal Incentives Act for the Development of Renewable Energy grants an exemption for the first 10 years on the payment of import duties on machinery and equipment necessary for the development of these power generation projects, plus an exemption on income tax for a period of 5 or 10 years depending on the size of the project, which benefits units up to 20 MW. Further, a total exemption from all income tax derived directly from the sale of the certified emission reductions (CERs) under the Clean Development Mechanism (CDM) or similar carbon markets.[3]

Legislation on small hydropower

If the length of the proposed canal water for hydropower is considerable, the maintenance of the river flow (ecological flow) must be considered. Usually, a required minimum flow for the river ecology is 10 per cent of the annual average over the year. There is no regulation or law controlling or regulating the condition of minimum flow The Ministerio de Medio Ambiente y Recursos Naturales (MARN) is currently working on this issue.[4]

Barriers to small hydropower development

The barriers to the development of small hydropower in El Salvador at present are as follows:

- Lack of governmental subsidies or grants for the study or development of small hydropower;
- Lack of hydrological data (limited number of hydrological stations (the observed periods are short at some stations);
- High cost of hydrological data from the National Service of Territorial Studies;
- Out-of-date nationwide hydropower potential information, obtained from a survey conducted in

1989 by the CEL and Universidad Centroamericana 'José Simeón Cañas';

- Limited human resource for small hydropower planning capacities available in the country;
- High administrative barriers: long lead time to obtain the required permits from the Environment and Natural Resources Ministry and the General Superintendency of Electricity and Telecommunications (SIGET), and to obtain grid connection authorization. Also, permitting procedures are complex;
- Lack of incentives for purchase of power generated from renewable energy sources.

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2.2.4 Guatemala

Lina Saldarriaga, Pan American Hydro, United States of America

Key facts

Population	14,099,032[1]
Area	108,889 km^2
Climate	Tropical; hot, humid in lowlands; cooler in highlands[1]
Topography	Mostly mountains with narrow coastal plains and rolling limestone plateau (highest point: Volcán Tajamulco, 4,211 m)[1]
Rain pattern	Average annual rainfall varies between 900 mm and 3,000 mm, depending on the region.[2] Rainy season from May to November

Electricity sector overview

The electricity generation capacity (2011) was 2,510 MW. Hydropower currently provides 50 per cent of Guatemala's electricity generation (figure 1), and its share is expected to grow significantly in the next decade. Nineteen large and small hydropower plants are in operation with a total installed capacity of 891 MW.[3]

Due to the steady growth of energy demand of nearly five per cent per year, Guatemala foresees the need to add an additional 2,000 MW to its current 2,510 MW capacity (2011). Poor grid infrastructure results in transmission and distribution losses of approximately five per cent of the electricity generation.[4]

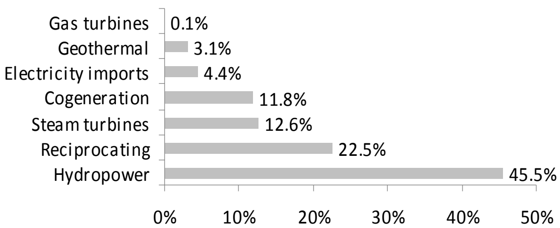

Figure 1 **Electricity generation in Guatemala**
Source: Administrador del Mercado Mayorista Guatemala [4]

The Sistema de Interconexión Eléctrica de los Países de América Central (SIEPAC, or Central American Electrical Interconnection System) line, which is scheduled to be completed by 2014, will aid in the consolidation of the Regional Electrical Market (MER) and increase the security of supply. This is likely to reduce electricity and transmission costs in general throughout Central America, by facilitating a shift towards renewable resources. This will also allow for the convergence of supply and demand of energy throughout the area. The Mexico-Guatemala interconnection line has allowed energy imports from Mexico since early 2010.

In 1996 the General Law of Electricity was enacted, establishing the freedom to produce electricity. The law allows free production, as well as private transportation and distribution of electricity, without authorization from the state. Authorization is required only if the use of goods from public domain is involved. The prices for the use of electrical services are subject to authorization as well. The transfer of energy between generators, traders, importers and exporters, which result from the operation of a wholesale market, are subject to the terms and conditions of the law.

Small hydropower sector overview and potential

Guatemala possesses a technically usable hydropower potential of about 5,000 MW, of which 13.5 per cent is currently being utilized. The specific small hydropower potential has not been identified. However, six small hydropower plants are under construction in Guatemala totalling 35.6 MW, with individual installed capacities ranging from 2 MW to 10 MW.

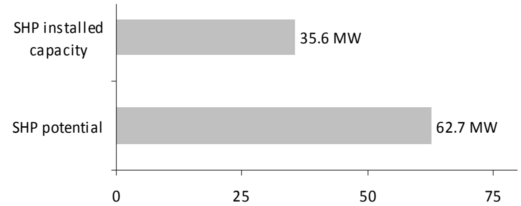

Figure 2 **Small hydropower capacities in Guatemala**

Two additional sites are in the pipeline, with individual installed capacities of 7 MW and 10 MW, having received authorization and included in Guatemala's Energy Expansion Plan 2010-2015.[5] Hidro Izabal (10 MW) is a third small hydropower site in the pipeline, which, despite being included in the Energy Expansion Plan 2008-2022, has neither received authorization nor has started construction yet (operation was planned to commence in 2012). Once these projects are finalized, Guatemala will have an installed small hydropower capacity of 62.6 MW (figure 3).

The small hydro value chain is significantly developed offering investors services in civil works, engineering, operations and maintenance, power purchase and matters concerning turbines.[6]

Renewable energy policy

In November 2003, the Guatemalan Government decreed the law 52-2003 Incentive Law for Renewable Energy Projects Development for establishment of fiscal, financial and administrative incentive measures. It declares the urgent need to ensure rational development of renewable energies, instructing the Ministry of Energy and Mines to harness these resources and award incentives (exemptions from customs tariff and value-added tax during the construction stage, and income tax during the first 10 years of commercial operation). In addition, with the purpose of promoting renewable resources, the Government has created the Information and Promotion of Renewable Resources Centre and the programme of Energy Project Promotion. For example, the individuals or enterprises engaged in renewable energy projects development enjoy tax relief on imports including value-added tax, relief on rental tax and commercial enterprises tax within 10 years from turnover.[7]

Legislation on small hydropower

With regard to the typical small hydropower licensing process in Guatemala, the first step, once the pre-feasibility study is ready (including plant layout, construction and production estimates), is to claim the temporary water rights at the Ministry of Mines and Energy. Next, the feasibility study must be concluded, including detailed hydrology and geology assessments, and design and construction cost estimates. Thereafter the environmental impact study must be carried out, and if approved by the Ministry of Environment, the grid connection study will follow.

If a project proposal is approved by the National Electrical Energy Commission, the procedure to follow depends on the project capacity. For projects with capacities up to 5 MW, water rights staking process consists of registering the project at the Ministry of Energy and Mines. For projects with capacity higher than 5 MW, a 50-year water rights claim must be submitted to the Ministry of Energy and Mines.

The next and final step, before construction and commission can begin, is the safety study required for all projects with a dam, which must be approved by the National Electrical Energy Commission.

Barriers to small hydropower development

Small hydropower development in Guatemala is strongly hindered by social-institutional barriers, comprising land rights issues between local communities and private developers in natural resource management. Inadequate benefit sharing mechanisms coupled with limited conflict resolution mechanisms have created a significant barrier for small hydropower development.[8] [9]

In addition, Guatemala currently portrays the second lowest Human Development Index (HDI) in Central and Southern America. The need for rural electrification is thus clear.[10] However, rural electrification is stalled due to ethnic disparities and poverty, which in turn provide a lack of incentive for private investors who are unable to justify high energy investments within communities with low energy demand and income, thus creating a financial and market barrier to small hydropower development.[8]

Small hydropower development is further faced with investment barriers, as domestic financing is difficult to obtain due to Guatemala's high interest rates and short loan terms. International finance is also difficult to obtain.[11]

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2.2.5 Honduras

Lara Esser and Laxmi Aggarwal, International Center on Small Hydro Power

Key facts

Population	8,296,693[1]
Area	112,090 km[2]
Climate	Subtropical in the lowlands and temperate in the mountain areas[1]
Topography	Mostly mountains in interior; narrow coastal plains. Highest point: Cerro las Minas, 2,870 m[1]
Rain pattern	Average annual rainfall: 1,470 mm. Rainy season from May to November, with regional variations.[2] Hurricanes and floods are common along the Caribbean coast

Electricity sector overview

The national (government-owned) electric power company, Empresa Nacional de Energia Electrica (ENEE) is in charge of generation, transmission and distribution of electric energy, in accordance with Article 9 of the Law (Ley Marco del Sub sector Eléctrico and Article 13 of the corresponding Bylaw) and the Expansion Plan 2008-2022. Forty six per cent of electricity is generated from hydropower (figure 1).

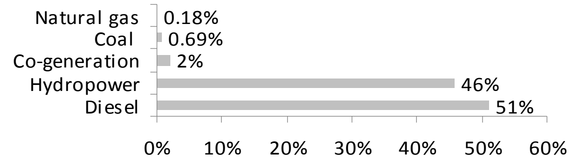

Figure 1 **Electricity generation in Honduras**
Source: Climate Investment Fund[3]

Grid coverage jumped from 39.1 per cent in 1990 to 81.3 per cent in 2010, making it close to 100 per cent in urban areas and 63.4 per cent in rural areas. However, the remaining 26.6 per cent of rural households still have no access to basic electricity services because they are scattered in low-density areas and it is expensive to connect them to the grid.[3]

Small hydropower sector overview and potential

There are 14 small hydropower plants in operation with a total capacity of 54.1 MW (figure 2). Seven new plants are in the initial phase of planning (with a total capacity of 12.5 MW) and another 26 are at bidding stage (with a total capacity of 84.4 MW). Therefore, once all of these investments are commissioned, the total small hydropower capacity in Honduras will be 92.6 MW.[4] The Scaling-up Renewable Energy Programme in Low-Income countries (SREP) Investment Report mentions that there are only 11 privately-owned small hydropower plants with a total capacity of 37 MW. The SREP Investment Plan for Honduras reports that small hydropower potential accounts for approximately 385 MW.[3]

Table 1
Small hydropower projects under the Clean Development Mechanism in Honduras

Name	*Installed capacity (MW)*	*Generation (GWh/year)*	*Type*	*Remarks*
Rio Blanco	5.00	32.00	Run-of river	Operating since 2004, CDM registered in January 2005
Cececapa	2.86	14.90	Run-of river	Provides electricity to local grid. Operating since 2005
Yojoa	0.63	2.99	Run-of river	Electricity to local village. Operating since September 2005
Zacapa	0.52	2.76		Electricity to local grid. March 2006

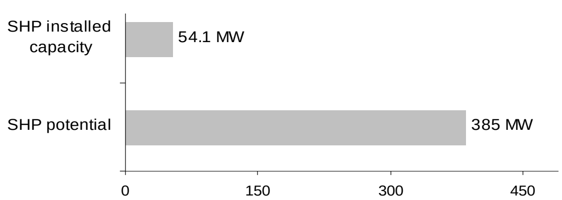

Figure 2 **Small hydropower capacities in Honduras**
Sources: Climate Investment Fund[3], *International Journal on Hydropower and Dams*[4]

Between 2010 and 2011, Honduras experienced peak clean energy investments of US$468.5 million, dedicated mainly to small hydropower (defined as up to 50 MW) and wind generation.[5] In addition to high levels of investment, small hydropower also had the chance to benefit from the first renewable energy tender, conducted in 2010, and consisted of 20 to 30 years of contracts for 250 MW capacity relating to small hydropower, biomass and geothermal generation.[5]

Renewable energy policy

The 1998 Legal Framework and Reforms of the Energy Sector Law and its Incentives Law for Renewable Energy Generation have provided incentives for the development of renewable energy coupled with Decrees No. 85-89 and No. 267-98. It promotes implementation of renewable energy plants via mechanisms such as tax breaks or tariffs equivalent to short-term marginal costs experienced by the system.[6]

In 2007, the Honduran Government issued Decree No.70-2007 (the Law to Promoting Electricity Generation by Renewable Resources), implementing a preferential tax policy and a preferential sales policy for natural and juridical persons who develop and operate renewable energy projects according to the Act 81 of the Environment General Law.[7] It grants additional benefits such as tax exemptions in the forms of import duty and income tax, and improvements in Power Purchase Agreements (PPAs) signed with ENEE to operators who generate electricity from renewable resources,.[3]

In 2010, ENEE held a public bidding process for the first time, allowing bidders to purchase electricity from renewable energy sources. Honduras was one of the six Latin American countries to do so.[3] Forty-eight projects were awarded PPAs for a total of 108 MW of renewable energy and an estimated investment of about US$2.5 billion.[8] With all these initiatives, the Government of Honduras intends to reverse the structure of the electricity sector by 2022 to a ratio of 60 per cent renewable and 40 per cent fossil fuel, thus complying with the provisions of the Country Vision and National Plan Law constituted into State Policy by Decree No. 286-2009.[3]

Legislation on small hydropower

Following the energy crisis of 1994, the Government of Honduras negotiated with the European Commission (EC) in order to promote electricity generation from renewable sources and to encourage energy conservation. In January 1996, a financing agreement was established between the EC and the national electricity utility ENEE. After an initial two-year project, the EC donated €250,000 to create a revolving fund called Fondo de Preinversión Hidroeléctrica that grants loans to the private sector. Since 1999, this ENEE Pre-investment Fund has helped finance feasibility studies for small hydropower plants of installed capacity up to 5 MW.[9]

Barriers to small hydropower development

The equity capacity by private investors in Honduras is concentrated in the larger, fossil-fuel-fired energy projects. It is not common for domestic commercial banks to provide equity to renewable energy projects. Market research indicates that given sound fundamentals (technical viability of project, good contracts, positive and adequate technical studies, competent sponsors) and a resulting reasonably low risk expectation, there are abundant international equity investors and sovereign investors that would be interested in providing equity to renewable energy projects in Honduras.[3]

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2.2.6 Mexico

Bajo en Carbono Team, Mexico

Key facts

Population	116,901,761[1]
Area	1,964,375 km^2, of which 1,959,248 km^2 is continental and the rest is islands
Climate	Varies from tropical to desert[2]
Topography	High, rugged mountains; low coastal plains; high plateaus; desert. Highest point: Volcan Pico de Orizaba 5,700 m
Rain pattern	Average annual rainfall varies depending on the region between 50 mm in the North West and 4,000 mm in the South East, with a national average of 780 mm. The rainy season from May to October accumulates 83 per cent of the annual rainfall.[3]

Electricity sector overview

The total installed electricity generation capacity in Mexico is 61.155 GW, of which 52.974 GW belongs to the Public Service by Comision Federal de Electricidad (CFE), including the capacity of independent power producers (IPP) who sell energy exclusively to CFE under long-term contracts; and 8.181 MW belong to private or other public generators, under the figures of Self Supply and Cogeneration.[4 5]

The installed capacity of the 30 large hydropower plants amounts to 11.254 GW, and that of small hydropower to 0.453 GW.[6] The share of hydropower in the total installed capacity is 19.1 per cent and the share of small hydropower is 0.7 per cent.

The total annual gross electricity generation in 2012 was 265.434 TWh.[4] Fossil fuels in various forms (coal, steam/gas, internal combustion, combined cycle) and nuclear power accounted for approximately 86 per cent. The total generation from renewable sources is 14 per cent. It is expected that the demand of electricity will grow 3.6-per cent each year over the next 15 years.

In 2010, 97.7 per cent of the population had access to electricity, with 98.9 per cent coverage in urban and 93.5 per cent in rural areas.[7] Most of the population had no access to the grid. The main barriers to rural electrification are difficulty of grid access to dispersed populations over a large area due to the country's rugged terrain and limited infrastructure. Renewable energy, not necessarily connected to the grid, is the most extensively explored source by most of Mexico's isolated communities, where small hydropower has significant untapped potential.

The framework of the Programme of Rural Electrification and of Popular Colonies has allowed more than one thousand localities to be connected to the grid by 2012. With the implementation of this programme, all localities with more than 100 inhabitants will be included in the statistics for rural electrification rate.[8]

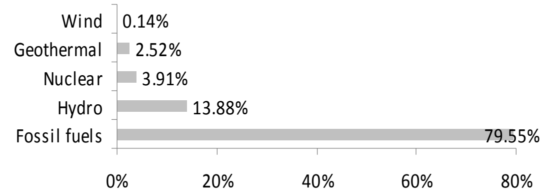

Figure 1 **Electricity generation in Mexico**
Source: Secretaría de Energía[9]
Note: Data from 2010.

Small hydropower sector overview and potential

In Mexico, a hydropower generation facility is considered eligible for regulatory and other incentives aimed at renewable energy projects when its capacity is lower than 30 MW.[11] There are two exceptions to this upper limit rule:

- When the small hydropower plant has a reservoir with volume of up to 50,000 m^3, or it occupies less than one hectare;
- When the small hydropower plant is developed in an existing reservoir, even with larger volume, that can be equipped to generate electricity.

Even though the participation of private investors in energy generation has been allowed by legislation since 1992, there are very few small hydropower projects in operation and the installed capacity is still incipient. In December 2012, the Energy Regulatory Commission (CRE) issued 36 permits to private generators for small hydropower plants with a total capacity of 466.8 MW; out of which 17 plants of 152.0 MW are in operation, 16 plants with 289.3 MW are under construction, and 3 plants with 25.2 MW are inactive. The total estimated annual generation of the 36 small hydropower private plants will be 2,325 GWh, of which 802 correspond to the 17 plants in operation.[5] The average plant factor that makes these small hydropower projects feasible is 57 per cent.

CFE has 42 small hydropower plants of up to 30 MW in operation with a total installed capacity of 301 MW.[6] In addition, it is currently planning nine projects of up to 30 MW with a total capacity of 172 MW. The total capacity of public and private small hydropower plants in operation is 453 MW (for plants up to 30 MW) (figure 2).

In 1995 the National Energy Saving Commission (CONAE, now CONUEE) estimated the small hydropower potential of Mexico at 3,250 MW (capacity from 2 MW to 10 MW), as part of a total national hydropower potential estimated by CFE.[10]

Since then, several values close to 3,250 MW or rounded to 3 GW have been reported in many official documents.[11] Conversely, in 1994, the CFE had published an estimated total hydropower potential for Mexico of 159 TWh in terms of annual energy generation. Extra effort will be needed to identify the exact national small hydropower potential.

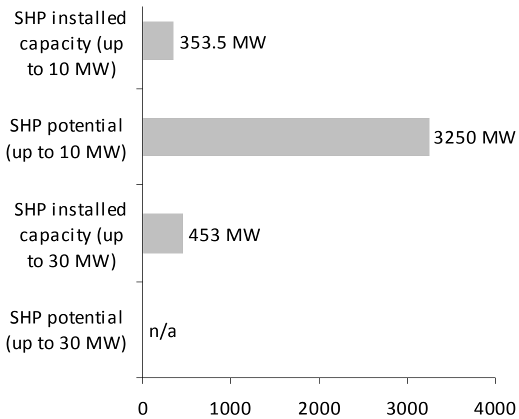

Figure 2 **Small hydropower capacities in Mexico**

In 2006, CFE solicited a study of the hydro power potential in three pilot river basins in Mexico.[12 13] Technology was adapted and developed for the systematic and exhaustive evaluation of the Culiacán, Nautla and Tecolutla river basins, covering a total of 30,000 km^2, about 1.5 per cent of the territory. The study focused on run-off river projects up to 30 MW. The basic hydropower potential of all stream reaches, with an average length close to 3 km, was successfully evaluated (table).[12 13]

Figure 3 **Small hydropower potential in pilot river basins in Mexico**

(Megawatts)

River basin	*Feasible project capacity*
Culiacán	29.8
Nautla	91.1
Tecolutla	148.5

Notes: Based on a distributed hydrologic model. The frequency analysis of runoff series (flow duration curves) was carried out, with daily data of 20 years.

These results strongly suggest that the real small hydropower potential of the country may be significantly greater than what was presented before. The hydropower potential would be even greater if the following were taken into account: small hydropower projects with reservoir, pumped storage schemes, installation of equipment in existing irrigation and urban hydraulic infrastructure, and rehabilitation of existing small hydropower plants. Only a national assessment with the available technology can elucidate the question.

Renewable energy policy

Mexico is committed to generating 35 per cent of its electricity through renewable sources by 2024 (currently 12 per cent). To do this, several laws and regulations have been passed, above all to facilitate connection to the power grid. By the end of 2012, the framework for small-scale renewable energy tender offers (<30 MW) was created to promote investments by allowing installations to contribute to the power grid through the use of technologies such as solar photovoltaic and thermal, co-generation and small hydro. Furthermore, the approval of the General Climate Change Law, an internal emission trading system is planned, possibly linked to other international initiatives, as a tool for Mexico to achieve its goal of reducing carbon dioxide (or CO_2 equivalent) emissions by 30 per cent by 2020 and by 50 per cent by 2050.

Within the energy sector, the following national policies seek to promote the development of renewable sources for electricity generation:

- In 2001, CRE adopted a specific regulation for renewable energy sources in order to encourage the development of electricity generating projects;
- In 2008, the Law on the Use of Renewable Energy and Energy Transition Financing (Ley para el Aprovechamiento de Energías Renovables y el Financiamiento de la Transición Energética) aimed at regulating the use of renewable energy sources and clean technologies to generate electricity for purposes other than providing public electricity service, as well as establishing the national strategy and the instruments to finance the energy transition.
- The National Strategy for Energy Transition and Sustainable Use of Energy is the instrument used by the Federal Government to promote policies, programme projects and actions to achieve greater use of renewable energy and clean technologies, and to promote energy efficiency and sustainability and reduced reliance on fossil fuels, mainly oil as the primary source of energy. It sets objectives, lines of action and goals related to 2024, while considering the impact that the energy sector has on the environment not only in relation to end use but considering the whole energy chain, from production to final consumption, and considering factors such as greenhouse gas emissions and the sustainable use of natural resources.
- In parallel, the Law for Sustainable Energy in all its processes and activities also published in 2008. This Law also provides the National Programme for Sustainable Energy (PRONASE) via the Advisory Council for Sustainable Energy, the National Information Subsystem on the Use of Energy and the National Commission for the Efficient Energy Use.

The new legislation of the electric sector places the obligation on the Secretariat of Energy (SENER) to elaborate and publish the inventory of all renewable energy sources.

Legislation on small hydropower

The Political Constitution of Mexico stipulated in Article 27 pertains exclusively to the Nation to generate, transmit, transform, distribute and supply electric energy which is intended for public service. In this matter no concessions will be awarded to particulars. The Public Service is carried only by the Federal Commission of Electricity (CFE).

In 1992 the Law of the Public Service of Electric Energy was modified to stipulate in Article 3 that it is not to be considered as Public Service. With that legal modification particulars have now the right to generate, co-generate and import energy, but not to sell it to the public; thus they can only use it for self-supply, export or to sell exclusively to CFE. It is then permitted to form a partnership of private developers of specific renewable energy projects with different technologies and a pool of industrial, commercial and municipal energy consumers. These new enterprises fulfil the condition of Self Supply.

The licensing process includes the following main procedures:

- Legal incorporation of the company (15 days) obtained by the developer
- Environmental Impact Assessment (EIA) authorization (20 or 60 days) issued by the Secretariat of Environment and Natural Resources (SEMARNAT). Three options with increasing levels of complexity depending on the project include either a preventive report, a particular or a regional EIA.
- Water authorization (60 days, for 5 to 50 years) issued by the National Water Commission (Conagua) which grants the concession to use surface water, exemption if eligible as a renewable energy project permit to use federal zone and a permit to build hydraulic infrastructure
- Feasibility studies by the CFE are also required. These consist of a study on grid connection (30 days) and a feasibility study on transmission (20 days). Moreover contracts issued by the CFE need to be obtained; these include: a contract on grid connection (90 days), a contract to buy/sell renewable energy to CFE, an agreement of electric backup and an agreement of transmission.
- Permits for electric energy generation are issued by the CRE within 20 to 50 days.
- Municipal Permits for construction are issued by the Municipal Governments involved.

Barriers to small hydropower development

The typical barriers to small hydropower development in Mexico are listed below. Most of them could also apply to other countries of Central America with due nuances.

Technological:

- Inexistence of a detailed and reliable national hydropower potential inventory in natural and artificial streams. Coupled with a high hydrological uncertainty due to lack of adequate basic meteorological and hydrometric information.
- Focus of the studies on local projects, rather than focus on entire river basins to systematically assess all feasible projects, with economies of scale in the planning and construction stages.
- Technical deficiencies in small hydropower project formulation, due to rudimentary methods applied in the early phases of prospecting and pre-feasibility studies. For this reason the success rate is too low, where only two out of ten identified sites attain the construction stage, but all consume effort, time and money. This discourages new investments in prospecting.
- Inadequate or incomplete assessment of small hydropower project flows of costs and benefits.

Social:

- Legitimate social and community concerns about hydropower projects, often based on lack of education and objective information. In addition to, disproportionate expectations of local communities regarding compensations to remedy regional underdevelopment and lack of services.
- Ideological and political opposition induced from within the country and from abroad against large and small hydropower projects, private participation in the electricity sector and foreign investments.
- Regional insecurity and delinquency.

Regulatory and Legal:

- Requirement for complete feasibility studies prior to having the assurance to obtain all the permits are costly. Coupled with complex and multiple licensing procedures with federal, state and municipal authorities.
- Restrictions play a vital role as a barrier to small hydropower development. High restrictions on projects proposed in protected areas, without impact analysis. Restrictions for licensing of small hydropower projects in existing hydraulic urban and irrigation infrastructure.
- Requirement to connect to the grid in higher voltage.
- Exposure to risk of issuance of new concessions for different water uses or diversions upstream of the project.
- Long period of licensing and legal processes in

addition to long period of contract preparation for structuring projects.

- Exposure to the risk of legal challenges by another developer for a site that is under prospecting or licensing process.
- Requirement to establish a trust to control the property of assets, contracts, rights and cash flows of the project.

Economic:

- A lack of coverage and capacity of electric grid in areas with high hydropower potential, thus requiring major investment in interconnection lines.
- A lack of coverage and maintenance of roads in areas with high hydropower potential, thus requiring major investment in access roads.
- Charges or duties for the volume of water used to generate energy, rather than for the energy produced.

Commercial:

- Saturation of the consumer market for self-supply.
- Low credit rating of prospective energy consumers. And the low price of the energy delivered to the national electric system.
- Exposure to the risk of gradual or sharp decline in energy prices due to energy bids.
- Difficulty to access mechanisms of payment for greenhouse gas emissions reduction

Financial:

- Lack of financing options for the prospecting and pre-feasibility phases.
- Limitation of funds made available by commercial banks for small hydropower projects, in some cases due to lack of specific experience.
- Terms of commercial credit in the country are not conducive, regarding interest rate, loan term and grace period.
- Requirement to augment the ratio of equity capital to debt and the condition to disburse equity capital prior to using debt capital.
- Requirement to structure syndicated loans for larger projects.
- Difficulty access to mezzanine funds, clearly subordinated to principal debt, to complement equity capital.
- High requirements of banks to assess the specific track record and financial solvency of the project developers.
- High requirements of financial guarantees, beyond the project expected cash flows, such as long term power delivery agreements, high credit rating of energy consumer partners, construction and supervision contracts with highly ranked firms (EPC), operation and maintenance contracts during the loan term and the requirement of opinions from independent experts.
- Difficulty to access mechanisms of partial guarantees of the loan and of guarantees against project cost overruns.

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2.2.7 Nicaragua

Yan Huang, International Center on Small Hydro Power

Key facts

Population	5,727,707[1]
Area	130,967 km[2]
Climate	Tropical in lowlands, cooler in highlands[1]
Topography	Three major zones: Pacific lowlands, central mountainous and volcanic highlands (some volcanoes still active), and Caribbean lowlands[1]
Rain pattern	Average annual rainfall is 1,462 mm; rainy season is from May to October.[2]

Electricity sector overview

Nicaragua has an electrification rate of 72 per cent. The Nicaraguan energy sector was restructured in the late 1990s. The new electricity Law from April 1998 separated generation, transmission, and distribution divisions of the state-owned Empresa Nicaragüense de Electricidad (ENEL). This sector reform initiated privatization of the generation and distribution activities. Four electricity generation companies (GEMOSA, GEOSA, HIDROGESA, and GECSA), one transmission company Empresa Nacional de Transmisión Eléctrica S.A., (ENTRESA) and two distribution companies (DISNORTE and DISSUR) were created. However, during 1990-2007, the privatization delayed the promotion of the electric service in rural areas. A plan was established for this purpose in 2004, with the creation of the Comisión Nacional de Energía (CNE).

Nearly 70 per cent of Nicaragua's electricity needs are supplied by fossil fuels plants (figure 1). According to the National Energy Institute (INE), installed electricity generation capacity in 2011 was 895 MW; 593 MW thermal (fuel oil and diesel), 98 MW large hydropower, 0.9 MW small hydropower, 63 MW wind power, 36 MW geothermal and 104 MW biomass (sugar cane bagasse).

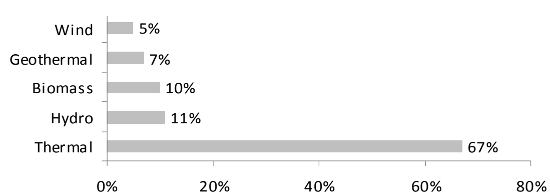

Figure 1 **Electricity generation in Nicaragua**
Source: National Energy Institute[3]
Note: Data from 2011. Thermal includes diesel and fuel oil.

Small hydropower sector overview and potential

The INE's annual statistics for 2011 only report operation and generation of one small hydro plant in Nicaragua. With an installed capacity of 930 kW and a head of 119 meter, the ATDER-BL El Bote small hydropower plant has a reservoir and operates two Pelton turbines. The plant is connected to the grid.

In addition, according to the Ministry of Energy and Mining, four other small hydro projects in operation with a total installed capacity of 1.64 MW and two other projects under construction with a total capacity of 1.78 MW can be found in Nicaragua (as of September 2012).

Based on this information, the total installed small hydro capacity in Nicaragua is 2.95 MW and the capacity of small hydro projects under construction is 1.78 MW (figure 2).

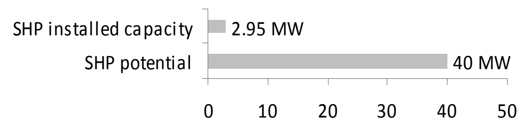

Figure 2 **Small hydropower capacities in Nicaragua**

The programme Usos Productivos de la Hidroelectricidad a Pequeña Escala aims to improve living conditions in rural areas through improved income generation based on hydropower. As part of the Global Environment Facility Project Development Fund Block B grant, several preparatory studies have been carried out by NGOs and consultancy companies. Among them is a reconnaissance study which identified 30 potential hydropower projects ranging from 150 kW to 1.5 MW and totalling some 11 MW. The financing required to implement the entire programme is estimated to amount to about US$30 million.[4 5]

Within the UNDP project NIC/02/G31, the Development of Small-scale Hydropower for Productive Use in Off-grid Areas, a small hydropower potential of 40 MW has been identified for Nicaragua, for stand-alone projects in rural areas.[6]

The value chain of small hydropower in Nicaragua is only developed to cover services in maintenance and operations; and in engineering.[7]

Renewable energy policy

Nicaragua provides investors of clean energy with fairly attractive tariffs in retail and power markets.[7] In 2005 a regulatory framework relating to the energy market was put into place, aiming to reduce oil and diesel dependency and adding power capacity by 700 MW via power purchase agreements scheduled over the coming 10 years.[7]

The Nicaraguan Government provides its investors with tax based incentives such as income tax and import duty tariffs to support the implementation of clean energy. Furthermore local micro finance institutions portray a robust system with 10 organizations providing green finance at an average cost of 1.5 per cent to 28 per cent.[7]

Legislation on small hydropower

The Nicaraguan Government has declared hydropower development to be an important part of its energy policy. A favourable legal framework and an attractive incentive structure have been established for hydropower plants with capacities below 5 MW. The necessary environmental permits are obtained from the Ministerio del Ambiente y los Recursos Naturales, generation of licences from Instituto Nicaragüense de Energía (INE), and water concessions from the Ministerio de Fomento, Industria y Comercio (MIFIC).[8]

Law 476 for the Promotion of Hydroelectric Sub sector stipulates that hydropower schemes below 1 MW do not need a water concession, instead producer will get a permit for 15 years.[8] For schemes with capacities between 1 MW and 5 MW, a simplified procedure applies to obtain a water concession from MIFIC. Law 217 General Law of the Protection of Environment and the Natural Resources stipulates that projects with capacities below 5 MW do not need an environmental impact assessement.[8]

Barriers to small hydropower development

- Difficulty in accessing finance because of the high initial cost of projects, commercial finance is needed for the long term. But in general, the finance assistance is short-term and hence shows high interest rates;
- Requirements and costs for permits are the same for large and small projects. The cost per MW for small projects is very high; in addition, the concession process is very slow, often lasting several years;
- Power purchase agreements are too short to motivate small hydropower project development, therefore it is difficult to take long-term investment decisions.;
- The approved fiscal incentives for hydropower projects do not yet create a level playing field for hydropower development in general compared to thermal projects, since the latter continue to be highly subsidized.

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2.2.8 Panama

Yan Huang, International Center on Small Hydro Power

Key facts

Population	3,510,045[1]
Area	78,200 km[2]
Climate	Tropical maritime: hot, humid, cloudy[1]
Topography	Interior mostly steep, rugged mountains and dissected, upland plains; coastal areas largely plains and rolling hills[1]
Rain pattern	Caribbean coast: precipitation in the rainy season from May to December accounts for 70-80 per cent and in the dry season only 20-30 per cent. Pacific coast: precipitation in rainy season is 85-93 per cent and 7-15 per cent during remaining time of the year[2]

Electricity sector overview

The electrification rate in Panama is 88.1 per cent.[3] By the end of 2011, Panama had 2,391 MW installed electricity generation capacity, 56.5 per cent (1,351 MW) hydropower, and 43.5 per cent (1,040 MW) thermal (figure 1).[4]

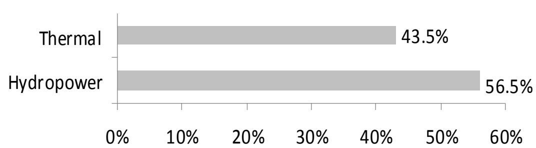

Figure 1 **Electricity generation in Panama**
Source: Secretaría Nacional de Energía[5]

The National Secretariat of Energy is in charge of formulating energy policies according to the National Plan of Development. In Panama, hydropower development started in 1915 with the construction of the Panama Canal. In 1961, the Instituto de Recursos Hidráulicos y Electrificación (IRHE) was established and served as a state-owned enterprise, which made a plan of a series of small/medium hydropower projects. In 1972, the nationalization of the electric sector covered the whole electric system. As a result in 1974, the Electric System of IRHE was created.

According to the Law No. 6 dated 3 February 1997, the generation (four enterprises), distribution (three enterprises) and transmission (one enterprise) were separated and parts of the shares of some generation and distribution enterprises were privatized.[5]

Small hydropower sector overview and potential

In Panama, hydropower plants are considered small hydropower if the capacity does not exceed 5 MW. There are 10 small hydropower plants in Panama with a capacity under 10 MW and a total installed capacity of 38.8 MW (figure 2). Four of the smaller plants are reported not to be operational.[6]

According to the Inventory of Hydroelectric Projects (Inventario de Proyectos Hidroelectricos) carried out by Empresa de Transmisión Eléctrica S.A. (ETESA), in 2000 the total potential for small hydropower projects with capacities ranging between 1 kW and 100 kW was 1.2 MW, for those ranging between 100 kW and 1 MW was 5.22 MW and for those ranging between 1MW and 10MW was 115.9 MW, thus with a total of 122.3 MW.[7]

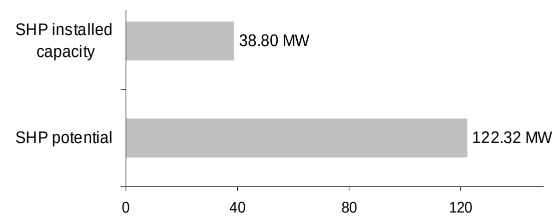

Figure 2 **Small hydropower capacities in Panama**

In order to overcome the low electrification rate in Panama the Oficina de Electrificación Rural aims to increase rural electrification by the use of micro hydro, photovoltaics and small wind projects.[8]

Renewable energy policy

Article 55 of Law No. 6 established in 1997, states that it is in the Government's agenda to encourage the diversity of energy sources and to mitigate adverse environmental impacts by reducing the country's dependency on traditional energy sources. Competitions and auctions for the sale of electricity are incorporated with a five per cent discount for renewable energy purchases.[9]

The Government of Panama has not established specific targets for renewable energy but it has increased its support through the approval of different incentives. The Law 45 has provided strong incentives for small renewable energy applications, including hydro, geothermal, wind, solar and other renewable energy technologies. In addition, the National Assembly has launched incentive laws for renewable energy such as import and other tax exemptions for equipment of wind generation (projects under 10 MW) and large hydropower. Wind generation benefits from 25 per cent of repaying the initial investment based on their carbon credits.[10]

Legislation on small hydropower

In 2004 the Government enacted Law 45 (Establishment of an Incentive Regime for Systems of Hydraulic Generation and of Other New, Renewable and Clean Sources) that established preferential measures for mini and small hydropower plants, i.e. mini hydropower plants may realize sales contracts directly with electric distribution companies with exemption from distribution and transmission costs. Small hydropower plants are granted this exemption for the first 10 MW during the first 10 years of commercial operation.[10]

Barriers to small hydropower development

Panama is disadvantaged by an underdeveloped value chain regarding small hydro, despite the room for development and growth of a value chain, encouraged by the generous policy tax incentive. In addition, a dearth of microfinance institutions and local investors further hinders the progress of the small hydropower sector.[8]

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2.3 South America

Teo Sanchez, Practical Action

Introduction to the region

South America comprises 14 countries and territories[i] covering 16 246,210 km^2, with a population of over 388 million inhabitants, of which, 84.1 million live in urban areas. Over 17 million have no access to electricity, which represents only 4.4 per cent of the total population and 27.7 per cent of the rural population.

South America enjoys a diverse set of climate conditions; from very warm in the Amazon and Caribbean coast, reaching maximum temperatures of over 30°C all the year round, to very cold average temperatures of 0°C in the higher locations of the Andes. Rainfall varies from 1 mm a year (Atacama Desert) to an average of 5,000 mm in wet areas. It is also home to the largest river in the world, the Amazon River.

In all countries, hydropower electricity comes from large plants feeding into the national grids. Hydropower has also been used to supply electricity to small towns and villages in rural areas, but small scale hydropower has not been developed to its full potential. National electricity supply is highly dependent on hydropower in Paraguay (96 per cent), Brazil (87 per cent), Venezuela (70 per cent) and Colombia (75-76 per cent). In other countries too, such as Ecuador, Peru and Bolivia, large proportions of annual electricity consumption is derived from hydropower-based sources.

Table 1
Overview of countries in Southern America

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Argentina[abcdei]	40.41	8	97.2	33 810	128 922	10 045	39 920
Plurinational State of Bolivia[abcehi]	9.92	33	77.5	1 459	6 085	477	3 876
Brazil[abcefi]	190.75	13	99.0	117 134	532 872	82 458	403 250
Chile[abcei]	17.11	11	98.5	17 530	62 429	5 991	23 871
Colombia[abcei]	46.29	25	93.6	14 424	64 230	9 718	38 714
Ecuador[abce]	14. 46	33	93.1	5 090	20 544	2 242	9 170
French Guiana[abceg]	0.23	24	..	284	838	129	..
Peru[abcei]	29.07	23	85.7	8 556	12 975	3 453	20 038
Uruguay[abce]	3.35	8	98.3	2 683	9 890	1 538	8 050
Total	**351.59**	**-**	**-**	**200 820**	**838 785**	**116 051**	**538 839**

Sources:
a. Central Intelligence Agency[1]
b. International Energy Agency[2]
c. World Bank[3]
d. Alvarez[4]
e. International Journal on Hydropower and Dams[5]
f. Tiago Filho, Geraldo Lucio[6]
g. Électricité de France and Direction des Systemes Energetiques Insulaires[7]
h. Comité Nacional de Despacho de Carga[8]
i. Organización Latinoamericana de Energía[9]

Small hydropower definition

Most countries do not have an official small hydropower definition (table 2).

Table 2
Classification of small hydropower in South America

Country	*Small (MW)*	*Mini (kW)*	*Micro (kW)*	*Pico (kW)*
Argentina	0.5-15	50-500	5-50	..
Plurinational State of Bolivia	..	..	..	
Brazil	30	..	..	..
Chile	2.1-20	101-2000	5.1-100	0.2–5
Colombia	0-10	..	..	..
Ecuador	0- 10	..	..	..
French Guiana	..	..	..	..
Peru	..		..	..
Uruguay	..	..	..	..

Regional overview and potential

Countries such as Peru and Argentina began using small hydropower installations either for the provision of lighting, small businesses or for industrial activities such as mining. Out of the 14 countries and territories only French Guiana and the Falkland Islands do not have small hydropower plants.[ii]

Small-scale hydropower programmes have been implemented in almost all countries in the region since the early 1970s, the Latin American Energy Organization (OLADE) being one of the most relevant promoters; OLADE especially championed the promotion of micro and mini hydropower systems during the 1970s and early 1980s. More recently, however, the promotion of small hydropower has been lowered in this region. One of the most important reasons appears to be a lack of the suitable incentives, for example concessions laws in most cases give exclusivity to large utilities, and subsidies to rural electrification exclude small independent generators.

Financial institutions like the World Bank, Inter-American Development Bank and others have been keen to provide financial assistance to the implementation of rural electrification projects including small hydropower systems mostly through governments; the private sector has not been a driver of the implementation of rural electrification hence, it has rarely financed private small hydro initiatives.

The total installed capacity of small hydropower is approximately 5,000 MW, defined as up to 10 MW. The potential is difficult to approximate because most reported small hydropower in the region uses a higher definition (table 3).[8]

The technically developable hydropower capacity for South America is estimated at 350 GW, 35.7 per cent of which has been developed. Presently, all countries have plans for large hydropower installations linked to national grids and regional integration.[8]

Table 3
Small hydropower in Southern America, up to 10 MW capacity
(Megawatts)

Country	*Potential*	*Installed capacity*
Argentina	430	66.0
Plurinational State of Bolivia	at least 21	21.3
Brazil[a]	at least 1 023	1 023.0
Chile	7 000	116.7
Colombia	at least 172	171.5
Ecuador	383	76.5
French Guiana	at least 6	5.5
Peru	at least 254	254.3
Uruguay	101	0.0
Total	**9 390**	**1 734.8**

Sources: See country reports
Notes: a. The potential of Brazil for plants up to 10 MW is not known, the gross technical potential up to 30 MW is 22,500 MW.

Countries with a larger share of rural population without access to electricity, coincidently, have greater small hydro resources, especially those in the Andes region: Peru, Bolivia, Colombia and Ecuador; at the same time these countries have a large number of small towns and villages located in isolated areas in the Andes and far from the grid. Besides supporting rural electrification, small hydropower can also play an important role in contributing to the national grids by supplying additional power.

The main challenges facing small hydropower is the lack of appropriate regulations related to tariffs, subsidies and concessions which presently do not help or encourage its development.

Notes

i. South America comprises Argentina, Plurinational State of Bolivia, Brazil, Chile, Colombia, Ecuador, Falkland Islands (Malvinas), French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Bolivarian Republic of Venezuela.
ii. There are no country reports available for Guyana and Venezuela due to insufficient information. Guyana has had two feasibility studies done for small hydropower plants (3 MW and 4 MW) and Venezuela may have potential but information on operating small or micro hydropower plants was not available.

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2.3.1 Argentina

Ariel R. Marchegiani, Universidad Nacional del Comahue, Argentina

Key facts

Population	42,192,494[1]
Area	2,780,400 km^2
Climate	Mostly temperate; arid in southeast; sub-antarctic in southwest[1]
Topography	Rich plains of the Pampas in northern half, flat to rolling plateau of Patagonia in south, rugged Andes along western border[1] (highest point: Aconcagua, 6,960 m)
Rain pattern	Variable, depending on location and elevation

Electricity sector overview

The state's role in Argentina's energy sector has experienced profound changes since 1992, when the restructuring of the sector began. The generation, transmission and distribution of electricity were opened to the private sector, but restricted to the ownership of no more than one property in the sector. The approved legal framework guaranteed access to the grid, creating a competitive environment and allowing the installation of generators to serve customers anywhere in the country.

Argentina has a high rate of electrification (95 per cent), but much of its rural population lacks electricity. Electricity is generated mainly through combustion (thermal plants), 30 per cent by large hydropower plants, 6 per cent by nuclear and less than 2 per cent from renewable energy sources, according to the Energy Department (figure 1). Electricity imported from Brazil, Paraguay or Uruguay is not uncommon in the winter months. According to the Argentine Association for Renewable Energy and Environment, the electricity from renewable energy is generated from 553 MW of installed capacity, of which 427 MW are small hydropower plants, 65 MW wind farms, 58 MW biomass (wood) plants and only 1.2 MW are solar panels.

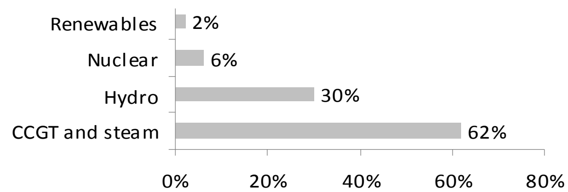

Figure 1 **Electricity generation in Argentina**
Source: Compañía Administradora del Mercado Mayorista Eléctrico, South America[2]
Note: GCGT – combined cycle gas turbine

Small hydropower sector overview and potential

Argentina has a total installed power capacity of 28 GW (data from 2012) of which two per cent is derived from small hydropower plants (defined as capacities of up to 15 MW).[3]

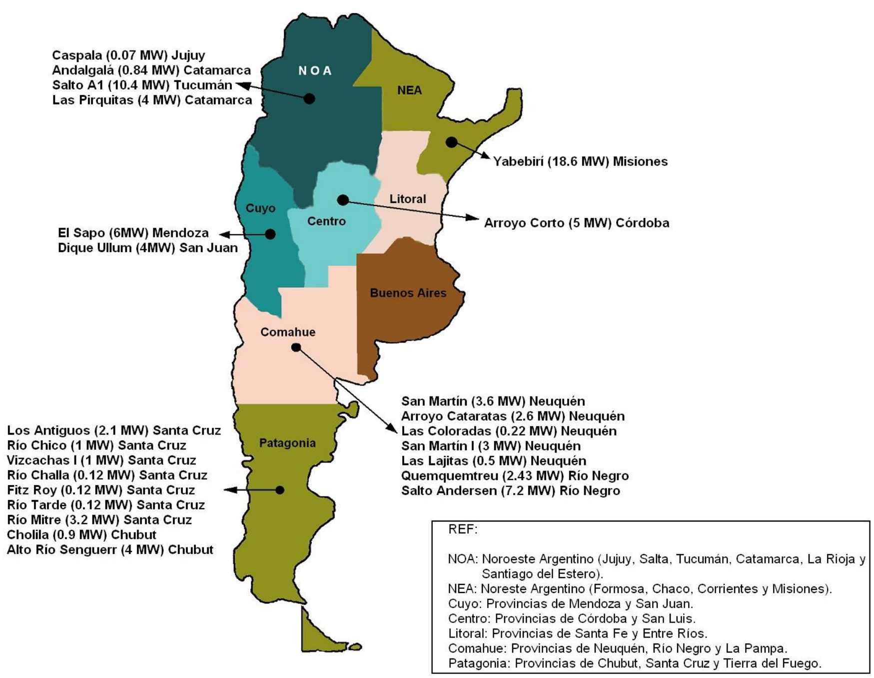

Figure 2 **Map of the main small hydropower schemes in Argentina**
Source: Argentina, Ministerio de Planificación Federal, Inversión Pública y Servicios[4]
Note: Small hydropower schemes shown are in operation or in study-phase

The upper limit of 15 MW is only a convention proposed by Law 26 190/06 according to the rules and context of the United Nations Framework Convention on Climate Change (UNFCCC). If so, and assuming a conservative 115,000 GWh/year of electricity consumption by 2013 (and counting the existing 180 MW), small hydropower could supply 22.7 per cent of the minimum contribution proposal, or about 1.81 per cent of the total. The convention adopted by the National Directorate of Promotion (Dirección Nacional de Promoción) for small hydropower classifies small hydropower plants by recognizing nominal installed capacity. There are three intervals: Micro (5-50 kW), Mini (50-500 kW), and Small (500 kW-15 MW).

The total small hydropower potential per region of the Argentinean Electricity Interconnection System (Sistema Argentino de Interconexión Eléctrica) is given the table below.

Small hydropower potential in Argentina
(Megawatts)

Potential category	*5-50 kW*	*50-500 kW*	*500 kW-15 000 kW*	*Total of region*
Central	0	0	36.25	36.25
Comahue	0.185	4.120	81.38	85.68
Cuyo	0.090	3.550	97.96	101.60
Northeast Argentina	0.040	0	1.28	1.32
Northwest Argentina	0.191	4.660	177.42	182.27
Patagonia	0.000	1.825	47.12	48.94
Total	**0.506**	**14.155**	**441.411**	**456.06**

In terms of renewable energy sources, the Government strategy first considers the development of small hydropower plants (up to 15 MW), because these projects represent an opportunity for Argentina's sustainable development in multiple geographic regions. The Energy Department has a national inventory of 116 small hydropower projects, with capacities lower than 15 MW and which represent an additional power supply of nearly 430 MW (figure 3).[5]

The results of the mentioned study favor, among others, the small hydropower in the southern region and, in general, isolated projects, thus, improving economic performance. However, the level of development of the studies is low. Of the 116 projects reviewed, only four have reached implementation stage and only 20 have reached the feasibility stage. The need to carry out a small hydropower development plan has been proposed, which will make further hydrological, geological, geotechnical and environmental impact studies necessary (done for only 12 small hydropower sites). It is also suggested to evaluate the additional environmental benefits, social cost of externalities, as well as the capability to supply potable drinking water.

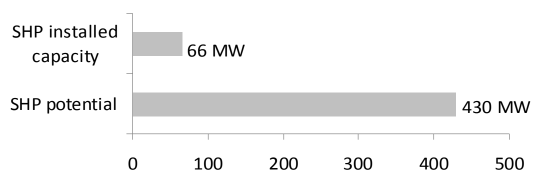

Figure 3 **Small hydropower capacities in Argentina**
Note: National small hydropower definition up to 15 MW, information provided up to 10 MW.

While the main small hydropower potential has been estimated to be over 400 MW, a new installed capacity of 100 MW may be incorporated within 10 years' time in different regions of the country. Small hydropower projects with a total capacity of 30 MW are currently under development.

Argentina has turbine manufacturers who are part of the clean energy value chain of small hydropower within the country.[3]

Renewable energy policy

The importance of renewable resources (i.e. photovoltaic, wind, biomass and small hydropower plants) as alternative sources for generating electricity in rural areas has increased through various programmes that are being conducted by the Ministry of Public Works and Services at the National Bureau of Promotion, in order to achieve basic power provision and lighting and communications, although the main authority on energy is the Ministry of Planning.[3]

Argentina has a national law on the promotion of renewable energy sources for the production of electricity (Law 26 190/06). It grants renewables the status of national interest and via a tax based incentive a non-binding renewable target of 8 per cent is set to be achieved by 2016, in addition to a 7 per cent biodiesel and a 5 per cent ethanol blending mandate.[3]

Studies and maps have been made to determine the renewable energy potential in each province and in 2009, the law was regulated by presidential decree. That same year, the national Government, together with Energía Argentina Sociedad Anónima, the public power company, launched the GENREN programme, which offers to buy 1,000 MW of renewable energy through fixed contracts for 15 years.

The Undersecretary of Electricity under the Ministry of Energy's Office has established a programme to supply the dispersed rural population with power (Programa de Abastecimiento Eléctrico a la Población Rural dispersa de Argentina). It aims to collaborate with the provinces through provincial energy programmes to electrify rural areas, primarily using photovoltaic, wind, micro hydro turbines and diesel generators. The national context is important to highlight the development and implementation of a project funded by the Global Environment Facility and the World Bank. The project, El Proyecto de Energías Renovables en Mercados Rurales (PERMER, renewable energy in dispersed rural markets), aims, among other objectives, to provide power to isolated rural areas in a sustainable manner, using renewable sources.

The most recent policy on renewable energy was established at the beginning of 2010, where Argentina had implemented feed-in tariffs granting power purchase agreements (PPA) for renewable energy. PPA's are obtainable from government-sponsored auctions.[3]

Legislation on small hydropower

The small hydropower action plan outlined by the National Directorate for Promotion (DNPROM) of the Ministry of Energy basically comprises:

- A survey of the facilities in operation and out of service, as well as those possible to be refurbished, and of public irrigation works that can be equipped with generating units.
- A search for new sites and to select a methodology for estimating total theoretical potential of regions and basins.
- Compilation, review, and proposal of a reformulation of the provincial legal regimes of water, environment and energy, in agreement and collaboration with governments and provincial agencies.
- An analysis of the profitability of small hydropower in isolated markets, the development of case studies and a roadmap of projects related (or not) to the Clean Development Mechanism (CDM).
- Identification and management of public and private financing lines for the execution of the technical and economically feasible works.

The Energy Department's Office is currently bound to encourage the construction of the 116 micro-hydro plants mentioned above. The Government considers several possibilities to avoid an energy crisis to impact the economic growth. One strategy is designed to further develop the country's water resources through micro-hydro facilities, which individually have a generating capacity of up to 30 MW.

Financial capacity is a key element to consider, particularly in the case of private investors looking for commercial opportunities in the small hydropower sector. Studies show that in order to encourage private initiatives, financial mechanisms are essential as they allow the collection of long-term loans at rates appropriate to the realities of such projects. Furthermore, it will be necessary to implement a system of guarantees that awards credits to private investors so that they are not inhibited by other commercial arrangements. At this point, the intervention of the federal, provincial and/or municipal state to facilitate and manage credit is needed. Complementary to this point, there is a need of an adequate remuneration system for the energy sold by small hydropower. When deciding the tariff structure of small hydropower, it will be convenient to take into account the environmental benefits and the social cost of externalities, both affecting the company but which are not incorporated yet by the generators.[6]

Argentina, which has a weak penetration of renewables in the national electricity supply, opted for the regulatory mechanism of 'quotas' for grid access. This system is advantageous for states with funding problems but does not ensure private investment.

Barriers to small hydropower development

Argentina has great small hydropower potential, however, a number of very diverse barriers hinder its realization, as in other countries. Hydropower is considered the most promising technology for national development, followed by wind, then solar and biomass. There are political constraints and structural limitations within the governmental agencies which are responsible for establishing policies that provide solutions to these problems. It is necessary to apply instruments that help formulate and implement an energy policy that includes renewable energy. At the moment the regulatory framework remains insufficient.

Foreign investors perceive high risks and a lack of incentive based on the limited availability of local finance. Local finance is hindered by the limited number of local banks and the lack of liquidity experienced in commercial banks. Furthermore, the difficulty in securing capital at reasonable costs in the short term strongly hinders the volume of investment, despite the countries resource potential.[3]

It is necessary to acknowledge that programmes like GENREN are being implemented, in which the generator is not paid a premium but a guaranteed price for the energy generated in order to provide a more reasonable rate of profit.

There is a specific need to update the incentives posed by Law 26190. It is not easy to meet the target to cover eight per cent of electric demand with emerging renewables, as established by the Law, without implementing the policies, instruments and specific promotional activities, particularly those aimed at financing.

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2.3.2 Bolivia (Plurinational State of)

Lara Esser, International Center on Small Hydro Power

Key facts

Population	10,290,003[1]
Area	1,098,581 km[2]
Climate	varies with altitude; humid and tropical to cold and semiarid[1]
Topography	Rugged Andes Mountains with a highland plateau (highest point: Nevado Sajama 6,542 m) hills, lowland plains of the Amazon[1]
Rain pattern	Variable, depending on location and elevation

Electricity sector overview

In the Plurinational State of Bolivia (hereafter Bolivia), electricity is nearly exclusively generated by private companies from hydropower and thermal power plants mainly based on natural gas (figure 1).
The total installed capacity in 2010 was 1,459 MW and the contribution of renewable sources other than hydropower is almost negligible.[2] While 85 per cent of the electricity was produced within the National Grid System (SIN, Sistema Interconectado Nacional), 15 per cent was produced in isolated systems (mainly by diesel-driven generators. The main energy authority in Bolivia is the Ministry of Hydrocarbon and Energy.[3]

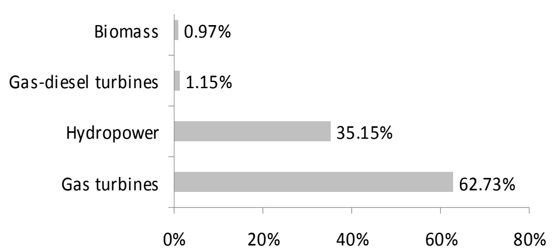

Figure1 **Electricity generation in the Plurinational State of Bolivia**
Source: Autoridad de Fiscalización y Control Social de Electricidad[4]

Bolivia has one of the lowest rural electrification rates of South America, covering only 77.5 per cent (hence, 2.2 million people without electricity) in 2010.[5]

Small hydropower sector overview and potential

According to the Bolivian Electricity Control Authority (AE), installed hydropower capacity in Bolivia is 563.6 MW of which only 21.3 MW corresponds to small hydropower, distributed between three plants with individual capacities of 3.3 MW, 8.7 MW and 9.3 MW (the latter not connected to the National Grid System) (figure 2).[6] , At least 22 stand-alone projects with a combined capacity of 600 kW small hydropower plants have been carried out by the Universidad Mayor de San Andrés (UMSA) hydro programme (see below).
Small hydropower potential in Bolivia is not known.

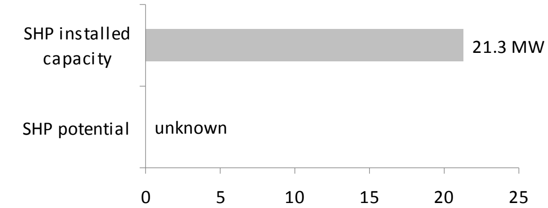

Figure 2 **Small hydropower capacities in the Plurinational State of Bolivia**

Moreover, Bolivia offers a robust multilateral investment fund (MIF) network offering micro-green finance. Out of the 30 available microfinance institutions (MFI) six offer green micro loans at an average cost of 9 per cent.[3]

Renewable energy policy

A new Rural Electrification Decree was approved in 2005 (Supreme Decree No. 28 567), which aims to increase rural electricity access through the extension and densification of electric networks, development of renewable energy and a change in the energy mix (substitution of diesel by natural gas, biomass and other renewable energies), and an increase in distribution capacity. The Rural Electrification Decree and its associated regulatory framework encourage stakeholders in the energy sector to establish partnerships with other governmental agencies to implement the rural electrification plan.[4]

In 2006 a new Law for Universal Access to Electricity (Ley de Acceso Universal) was proposed. Under the framework of this Law, the programme called 'Electricity for a Decent Living' has been designed to improve both rural and urban electrification. The medium term goal (2010-2015) is to achieve universal access in urban areas and a 70 per cent access in rural ones. By 2020, in the final stages, rural access should increase to 87 per cent, and universal coverage should be reached by 2025. The Law also mandates the creation of a Common Fund for Universal Access to Public Electricity Service (FOCO) and creates a co-financing mechanism of the National Government with Prefectures, municipalities and the private sector. Approval of the Law and the related mechanism is expected soon.[4]

The Hydro Programme (el Programa Hidroenergético) by the UMSA is dedicated to the development of technologies to utilize water resources. It aims to achieve technological packages, developed at different research projects, ready to be transferred to end users, preferably the rural population, in order to alleviate rural poverty. The programme works on the basis of local initiatives by helping local actors with project identification and design phase, as well as fundraising. During the construction phase the programme directs, supervises and manages the implementation of the project. The main actors, who are also the implementers and beneficiaries, often provide not only labor, but local materials. Before the project is finally transferred to the community for operation, maintenance and administration, an agreement on the management model is decided upon, in order to ensure sustainable management. This agreement provides drafts of rules and regulations and facilitates its adoption and implementation. Once transferred, the programme is limited to the provision of specialized technical assistance when called upon by the local organization.[7] More than 22 small hydropower plants with a combined capacity of 600 kW have been developed through this project.

In 2007, the Vice-Ministry of Land Planning and Environment, through its National Plan of Development, established the Energetic Sovereignty and Independence Policy to promote the investigation and sustainable development of alternatives sources of energy, such as hydropower, biomass, wind, etc.) by implementing specific programmes.

As of 2009, the role of issuing policies has been decentralized from the national Government to the prefectures (the Government of each state, in 2009, nine states won the bid for autonomy) who have become vital policy institutes with their own budget. In addition the Alcaldías, (the municipal magistrate) play a fundamental role as intermediate actors between the villages and the main institutional electricity providers. The Alcaldías also have their own economic policies and co-finance rural electrification projects.[8]

Legislation on small hydropower

The Government of Bolivia presses a strong importance on the central electricity grid which significantly suppresses the development of small hydropower. Until 1996 the tariff advantage (25 per cent discount for small users of the central grid) hindered the use of small hydropower and promoted the use of other resources such as solar. Companies such as Energética, as of 2009, have however considered increasing the use of small hydropower.[8]

The Superintendencia de Electricidad is the main institute of the sector; they control the tariffs, monitor the quality and are also in charge of licence distribution. These stages were crucial for small scale systems, however, systems smaller than 300 kW were set free, from these obligations thus allowing easier implementation without the input of the Superintendencia de Electricidad.[8]

Barriers to small hydropower development

Various attempts at power market liberalization had little success, causing Bolivia to move towards greater Government intervention in the power sector. This is evidenced by the nationalization of Red Electrica, the grid operator, in 2012. Investment in the sector is often hindered by a stronger governmental presence.[3]

The main disadvantage facing small hydropower development in Bolivia is the political predisposition towards the central electricity grid and the unequal distribution of funds. In addition, a lack of financial expertise in the department of tariffs to keep up with inflation rates, causes the plants to strongly rely on Government support.

Political and financial constraints coupled with scarce local technological knowledge and training further hamper the growth of the small hydropower sector. Thus, not only do plants have to rely on governmental support but they also have to turn towards organizations and large corporations for aid.[9]

However organizations such as the Instituto de Hidraulica e Hidrologia (IHH) shine a positive light on the future of small hydropower in Bolivia, thanks to their networking policy and follow-up habits with project benefactors.[9]

Bolivia's value chain in relevance to overall renewables remains fairly underdeveloped with only one company active in small hydropower and two in the biomass sector.[3]

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2.3.3 Brazil

Geraldo Lúcio Tiago Filho, Camila Galhardo and Luciano Silva, National Reference Centre for Small Hydropower Plants (CERPCH), Brazil

Key facts

Population	199,321,413[1]
Area	8,515,692 km^2
Climate	Mostly tropical but temperate in south[1]
Topography	Mostly flat to rolling lowlands in north; some plains, hills, mountains, and narrow coastal belt (highest point: Pico da Neblina, 2,994 m)[1]
Rain pattern	Northwest (Amazon basin): uniform rainfall, up to 3,000 mm/year. Central interior: rainy season December to February. Northeast: 500 -1,150 mm/ year depending on the zone. Narrow coastal belt: South: uniform rainfall, 1,250-2,000 mm/year. Southeast and West-Centre: 1,500-2,000 mm/year.[2]

Electricity sector overview

Approximately 9.7 million Brazilians do not have access to electricity, despite the relatively high electrification rate of 95 per cent. The Luz Para Todos Program aims to use small photovoltaic systems and micro hydro facilities to overcome the deficiency in electrification.[3] It benefits approximately 1.24 million people through 247,862 connections.[4]

As of 2011, Brazil had an installed power generating capacity of 117,134 MW.[4] Hydropower is the most important electricity generation technology in Brazil, as can be seen in Figure 2 below. Furthermore, Brazil was the world's second largest hydropower producer in 2009 (391 TWh) and the world's third largest in terms of installed hydropower capacity in 2008 with 78 GW.[5]

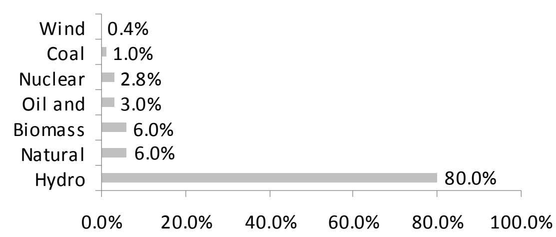

Figure 1 **Electricity generation in Brazil**
Source: Empresa de Pesquisa Energética, Ministerio de Minas e Energia[6]

The Brazilian hydropower sector has acquired significant experience and knowledge in the design, construction and assembly of electromechanical generation equipment. Today, the country masters the technology of implementing hydropower ventures, whether it is large or small-scale.

Small hydropower sector overview and potential

In Brazil small hydropower plants are defined as hydropower developments with power above 1 MW and below 30 MW, and with a maximum flooded area of 3 km^2, as per Law No.9648/98.[7] On 9 December 2003, with Resolution No.652, the flooded area was authorized to reach 13 km^2, provided it met the equation $A \geq (14,3 \times P)/Hb$, where P is the power of the venture, given in Megawatts (MW) and Hb is the venture's available gross head, given in metres; or when the reservoir has been designed based on other uses which are not for power generation.[8]

Hydroelectric ventures with power below 1 MW are classified as Hydroelectric Generation Plants (CGH) and receive different treatment from the National Agency of Electric Energy (ANEEL) on registration procedures. According to data from ANEEL on 31 December 2011, Brazil had 373 plants operating with a power of up to 1 MW, totaling 217 MW, and 423 plants with a power of 1 to 30 MW, corresponding to 3,889 MW. Of these ventures, the majority of the concessions are generally granted for private capital.

Brazil still has a small hydropower potential of 22,500 MW (figure 2).[9]

Among the latest small hydropower research programmes in Brazil in the last five years, the following stand out: improving the quality of hydraulic turbines through numeric computational systems for designing the flow in turbines; distribution of losses in electric generators; use of automated operation systems and supervision of generator groups; use of group generators with variable rotation; studies on the interaction of fish-friendly hydraulic turbines; research on the behavior of Brazilian fish for preservation purposes; restocking of fish into the river; the development of procedures for designing suitable transposition mechanisms for tropical and temperate climate fish. There are also studies on movable dams, equipment and devices for low and very low heads, hydrokinetic turbines, system supervision by telemetry and the use of asynchronous generators interconnected to the grid.

Brazil has a highly developed value chain for small hydropower, not only with a turbine manufacturing sector, but offering other small hydropower services in civil works/building, engineering, operations and maintenance.[3]

In Brazil, the investments in small hydropower projects are made through bank loans, mainly from the National Bank of Social Development (BNDES), which offers lines of credit with a grace period of up to six months after the project enters commercial operation, an amortization period of up to 12 years and a constant amortization system.

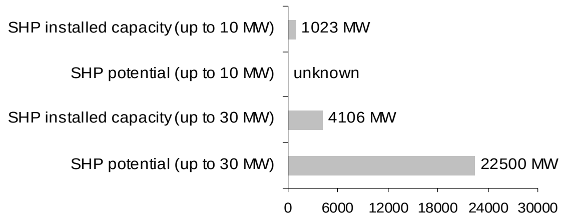

Figure 2 **Small hydropower capacities in Brazil**

The decreasing share of small hydropower in the country's renewable energy mix is associated with the growth of wind energy. In the years of 2006-2008 small hydropower gained its highest amount of grant aid to diminishing amounts from 2009 onwards reaching its lowest grant gains in 2011.[3]

The 2009-2019 Ten-Year Plan (PDE) predicted a growth rate of 72.3 per cent for small hydropower in 2009, however, this estimate dropped down to 69.4 per cent in the 2010 PDE.[10]

In 2012, the National Interconnected System increased its electrical capacity by 1.212 MW from which small hydropower plants covered 21 MW.[4]

Renewable energy policy

According to (PDE) of 2020, the participation of renewable sources such as hydro, wind, ethanol and biomass in the Brazilian energy matrix will rise from 45.5 per cent in 2011 to 46.2 per cent by 2020.

According to the PDE 2020, the Brazilian Government predicts that the electric matrix will, in relation to small hydropower, present 4,957 MW (3.5 per cent) in 2015 and 6,447 MW (3.8 per cent) in 2020. The increase is not very significant, but when observing the growth rate of other renewable energies in the country, it can be seen that governmental incentives, like tax exemption, are having positive results.

The Environmental National Council (CONAMA) Resolution 01/86, in Article II states that power-generating plants having power above 10 MW are activities that are potentially impacting the environment and are therefore Environmental Impact Assessment (EIA) and Environmental Impact Report (EIR) liable, regardless of the primary energy source . Under this legislation, EIA is required for all small hydropower projects with generating capacities ranging between 10 and 30 MW. Furthermore, small hydropower projects are also classified as ventures with a high impact to the environment, graded as three in a classification of one to five. Small hydropower projects with less than 10 MW of generating capacity require simplified environmental studies.

The energy policies of Brazil can be summarized to those relating to the market (feed-in-tariff, auctions and biofuel mandates), to finance (funds available for infrastructure), to debt funding and tax based polices consisting of tax relief, import duty and tax rebates.[3]

Legislation on small hydropower

Law 9658 of 1998 created incentives to encourage the use of small hydropower by allowing small hydropower producers to sell the energy directly to the consumers via the grid at a 50 per cent discount rate for grid use. In addition the recent Law 10438/02 gave way for the Incentive Program for Alternative Electric Generation (Programma de Incentivo a Fonres Alternativas, PROINFA) that aims to encourage the linkage of small hydropower, *inter alia*, with the national grid. The second stage of PROINFA is currently underway with the main objective of attaining 10 per cent of electricity production, over the next 20 years, from renewable sources.[11]

Barriers to small hydropower development

Small hydropower currently faces disadvantage among renewable energy sources, mainly in comparison to wind energy, which has more incentives. Small hydropower has lost competitiveness and has difficulty in competing within the regulated market. As far as other energy sources are concerned, the cost of constructing and operating small hydropower plants has been shown to be more expensive. The costs for civil construction and electro-mechanical equipment are elevated and are not covered by tax exemptions unlike the equipment for wind farms, which are exempt from taxes such as the Tax on Circulation of Goods and Services (ICMS). Also, the environmental licensing processes pose a challenge.

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2.3.4 Chile

Carlos Bonifetti, BMG Hidroconsultores, Chile

Key facts

Population	17,067,369[1]
Area	756,096 km[2]
Climate	Mild, with marked seasons in the central region. Very dry (desert) in the north. Cool and damp in south.[1]
Topography	Low coastal mountains; fertile central valley; rugged Andes in east (highest point: Nevado Ojos del Salado, 6,880 m)[1]
Rain pattern	Almost no rainfall in the north (desert). From the central to the southern regions rainfall increases up to 4,000 mm per year.

Electricity sector overview

The current national electrification rate in Chile is about 98 per cent and the population without electricity is estimated at some 340,000 inhabitants.[2]

In Chile, power generation, transmission and distribution activities are carried out by private companies.. The State only has functions of regulation, oversight and indicative planning of investments in generation and transmission.[3] The main authority on energy in the country is the Ministry of Energy. There are four interconnected grids in Chile: Sistema Interconectado del Norte Grande (SING) is the grid in the north of the country, hosting 28.06 per cent of the installed capacity in the country; Sistema Interconectado Central (SIC) is the grid in the central part that hosts 71.03 per cent of the installed capacity and is strongly hydro dominated; Aysen system and Magallanes system, both in the south, host 0.29 per cent and 0.62 per cent of the installed capacity respectively.

The total installed electricity generation capacity connected to the grids is 17,530 MW.[4] Additionally, approximately 700 MW are owned by private entities for self-generation.

Chile's electricity is generated mostly from fossil fuels (natural gas, coal, fuel and diesel). Hydropower however, plays an important role as well (figure 1).[5]

Small hydropower sector overview and potential

Hydropower resources are available mainly in the central and southern areas of the country (included in the SIC grid) and the Aysen and Magallanes regions. Hydropower resources are scarce in the north (the Atacama Desert area) - one of the driest places on Earth.

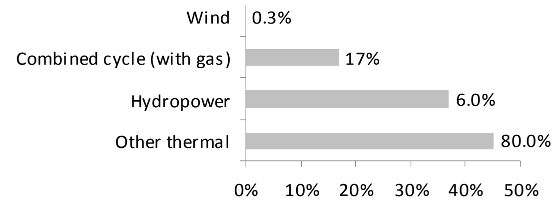

Figure 1 **Electricity generation in Chile**
Source: Instituto Nacional de Estadística[5]

According to La Comisión Nacional de Energía (CNE), there are currently 42 small hydropower plants in Chile connected to the above-mentioned grids, with individual capacities ranging between 0.1 MW and 20 MW. The total installed capacity of small hydropower is 261.02 MW.[3] The hydropower power ranges commonly used in Chile are: pico hyro: 200W–5kW; micro hydro: 5.1–100 kW; mini hydro: 101–2,000 kW; small hydro (small hydropower): 2.1–20 MW.[3] For the purpose of this report, the 20 MW-limit for small hydropower will be used. Apart from that, 17 new projects are under construction. They will add 120 MW to Chile's small hydropower installed capacity. Also, 26 projects have been approved recently accounting for 174 MW in total.

Three hydropower plants (27.3 MW) that are located in Bonito, Pulelfu and Renaico are planned to be completed in 2013. These new plants will contribute towards reaching the 990 MW goal the SIC has planned to install during 2013. Moreover, another 158 MW will be added during the summer with the construction of the hydro plant Los Hierros de Besalco (23 MW), Laja I (34.4 MW) by GDF Suez, and two other hydro plants of 40 MW each under the supervision of HydroChile.[6]

Chile is endowed with a total hydropower potential of about 60,000 MW. The Chilean Association for Small and Medium Hydroelectric Plants (APEMEC) reports, in its May 2012 bulletin, a mini-hydropower potential between 7,000 MW and 17,000 MW was estimated by the Energy Ministry (figure 2).[7] This theoretical potential is located in the central and southern regions of Chile.

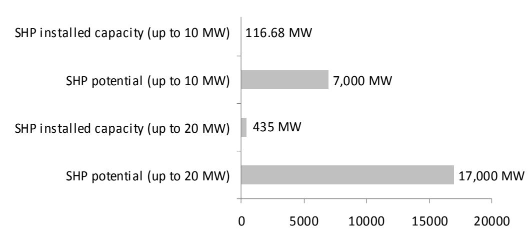

Figure 2 **Small hydropower capacities in Chile**

By means of the international agreement for stabilization of greenhouse gases in the atmosphere, the UNDP Global Environment Fund (GEF) had co-financed the Barrier Elimination for Rural

Electrification with Renewable Energies Programme (US$6 million).[7] This programme has been managed together with CNE, generating projects for rural electrification.

In recent years, because of climate change, rising carbon dioxide levels and the Renewable Energy Law, mini hydropower and small hydropower projects have become profitable and are planned and constructed for interconnection to the grid as well as off-grid/isolated. Some of the abandoned old mini hydropower plants are in rehabilitation stage.

There are many irrigation channels in Chile which can be used for mini and small hydropower plant projects. These are being promoted by the National Irrigation Commission (CNR) and CNE.

Small hydropower currently plays a flagship role in the clean energy sector. The country has a significant value chain for small hydropower, offering services in turbine manufacturing, building, engineering, operations and maintenance and power purchase.[9]

Renewable energy policy

The Ministry of Energy (Ministerio de Energía) is the Government organization for preparing policy for promotion of Alternative Renewable Energy (ARE) or Non-Conventional Renewable Energies (Energías Renovables No Convencionales, ERNC). The promotion is reinforced by means of the Renewable Energy Law (Ley Eléctrica de Energías Renovables) and Electricity Short Laws I & II (Leyes Eléctricas Cortas I y II). The main promotion strategy with both laws is: free energy transit through the interconnected electric systems grid for small ARE plants of less than 9 MW capacity and proportional transit fees for power between 9 MW and 20 MW; the electric distribution companies must purchase the energy generated by all types of small ARE plants at a price fixed periodically by the Ministry of Energy.[2] The ARE plants include small hydropower, wind power, geothermal power, solar photovoltaic (PV), alternative fuels (biogas, biodiesel), tidal and marine power and thermal biomass plants.

Today ARE generation is about three per cent in total. Moreover, the generating companies must produce at least 8 per cent of the total generated energy by ARE, before the year 2020 and a further increase up to 10 per cent before 2024 is planned.[7]

The Chilean Environmental Protection Ministry is responsible for environmental protection. The Environmental Impact Assessment (EIA) and the Declaration of Environmental Impacts ('DIA' in Spanish) are carried out and financed by the investor. The environment assessment procedure has guidelines on the following aspects:

- Policy and Procedures for carrying out, obtaining review and approval of environmental assessments;
- Guidelines for the preparation and review of Environmental Reports (EIA and DIA);
- Guidelines for public consultation;
- Guidelines for sensitive and critical areas (historical, archaeological and original people sites);
- Chilean environmental legislation and the National Environmental Quality Standards.

All small hydropower development projects with capacities higher than 3 MW and/or water flow higher than $2m^3/s$ follow the legal framework for EIA, which forms an integral part of the feasibility study.[7] Smaller projects only have to prepare an Environmental Impact Declaration Report, much shorter than an EIA.

The Citizen-Technical Parliamentary Commission for Policy and Electric Matrix (Comisión Ciudadana Técnico Parlamentaria para Política y la Matriz Eléctrica, CCTP), proposes structural changes to the electrical development model, for optimization of the administration and the institutions involved in the Chilean electric market. One of the proposals is the obligation for electricity generating companies to deliver 20 per cent electricity from renewables by 2020, to ensure sustainable development with low generation costs. Another proposal is an effort to reduce energy consumption; the estimations said that the electrical consumption of the country could be reduced by 15 per cent by 2020. The potential of renewable energy resources for the country is about 190,000 MW, which is 11 times the current installed power.[8]

Legislation on small hydropower

Laws 19940 and 20018 promote non-conventional renewable energies such as geothermal, wind, solar, biomass, co-generation and small hydropower. In the first case, these types of energies can deliver the generation to the grid free of transportation charges below 9 MW and with partial payment between 9 and 20 MW. In the second case, law No. 20018 grants project owners five per cent of the total electricity distribution rights to meet the total demand for regulated purchasers.

Barriers to small hydropower development

The main administrative barriers to small hydropower development in Chile are:

- Long lead times (about one to two years);
- Too many state organizations involved in authorizations and insufficient coordination among them.

The main technical barriers to small hydropower development in Chile are:

- Difficulties and high costs for small hydropower connection to the secondary (medium voltage) grids because of lack of transportation capacity on existing lines, thus hindering the transport to the main grid lines;
- Small/mini hydropower schemes are generally projected in remote areas near the Andes Mountains, without grids nearby.

The main political barrier is the lack of a clear energy development programme for the country.

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2.3.5 Colombia

Elena Quiroga Fernández, International Center on Small Hydro Power

Key Facts

Population	45,239,079[1]
Area	1,138,910 km[2]
Climate	Tropical along coast and eastern plains; cooler in highlands[1]
Topography	Flat coastal lowlands, central highlands, high Andes Mountains (highest point: Pico Cristóbal Colón, 5,775 m), eastern lowland plains[1]
Rain pattern	Average annual precipitation over land is 500mm, but varies greatly from year to year and from place to place. On average, it rains mostly in the regions of El Choco due to the concentrated air humidity originated in the Pacific ocean accumulating at the Cordillera Occidental and producing 3,000 to 12,000 mm per annum[2]

Electricity sector overview

Colombia's electricity and energy sector is under the jurisdiction of the Ministry of Energy and Mines. Currently Colombia has a total installed capacity of 14,424 MW.[3]

The Colombian energy industry comprises both public and private players. Private sector involvement was opened up through deregulation in 1990. La Comisión de Regulación de Energía y Gas de Colombia (CREG) is one of the main participants with regulatory oversight within the sector.[4] The Colombian National Transmission System (STN), a monopoly by nature, is the middle man between the generators and the traders and is regulated by CREG.[5] Eleven companies are involved in transmission from which, the Government runs the company, Interconexión Eléctrica S.A. E.S.P. (ISA), and controls 83 per cent of the market.[5]

The supply of Colombian electricity is based on the National Interconnected System (SIN) which is one third of the territory and covers 96 per cent of the population. Other local systems in the non-interconnected areas (ZNI) provide the remaining four per cent of the population mainly residing in the east of the country.[4]

In 2010, Colombia saw its highest growth for renewable generation at 14 per cent totaling to 2,543 GWh.[6]

In 2011, Colombia imported 8 GWh and exported 1,294 GWh.[3] In 2010, 72.8 per cent (57,300 GWh) of Colombia's electricity is produced by renewable energy sources, whereas its renewable electricity capacity corresponds to 67.1 per cent (9.1 GW) (figure 1).[8] Colombia has wide non-interconnected areas (52 per cent of its territory), and although these areas have a high renewable energy potential, there is a more intense fossil fuel based electricity expansion rather than an adequate renewable strategy.[9]

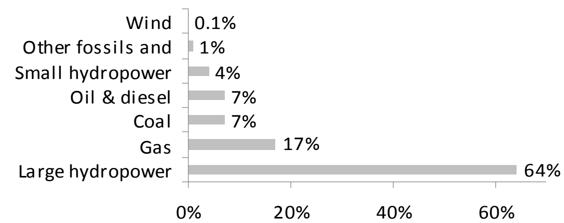

Figure 1 **Electricity generation in Colombia**
Source: XM S.A. E.S.P.[7]

Small hydropower sector overview and potential

The definition of small hydropower in Colombia seems to be ambiguous and inconsistent in many documents (see section on Legislation on small hydropower). In 2010, the total estimated small hydropower potential was 25,000 MW.[7 9]

According to the legal framework, small hydropower is only considered as renewable energy if it is under 10 MW.[9] In 2012, the small hydropower installed capacity was 171.52 MW (up to 10 MW) and the author's calculations indicate that the installed capacity for plants 10-20 MW was 512 MW, however 591 MW (according to the countries small hydropower definition of up to 20 MW) is reported (figure 2).[7] Small hydropower provided five per cent of the total electricity generation in 2010.[6]

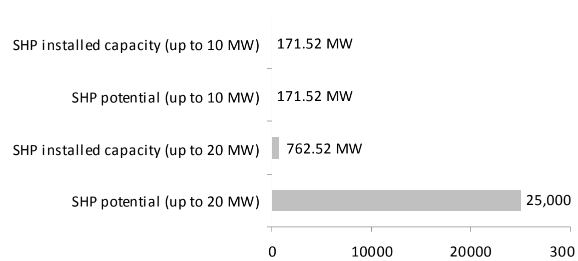

Figure 2 **Small hydropower capacities in Colombia**
Sources: International American Development Bank and the Colombian Ministry of Mines and Energy[9], XM S.A. E.S.P.[7]

Small hydropower is seen in Colombia as an attractive potential electricity generation technology due to the low construction investment required and its adequacy to supply off-grid rural areas with electricity. The Colombian Government is currently working on small hydropower implementation projects in currently off-grid areas.[9]

Between 2006 and 2011, Colombia experienced clean energy investments totalling to US$1.06 billion, with the clean energy sector dominated by biofuels and small hydropower, which gained 48 per cent and 37 per cent of cumulative investment, respectively.[6]

Currently, small hydropower projects in Colombia are financially attractive, but in addition to this positive outlook, studies indicate that future cost scenarios for small hydropower, along with modern biomass, are expected to improve, making them strong contenders in the future market, given that the Government favors these technologies.[9] There is at least one local company for turbine manufacturing and at least one company for operations and maintenance active in the small hydropower sector.[6]

Renewable energy policy

Environmental laws have been applied in Colombia since the late 1990s concerning general ecological aspects and environmental impacts. However, all legislation concerning renewable energies were initiated in 2001.[11] Law No. 697/2001 and its Regulatory Decree 3683 of 19 December 2003 provide certain incentives for scholarship, research and development for renewable and alternative energy sources.[11]

Since 2002 various tax based incentives have been incorporated into Colombian policy, such as income tax exemptions for biomass and wind generation and exemption from import duty on all equipment related to carbon credits.[6]

Thereafter, resolution 18-0919 on 1 June 2010 adopted the 2010-2015 Indicative Plan of Action to develop the Program on Rational and Efficient Use of Energy and other forms of Non-Conventional Energy (PROURE). PROURE gives high priority to several lines of action related to the promotion of non-conventional energy sources, for instance the characterization of the country's small hydropower potential, for which the required investment is estimated to be Col$300 million.

Legislation on small hydropower

According to Article 3.14 of Law 697/2001, which establishes and promotes the rational and efficient use of energy as well as the use of alternative energy devices, small hydropower is defined as the potential energy gained from a hydraulic flow on a certain altitude not exceeding 10 MW of electricity production.[10] In addition, Law No. 697 makes available incentives for research and development in the field of small hydropower.[11]

Legislation surrounding small hydropower does not consist of significant financial tax or subsidies. However a few incentives have been implemented such as research grants, tax exemptions and reliability charge exemptions for small hydropower (<20 MW).[7]

Moreover, the Government's recent engagement to determine the quantity and localities of non-conventional energy sources (Fuentes No Convencionales de Energia) is in the process of producing a multi-year average small hydropower potential map.[9]

Barriers to small hydropower development

Although small hydropower plays a vital role in Colombia's energy sector, it is not without its problems. The main concern surrounding small hydropower relates back to the El Niño event (1991/1992) and climatic variations which produce lower rainfall that impact energy production.[12] In addition to climatic variations, governments are inclined to reduce concrete small hydropower promotion strategies and incentives to slow down small hydropower development and implementation in Colombia due to the fear of high dependency on a climatic vulnerable energy source.

Although microfinance institutions (MIFs) are available in Colombia, only 3 out of the 29 MFIs offer low-income loans for micro, small, medium and large borrowers, thus significantly reducing the support available for small hydropower investors.[6]

Small hydropower growth is also disadvantaged by the lacking of support systems that would help to identify mechanisms that could be better suited to the characteristics of Colombia coupled with a deficit in outlined budgeting for scientific research and development. Definition and standardization of technical norms and a lack of rural and urban technical support also hinder the growth of the small hydropower sector.[13]

Moreover, local political instabilities also strongly hinders foreign investment in small hydropower; many sites are located in areas where guerilla activities have taken place.[12]

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2.3.6 Ecuador

Marcela Portaluppi, Corporación Nacional de Energía, Ecuador; Oscar Antepara and Alfredo Barriga, ESPOL

Key facts

Population	115,223 680[1]
Area	256,370 km[2]
Climate	Tropical along coast and in Galapagos, becoming cooler inland at higher elevations; tropical in Amazonian jungle lowlands[1]
Topography	Four defined regions: the Amazon, the Highlands, the Coast, and the Galapagos Islands (highest point: Chimborazo 6,267 m)
Rain pattern	Variable, depending on location and elevation, ranging between 300 mm in the south coast and 5,000 mm in the Amazon basin[3]

Electricity sector overview

The effective electricity generation capacity in Ecuador reached 5,090 MW in July 2012. In 2011, 20,544 GWh were generated (excluding electricity imports from Colombia and Peru). According to the 2010 country census, 93.1 per cent of the households in Ecuador have access to electricity services provided by one of the 20 electricity distribution companies.[4] The Ministry of Electricity and Renewable Energy (MEER) is the Government entity in charge of the national policy regarding the electricity supply.

Ecuador's electricity is generated mostly by hydropower and fossil fuels (natural gas, coal, fuel and diesel). Figure 1 depicts the gross electricity generation for 2011, as published by the Ecuadorian National Electricity Council (Consejo Nacional de Electricidad, CONELEC).[4]

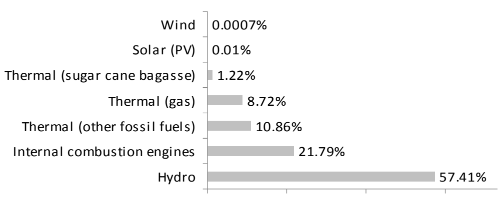


Figure 1 **Electricity generation in Ecuador**
Source: Consejo Nacional de Electricidad[4]

The hydrological system of Ecuador is highly influenced by the Andean mountain chain that crosses the country from north to south. The Andes divide the country into two slopes - one ranging from the top of the mountains to the Pacific Ocean (Western region) and one leading towards the Amazon jungle, (Eastern region). The western region holds 24 basins, which represent 48 per cent of Ecuadorian territory, and the eastern region holds seven basins, which represent 52 per cent of the country territory.

The former Ecuadorian Institute of Electrification (INECEL) conducted in-depth studies on the vast hydropower potential of the country during the 1970s and the 1980s.

Small hydropower projects of less than 5 MW have been on hold recently due to official preference for large hydropower; nevertheless, the present report will try to evaluate the current status of these projects, and ascertain their possibilities and prospective implementations.

Small hydropower sector overview and potential

Small hydropower projects (with capacities up to 10 MW) in operation in Ecuador amount to a cumulative nominal power of 76.54 MW, 74 per cent of which are owned by the Government and 26 per cent are owned by private companies.[5] The total electricity produced by small hydropower in 2010 was about 308.02 GWh.[5]

The small hydropower potential in Ecuador has been identified by various governmental institutions and in various publications since 1997. The remaining small hydropower potential (for capacities up to 10 MW) is around 306 MW and encompasses only those projects to be installed (economically or technically feasible) (figure 2).

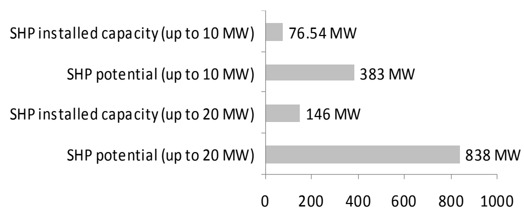


Figure 2 **Small hydropower capacities in Ecuador**

Until the national grid was built and came into operation, there were many small hydropower generation projects that provided electricity to the nearest communities (during the 1960s, 1970s and into the 1980s). Once the national interconnected grid was operational and many of those communities were connected to a network that provided a better service, the small hydropower plants were gradually abandoned.[6]

The Ministry of Electricity and Renewable Energy of Ecuador and the Association of Mechanical Engineers from the Pichincha province developed an inventory of all these projects in 2008 and evaluated the possibility of recovering them. A total of, then old, small hydropower projects with a cumulative installed capacity of 8.72 MW were considered eligible for restoration.[7]

Renewable energy policy

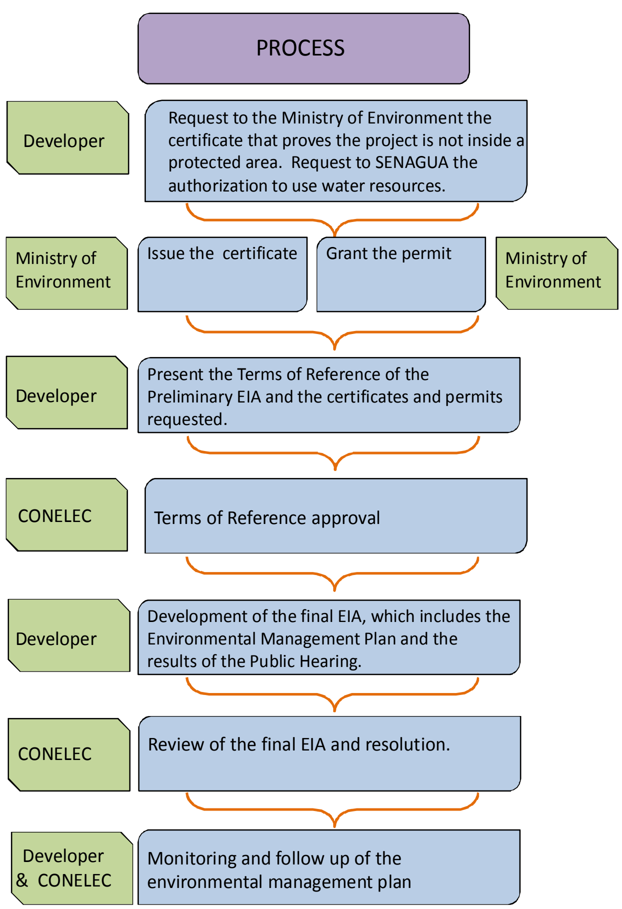
The Constitution of Ecuador, approved by the Ecuadorian people in 2008:[4]

- Chapter I. Art. 3. - To protect the natural and cultural assets of the Country.
- Section II. Art. 15. - The Government will promote the use of clean and alternatives technologies in the public and private sector. The energy independence shall not compromise the food independence or the right of the people to water.
- Regulations No. 004/011 issued by the CONELEC, specifying the requirements for renewable energy projects, the prices of the energy depending on the source, the time period during which the prices will be valid, and the preferential dispatch to the grid (table)

Energy prices in Ecuador

(US dollar cent/kWh)

Type of plants	*Continental territory*	*Galapagos Island*
Wind	9.13	10.04
Solar	40.03	44.03
Biomass or Biogas <5MW	11.05	12.16
Biomass or Biogas >5MW	9.60	10.56
Geothermic	13.21	14.53
Hydro <10MW	7.17	..
Hydro >10MW, <30MW	6.88	..
Hydro >30, <50MW	6.21	..



These prices will be valid for 15 years. For renewable energy projects, the State does not recognize a fixed charge, which usually the State pays to the generation plants for being available to start at any time.

- Regulation No. 009/08, issued by CONELEC, is applicable to all projects with power not exceeding 1 MW. The developers of the projects will not need a license to operate. Instead they have to register the project on CONELEC after getting the permit from the National Water Resources Secretariat (Senagua) to use the water for industrial purposes and the certificate from the Environmental Ministry that certifies that the project is not located in a National Protected Area.
- For all projects with power exceeding 1 MW, the project developer has to follow the process shown below in figure 3.

Legislation on small hydropower

Regulation No. 009/06 issued by CONELEC, defines small hydropower as power generation from hydropower plants with installed capacity of less than or equal to 10 MW. The Electric Law (1996) was modified in 2010 pending approval. The changes establish a mechanism to promote the spread of unusual renewable energies (ERNC). Companies will have to generate at least 5 per cent of renewable energy from 2010 until 2014. Small Hydropower dams with less than 20 MW are included.[9]

Figure 3 **Hydropower project development process in Ecuador**
Sources: Galárraga Sánchez[8]

Barriers to small hydropower development

• Instability in the Electricity Generation Market. During the last four years (2007-2011), the Government policy for the electricity sector has switched from an open market for generation (where the generators could sell their electricity on the electricity wholesale market) to a more state-centred market. For this reason, private investment into new generation projects was limited until the new rules of the market were established. In 2011, CONELEC issued regulations No. 002/11, No. 003/11 and No. 004/11, which determine that the State will promote private investment in renewable energy projects.

• Lack of Tax Incentives for Private Investors

With the new regulations, the investors of renewable energy projects will have a preferred price for each kWh sold to the grid and the certainty that the electricity generated will always be bought by the State (as long as it does not surpass 6 per cent of the total generation available in the country). However, investors cannot count on any incentives for revenue tax reductions.

• Large projects receive all the attention

In 2010, the country underwent an extended dry season which caused electricity shortages, with ensuing blackouts which concerned the population and slowed down the economy. The Government introduced plans for projects to counteract this situation. These projects were divided in two categories: the first one comprises large thermoelectric plants with internal combustion engines that started to be installed in 2011; this process will last until 2013. The second category is composed of large hydropower projects programmed to start operating in 2015. With this new priority to build large hydropower projects to prevent electricity shortages, small hydropower has been pushed behind in the list of State priorities.

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2.3.7 French Guiana

Laxmi Aggarwal and Lara Esser, International Center on Small Hydro Power

Key facts

Population	200,000
Area	91,000 km^2
Climate	Tropical; hot, humid; little seasonal temperature variation[1]
Topography	Low-lying coastal plains rising to hills and small mountains
Rain pattern	One rainy season from mid-November to late January and another more significant one from late March to early July. Average annual rainfall of 1,700 mm in the north-west, 3,800 mm in the Regina-Cacao region, 3,000 mm in the coastal areas and 2,500 mm in the interior[2]

Electricity sector overview

The total installed capacity in French Guiana for electricity generation is 285 MW. A detailed description of the installed capacity in French Guiana as of July 2012 can be seen in table below.[3]

Grid connected electricity generation capacity in French Guiana

Owner	*Site*	*Type*	*Installed capacity (MW)*
EDF	Degrad des Cannes	Diesel	71
EDF	Degrad des Cannes	Gas turbines	2 x 20
EDF	Kourou	Gas turbines	20
EDF	Petit Saut	Hydropower	4 x 28.4
Voltalia	La Mana	Hydropower	4.5
Voltalia	Kourou	Biomass	1.7
Multiple owners	multiples	PV	34
Total			**284.8**

Source: EDF and Direction des Systemes Energetiques Insulaires[3]
Note: EDF - Électricité de France, PV – photovoltaic. Data as of July 2012.

It can be seen that the main player in the French Guiana electricity generation field is Électricité de France (EDF) that is mainly focusing on gas and hydropower resources primarily via the Petit-Saut dam which produces 50-70 per cent of electricity used by French Guiana.[4] In 2011, 838 GWh of electricity were generated in French Guiana and fed into the grid.[3] Figure 1 shows that hydropower is the greatest contributing source as of 2011, followed by thermal input, whereas photovoltaic and biomass make a smaller contribution.

Small hydropower sector overview and potential

Electrification in French Guiana was only recently realized in 2005 using hydropower. Electrification of Antecume Pata was materialized thanks to a micro-hydropower plant (50 kW). There are two small hydropower plants in French Guiana, La Mana with an installed capacity of 4.5 MW and Saut-Maripa with a capacity of 0.88 MW. There is also a micro hydropower plant (100 kW). There is still potential for greater hydropower generation (figure 2).[5 6]

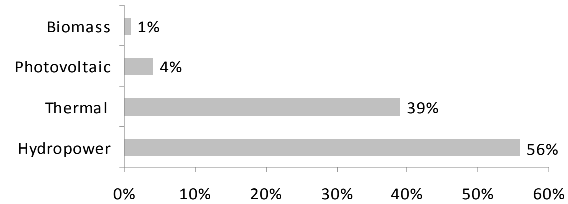

Figure 1 **Electricity generation in French Guiana**
Source: Électricité de France and Direction des Systemes Energetiques Insulaires[3]

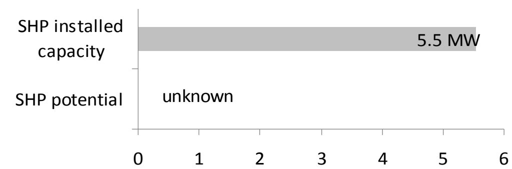

Figure 2 **Small hydropower capacities in French Guiana**

Special conditions prevail in non-interconnected power systems in areas described as 'island' by the European Community, which do not allow the emergence of a competitive market in the energy sector. Therefore French Guiana, as an overseas territory of France, has an exemption specially set by the European Community in favour of 'small isolated systems'.

As a result, utilities in French Guiana are not required to separate their network management from their business. EDF continues to integrate all the electrical trades to ensure the public service. As such, they are committed to generate electricity in competition with other producers; purchase all electricity produced in the territory; running 24 hours to ensure power system balance between customer demand and supply of electricity producers; the transportation and distribution of electricity to all customers.

Renewable energy policy

French law is applicable in French Guiana. However it can be altered to meet its specific characteristics (on the basis of Article 73 of the Constitution), therefore the Climate Plan to reduce GHG emissions by a quarter by 2050, also applied to French Guiana. Thus, the National Assembly voted for the Grenelle de l'Environnement (Environmental Forum) law in October 2008. This law applies to the French overseas departments of which French Guiana is a part of. The law states that "energy independence shall be achieved by reaching an objective of 50 per cent of final energy consumption in French Guiana, Guadeloupe, Martinique, and La Réunion from renewable sources by 2020, and that exemplary programmes, specific to each department, shall subsequently be developed with the end goal of achieving energy independence by 2030”.[4]

In addition, French Guiana has a Regional Development Strategy (La Stratégie Régionale de Développement pour la Guyane), which identifies the challenges and solutions of the region, such as basic infrastructure, local employment and endogenous economic development. Under the development of infrastructure, the issue of access to energy is addressed. This section aims to achieve access to energy and a self-sufficient status “by developing local, green sources: biomass, hydropower, wind turbines and solar”.[7]

Barriers to small hydropower development

The trepidation of a re-occurrence of the El Nino phenomenon plays a crucial role in the Government’s decisions to increase dependence on small hydro and as a whole as an energy source. The geographical barrier stems from the specialty of French Guiana, which has a vast landmass with clearly separated coastal and inland areas, coupled with a flat topography, which makes it more difficult to develop small hydropower.[4] However, French Guiana is faced with other challenges that strongly hinder the development of small hydropower, more so than natural climatic variations.[4]

The most important factors that impose on development are geographical isolation and high demographic growth. Borders with Brazil and Suriname suffer from a lack of control which results in high crime rates preventing foreign investment in the region.[6] Also, lacking incentives and technical standardization as well as the low population density makes it difficult and less attractive to develop small hydropower.[6 7]

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2.3.8 Peru

Lara Esser, International Center on Small Hydro Power

Key facts

Population	29,549,517[1]
Area	1,285,216 km^2
Climate	Coastal plain: desertic arid sub-tropical or arid tropical; Andes sierra: temperate to frigid
Topography	Western coastal plain; high and rugged Andes in centre (highest point: Nevado Huascaran 6,768 m); eastern lowland jungle of Amazon basin[1]
Rain pattern	Coastal plain: annual average up to 500 mm. Andes sierra: Annual average range 500-1,200 mm depending on altitude and location (above 3,800 m altitude as snow or hail). Wet season: December to April. Amazon basin: frequent rains all year long, especially January to April. Annual average 2,000 mm [3]

Electricity sector overview

Peru had, for a long time, successfully utilized hydropower, until natural gas was discovered and developed in the 1990s (Camisea project[i]), causing hydropower development to slow down. The Government is taking renewed interest in development of hydropower of all sizes, including small hydropower, since it is seen as a national resource that can be developed by local entrepreneurs, with minimal social and environmental impact.[4]

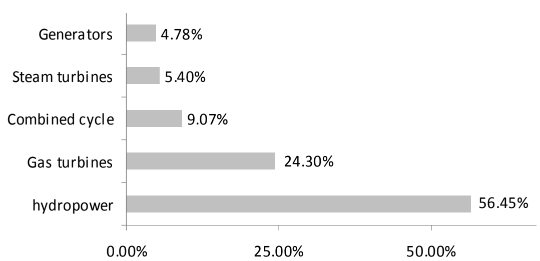

Figure 1 **Electricity generation in Peru**
Source: Ministerio de Energía y Minas[5]
Note: Data from 2010.

The electrification rate in Peru is about 78.7 per cent at the national level (2010). Mainly, scarcely populated areas lack electricity access, showing the need for electrification in rural areas. Of Peru's rural population (more than six million people), 60 per cent does not have access to electricity. This is one of the lowest rural electrification rates in Latin America. The access to grid electricity varies across the different regions: the Andean North and Amazon region have the lowest rural electrification rate (22 per cent and 18 per cent respectively) compared to the more densely populated and also more easily accessible Coastal Central and South regions (60 per cent and 71 per cent, respectively).[6]

The effective electricity generation capacity in Peru reached 8,816 MW in 2011 and its electricity generation in the national electric market and for self-consumption reached 38,509 GWh.[7]

Deregulation coupled with privatization in the late 1990s allowed private sector participation in Peru's power market allowing private players to contribute to generation, distribution and transmission.[8]

Small hydropower sector overview and potential

Development of the hydropower resources of Peru started over a hundred years ago. Particular advantages for this development were the accentuated topography on the Pacific side of the Andean chain with its many rivers, and augmentation of the dry season flows by snowmelt. Hydropower plants were intended for the supply of local electricity demands and, increasingly, the requirements of the mining industry. In the second half of the last century, regional power networks emerged and hydropower development began to encompass large-scale schemes.

In 2011, the total installed hydropower capacity in Peru was 3,453 MW.[7] According to the Ministry of Energy and Mining (MEM), in 2010, there were 136 small hydropower plants in 2010 with a combined capacity of 254.32 MW and individual capacities up to 10 MW.[5] Out of the 136 small hydropower plants, 57 were connected to the grid and 78 were stand-alone plants. Additionally, 105 plants generated electricity for the national interconnected system and 30 plants generated electricity for self-consumption (mostly mining companies).

Eleven small hydropower projects were under construction in 2011, adding 69.4 MW of small hydro-power capacity.[4] [6] The individual power capacities range between 1 MW and 10 MW.

There have been three purchase auctions for electricity from renewable sources (including small hydropower below 20 MW, wind and biomass). In the case of small hydropower, the first auction has awarded approximately 170 MW of small hydropower with capacities below 20 MW which should start construction in 2012. The power purchase contracts run up to 20 years at rates higher than the regulated market and with an additional bonus for being renewable. More auctions are expected to promote renewable energies in the future.[9]

There are possibilities for incorporation of small hydropower projects in existing hydraulic structures (at reservoir outlet works, canal drop structures, etc.). Assuming a similar ratio of total installed capacity to irrigated areas in Peru as in Chile, Peru possibly has a potential of 510 MW for small- to medium-hydropower plants that could be incorporated into existing irrigation infrastructure (figure 2).[4]

The gross small hydropower potential (up to 20 MW) is 170,000 MW, while both the technical and economic potential is reported as 69,445 MW in a questionnaire by the Ministry of Energy (figure 2).[10]

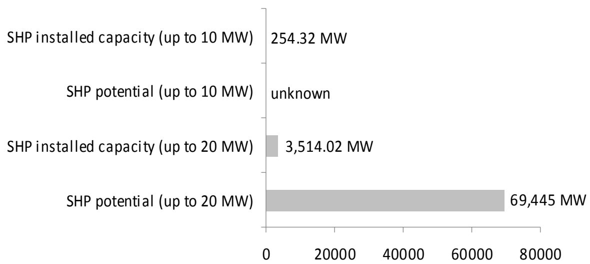

Figure 2 **Small hydropower capacities in Peru**

The Rural Electrification Project assisted by the World Bank will provide a more reliable assessment of the technical potential for small- to medium-sized hydropower development through a new Hydro-GIS study underway by MEM. It should be noted that the technical potential will not be necessarily economically or financially feasible.

There is sufficient local capacity for project design, local topographic, geological and hydrometric investigations, and a number of firms that offer up-to-date services. There are also a number of national and international consulting engineering companies that can carry out project design services. There is also sufficient capacity for environmental services, including EIA and a number of locally based companies offering services relating to the Clean Development Mechanism and the acquisition of carbon credits.

With regard to equipment and manufacturing, there is technical capacity available in Peru for manufacturing small hydropower components and related piping. This helps lower the costs of small hydropower.[9] There is at present only one manufacturing company in Peru that manufactures Francis and Pelton turbines, suitable for small hydropower projects with medium to high heads. Other companies manufacture cross-flow turbines of the Mitchell-Banki type. The maximum size of Pelton or Francis turbines currently manufactured locally is 5 MW. Projects with large unit sizes are therefore subject to the current rapidly increasing prices of turbines on the international market, as well as to the increasingly long delivery times. Most hydraulic steel structures (gates, valves, etc.) required in small hydropower projects can be manufactured in Peru, although equipment for opening/closing (servomotors) may need to be imported. Transmission lines at the voltages associated with small to medium sized hydropower projects, including towers and cables, can also be manufactured in Peru, with some components (e.g. insulators) being imported.[4]

A few years ago, hydropower equipment manufactured from China was imported to Peru with acceptable technical quality and economic costs (compared to U.S. or European alternatives in the range between 0.5 MW and 5 MW). Power projects up to 20 MW are likely to use Chinese manufactured equipment.

Renewable energy policy

Rural electrification is promoted by the Law on Rural Electrification (Ley de Electrificación Rural y de Localidades Aisladas y de Frontera), enacted in 2002. It clearly states the objective of fostering socioeconomic development and establishes a fund for rural electrification, which is administered by the General Directorate of Rural Electrification (Dirección General de Electrificación Rural), a division of the MEM. After the implementation of the project, management is transferred to a public enterprise – Electric Infrastructure Administration Enterprise (ADINELSA).[11]

The funding for rural electrification projects is centralized at the National fund for Rural Electrification (Fondo Nacional de Electrificación Rural). Besides government support, funding is also acquired from the International Bank for Reconstruction and Development and the Global Environment Facility. Between 2007 and 2009, 4,000 households (20,000 people) were provided with grid access via the Energising Development Program, financed by the Netherlands Directorate General for International Cooperation (DGIS) and implemented by the German Technical Cooperation Agency. According to the Renewable Energy Rural Electrification Plan, the goal is to electrify about 260,000 households with PV and about 20,000 with small hydropower by 2020.[11]

On 2 May 2008, the Government issued a Renewable Energy Decree for the promotion of electricity generation using renewable energy (Decreto Legislativo de Promoción de la Inversión Para la Generación de Electricidad con el Uso de Energía Renovable). In this Decree, the Government has chosen to set a target ceiling for a share of renewable sources in electricity generation, in combination with a premium price. Although small hydropower will not be considered in the indicated ceiling it will benefit from the incentives in the law. It may be expected that small hydropower projects would compete in the auctions for the premium mainly with wind based technologies.

In addition, Peru has a clean energy mandate in place which requires a 5 per cent consumption of renewable electricity by 2013 coupled with reverse auctions to aid the capacity growth of clean energy. The period from 2009 to 2011 saw two main auctions yielding US$420 million for clean energy investment allowing Peru to achieve 588 MW clean energy capacity by 2014. However, the country has previously failed to meet its mandate of a 7.8 per cent ethanol and 5 per cent bio-diesel share which were implemented in 2007.[8]

Legislation on small hydropower

To support small hydropower, the Peruvian Congress eliminated the import duty on hydropower equipment in December 2006, and the Ministry of Economy and Finance has permitted early recovery of the value-added tax (IGV) for projects with construction periods of four years or more; however this does not apply to small hydropower projects, which on average need three years of construction. The MEM has simplified the permitting process for small hydropower projects.

Barriers to small hydropower development

With regard to financial barriers, development of small hydropower has not been financially viable in Peru, since the price of electricity is low due to the low price for natural gas from the Camisea project.[i] Carbon financing has improved the financial viability of projects.

Finding access to long-term financing for small hydropower projects has been difficult for companies without strong balance sheets, especially considering the limited interest of commercial banks in project finance and/or small-scale projects. Other issues include unrealistic risk assessments by the commercial banks, high transaction costs, and lack of long-term loans. The present 100 per cent collateral/corporate guarantee requirements of the commercial banks will remain a major barrier to all but large corporate sponsors.

Water rights difficulties have been cited as impeding the development of projects. Most developers indicated that the main problem in obtaining water rights is the unpredictable process. The lack of a specific Consolidated Text of Administrative Procedure (TUPA) is the main barrier.[4]

Under current circumstances, companies are unable to get early VAT recovery from Government (e.g. if construction time is less than four years), which negatively impacts most small hydropower projects.

Note

i. The Camisea gas field is situated in the San Martín reservoir in the Amazon rainforest. The project is one of the largest energy projects in Peru, extracting and transporting natural gas.

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2.3.9 Uruguay

Yan Huang, International Center on Small Hydro Power

Key facts:

Population	3,316,328[1]
Area	177,000 km[2]
Climate	Temperate. Summer: January to March (17-28°C). Winter: June to September (6-14°C)
Topography	Smooth terrain; average elevation 116 m (highest point: Cerro Catedral, 514 m). Undulating plains, suitable for agri-cultural and/or livestock production. Abundance of rivers, high discharge[1]
Rain pattern	Average annual precipitation: 950 mm in the south, 1,250 mm in the north

Electricity sector overview

Uruguay is highly dependent on hydropower for its electricity generation. According to the National Directorate for Energy and Nuclear Technology (DNETN), Uruguay had 1,538 MW of installed hydropower generating capacity in 2010, which represents almost 65 per cent of the installed capacity of the country (figure 1). According to the regulatory framework of Uruguay, the potential for large hydropower has already been fully developed.

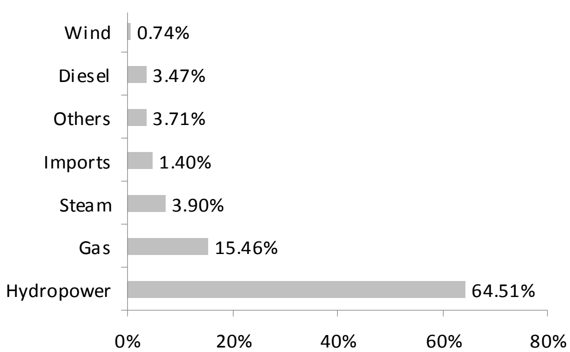

Figure 1 **Electricity generation in Uruguay**
Source: Administracion Nacional de Usinas y Trasmisiones Eléctricas[2]

In 2011, 9,806 GWh of electricity, of which 4.8 per cent was imported from Argentina and Brazil was consumed in Uruguay.[2]

Four large hydropower stations are operating in Uruguay: Salto Grande with a total installed capacity of 1,850 MW, (945 MW supplied to Uruguay and 945 MW to Argentina), Palmar with 330 MW, Gabriel Terra with 152 MW and Baygorria with 108 MW.

Small hydropower sector overview and potential

Currently there are no small hydropower plants in Uruguay (figure 2). There are 1,100 water reservoirs in Uruguay used for irrigation -mainly linked to the rice agro industrial sector- with strong potential for hydropower generation. A local study conducted by the Uruguayan State University of Engineering identified 50 sites among the existing reservoirs with individual potential below 10 MW, concluding that the national potential for small hydropower is at least 101 MW.[3]

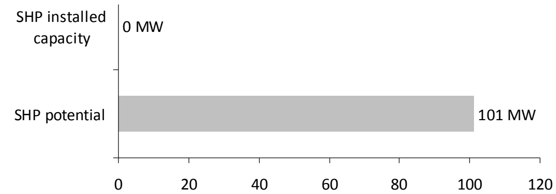

Figure 2 **Small hydropower capacities in Urugua**y
Source: Scarone[3]
Note: More potential could be identified.

Renewable energy policy

Moreover, in the Uruguayan 2005-2030 National Energy Policy, the Government has set the goal of 50 per cent native renewable sources in its primary energy matrix by 2015. Among other measures to accomplish this, non-traditional renewable energy sources (wind, biomass residues and micro-hydraulic generation) will contribute 15 per cent of the total electric generation.

In 2008 the Government issued a clean energy target of 200 MW of biomass and 300 MW of wind to be added by 2015. This is again being encouraged by reverse auctions sponsored by the Government. Other incentives for clean energy consists of tax based instruments such as tax relief.[4]

Legislation on small hydropower

In Uruguay, the electricity generation is open only with certain technical conditions. Every generator can connect with the public electric grid. But all the private generation companies must sign contracts with the electricity utility Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE), which is the only distribution and transmission operator in Uruguay.

In 2007 the Government of Uruguay offered 20 MW to be added to the grid from small hydropower, but no private investors applied. The Government still plans to develop small hydropower to promote rural development and to reach a 100 per cent electrification rate, which is planned for 2015.

Article 47 of the Uruguayan Constitution explains the utilization of water and defines the right to water and sanitation as a fundamental right for human beings. In September 2009, Law No. 18610 (Law for National Policy on Water) was approved and the Article 6 designates the Ministry of Residence, Territorial and Environmental Order to propose a national water policy.

In accordance with the requirements established by Law No. 16466 of Environmental Impact (on 19 January 1994) and enabling regulations established in regulatory code No. 349/005 (Evaluation of Environmental Impact), an environmental permit must be requested for hydropower projects with capacities exceeding 10 MW or water flows higher than 0.5 m^3/s.

Law No. 16 906 on the Promotion and Protection of Investments provides a framework for encouraging investments in the country, upon approval by the designated Commission. Enabling regulation No. 354/009 promotes the generation of electricity from non-traditional renewable sources and grants the exemption of a significant percentage of the income tax for electric generating companies at the start of business, with subsequent reductions in following years. Decree 455/007 of 26 November 2007 establishes tax benefits that may be granted (income tax deduction according to amount of investment, tax exemptions, VAT returns).

Barriers for small hydropower development

Uruguay has the technical capacity to construct medium- and large-scale hydropower, plus broad experience of constructing reservoirs or dams. However, as there are no small hydropower constructions in the country, the experience with small hydropower is not available. There are no companies dedicated exclusively to this sector.

A high electrification rate of 97 per cent leaves little room for potential foreign investors to expand or those seeking finance initiatives to connect residents to the grid.[4]

An unsuccessful attempt to reform the power sector has left a weak policy framework surrounding clean energy, which could act as a disadvantage towards potential investors. That coupled with a weak green microfinance sector with only one institution offering micro green loans makes the implementation of small hydropower or green energy in general more difficult.[4]

The topographic conditions (low head difference) and variable river flows due to variable rainfall patterns could be the causes for no small hydropower development in Uruguay.

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2.4 Northern America

Lara Esser, International Center on Small Hydro Power

Introduction to the region

North America comprises five countries and territories: Bermuda, Canada, Greenland, Saint Pierre and Miquelon and the United States of America (USA). Canada, Greenland and the USA contain exceptionally large areas with varying climate. Greenland has an exceedingly large ice-covered area (1,755,637 km^2), whereas the Canadian territory has mild temperate to subarctic and arctic areas. The climate in the USA is mostly temperate. A tropical climate is present in Hawaii and Florida, arctic in Alaska, semi-arid in the Great Plains west of the Mississippi River, and arid in the Great Basin in the southwest. The USA and Canada trade electricity between each other. Canadian provinces export, on average, 40 TWh of electricity to the northern states of USA every year. Most of that electricity is hydropower. The current power strategy of these northern states i.e. New England, New York, Midwestern states and Pacific Northwest is to purchase electricity rather than to build new plants. Canada also benefits from this inter-State energy trade, since north-south trade distances between provinces and states are shorter than if electricity was to be transmitted from east to west and vice versa within Canada. During periods of peak demand, Canada also imports electricity from the USA.[1]

Table 1
Overview of countries in Northern America

Country	*Total population (million)*	*Rural population (%)*	*Electrification access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Canada[bcd]	33.70	19	100	130 543	588 016	75 077	348 100
Greenland[ad]	0.05	16	--	140	468	69	281
USA[de]	311.50	18	100	1 040 000	4 120 000	78 200	257 000
Total	**345.25**	**-**	**-**	**1 170 683**	**4 708 484**	**153 346**	**605 381**

Sources:
a. Greenland Development Inc.[2]
b. Natural Resources Canada[3]
c. Statistics Canada[4]
d. International Journal on Hydropower and Dams[5]
e. U.S. Energy Information Administration[6]
Notes: Greenland has no main grid.

Small hydropower definition

In Canada, units of a capacity that are up to 30 MW are considered small hydropower plants; in the USA the threshold of small hydropower is 50 MW. Greenland does not have a definition yet (table 2).

Table 2
Classification of small hydropower in Northern America
(Megawatts)

Country	*Small hydropower*
Canada	up to 50
Greenland	..
United States	up to 30

Regional overview

Canada, the USA and Greenland all use small hydropower, though Greenland has only recently started using hydropower (1993). In 2012, the country has only one small hydropower plant at Tasiilaq (with an installed capacity of 1.2 MW).[2]

The US Department of Energy (DOE) has two programmes that support hydropower which include small hydropower. The Wind and Water Power Program by the DOE focuses on increasing generating capacity and efficiency at existing hydropower facilities as well as adding hydropower generating capacity to existing non-powered dams.[i] The programme also focuses on adding new low-impact hydropower, increasing advanced pumped-storage hydropower capacity and reducing potential environmental impacts of conventional hydropower production.[7] The Wind and Water Program funds the Electric Power Research Institute (EPRI) to develop market-ready and fish-friendly hydropower turbines.[7]

The DOE also supports the National Hydropower Asset Assessment Program (NHAAP), which is an integrated water-infrastructure information platform for sustainable hydroelectricity generation and management. The NHAAP includes a cross-referenced geospatial database that can be maintained, updated and integrated with other generation resource assessments on a regular basis to support water-energy research and policy planning. The database can be used to study regional patterns in generation variability, their causes, plus opportunities for upgrading hydropower facilities to stabilize and increase generation in the United States.[8 9]

Information on the total installed capacity for small hydropower plants of up to 10 MW is not available for the United States (table 3). The Federal Government of Canada has been supporting its small-scale hydro technologies through Natural Resources Canada (NRCan). In 2010, there were about 3,400 MW of small hydropower plants (up to 50 MW), including of 1,049 MW of plants with up to 10 MW.

Table 3
Small hydropower in Northern America
(Megawatts)

Country	*Potential capacity*	*Installed capacity*
Canada (up to 10 MW)	..	1 049.0
Canada (up to 50 MW)	15 000	3 400.0
Greenland (up to 10 MW)	at least 8.7	8.7
USA (up to 10 MW)	estimate 8 041	6785.0
Total (up to 10 MW)	**9 098.7**	**7 842.7**

Sources:
Natural Resources Canada[3], Greenland Development Inc[2], International Journal on Hydropower and Dams[5], adapted from National Hydropower Asset Assessment Program[8]
Note: Canada's small hydropower potential is gross and does not include potential gained from refurbishment.

There is a large untapped small hydropower potential in the region, particularly in Canada and the USA. Information on small hydropower potential, especially up to 10 MW, was not officially available for the USA as different hydropower classifications were used. The total small hydropower potential in Canada is estimated at 15,000 MW (for plants up to 50 MW); however, under the current available technologies and socio-economic conditions, only about 15 per cent is likely to be developed. The installed small hydropower capacity is expected to double from 3,400 to 7,700 MW by the year 2050. Furthermore, there is additional room for refurbishment of small and medium hydropower plants, which could add additional 1,000 MW. Growth areas can be found in areas around existing water-control dams across the country and in the North, where off-grid locations and First Nation communities depend on expensive diesel based electricity generation.[ii]

In Greenland, the potential for small hydropower is unknown. There is no main grid due to the large distances and many small and dispersed settlements. Small hydropower would be an adequate technology for isolated operations in Greenland, in conjunction with other energy sources.[5] However, more micro-scale hydropower plants are expected to be commissioned in the future.

As most of the larger, more traditional hydropower resources have already been developed in the USA, a clean energy rationale for development of small and low-head hydropower resources exist.[10] A recent study identified a 15,140 MW potential capacity in the range of 1-50 MW in the Northwest region of the USA alone, i.e. Idaho, Oregon and Washington state. However, research on small hydropower potential on existing water infrastructure has identified 397 non-powered dams, each of which has a potential capacity between 1 and 10 MW, with a total of 1,306 MW.[8] Another resource assessment identified 65 sites with a total potential capacity of about 170 MW among existing non-powered dams that are owned by the U.S. Bureau of Reclamation.[11] These assessments probably overlap in parts.

Notes

i. Non-powered dams are dams that do not produce electricity.
ii. First Nation is a term that came into common usage in the 1970s to replace the word 'Indian' in Canada. Although the term First Nation is widely used, no legal definition of it exists.

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2.4.1 Canada

Jinxing Huang, Canmet Energy, Natural Resources Canada; Kearon Bennett, International Energy Agency Hydropower Implementing Agreement

Key facts

Population	34,300,083[1]
Area	10,000,000 km^2 approximately – about 7.5% is water
Climate	From relatively mild-temperate in south, to subarctic and arctic in north. In winter, temperatures can fall below freezing point throughout most of Canada[1]
Topography	Mostly plains; mountains in the west and lowlands in the southeast[1]
Rain pattern	Average annual rainfall is 865 mm. Western and south-eastern Canada has higher than average rainfall levels. The prairie provinces (Alberta, Saskatchewan and Manitoba) are drier, with 250-500 mm of annual precipitation.[2]

Electricity sector overview

Canada's electricity mix includes hydropower, natural gas, oil, coal, nuclear power, biomass and wind power (table 1 and 2). Renewable energy sources account for 17 per cent of the country's energy supply.[3] Hydropower is the dominant source of electricity in Canada, representing 60 per cent of its electricity generation (figure 1). Coal and nuclear power are the second and third most important sources of electricity. Natural gas, bioenergy and wind have relatively small market shares but are increasingly important in the mix. Over time, the viability, importance and market share of each resource has fluctuated due to changes in fuel prices, technology and political direction.

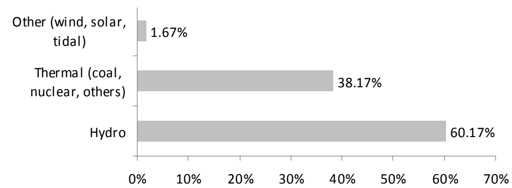

Figure 1 **Electricity generation in Canada**
Source: Statistics Canada[4]
Note: Data from 2011.

Table 1
Installed capacity of renewable energy in Canada
(Megawatts)

Type of electricity generation	*2006*	*2007*	*2008*	*2009*	*2010*
Hydro	72 644	73 443	74 387	74 688	75 077
Wind	1 470	1 824	2 229	3 026	3 973
Tidal	3	20	20	20	20
Solar	..	..	..	..	108
Total thermal	48 885	49 060	48 714	51 211	51 365
Total installed capacity	**123 002**	**124 347**	**125 350**	**128 945**	**130 543**

Source: Statistics Canada[4]

Table 2
Electricity generation in Canada
(Gigawatthours)

Type of electricity generation	*2006*	*2007*	*2008*	*2009*	*2010*
Hydro	349 468	364 055	373 822	365 108	348 110
Wind	19	22	15	29	28
Tidal	2 448	2 977	3 750	6 575	9 461
Solar	..	..	..	5	156
Other types of electricity generation	..	..	..	1 918	2 976
Total thermal generation	240 699	249 705	241 103	221 879	228 301
Total electricity generation	**592 634**	**616 759**	**618 690**	**595 514**	**589 032**

Source: Statistics Canada[4]

Canada is one of the world's largest exporters of electricity. Canada exports, on average, 40 TWh of electricity to the United States each year.[3]

Canada is a world leader in hydropower production, with an installed capacity of over 75 GW from about 475 plants. It reaches an annual average production of 350 TWh which equals to about 60 per cent of Canada's electricity demand.[4] According to the Canadian National Energy Board Scenarios, the share of hydropower in the electricity mix is expected to grow to 65 per cent by 2015, reaching 79.3 GW of installed capacity.[5]Half of the hydropower plants have a generating capacity of over 10 MW and represent 99 per cent of the total capacity. With an estimated technical potential of over 163 GW, Canada still has significant untapped hydropower resources across all provinces and territories.

Small hydropower sector overview and potential

About 3,400 MW is the installed small hydropower capacity in Canada, contributing about 4.5 per cent to the total Canadian installed hydropower capacity (table 3).The small hydropower sub-sector contributes with CAD$ 150 million (approx. US$145 million dollars) to the Canadian economy annually through local and overseas projects. Annual investments in new small hydropower generation capacity represent an estimated CAD$200 million (approx. US$193.33 million dollars). The typical investment costs range from CAD$3000 to CAD$5000 per installed kW, with an overall cost of energy of CAD$0.07 to CAD$0.10 per kWh. However, capital costs for low-head projects or projects in remote areas are usually much higher and can exceed CAD$6000 per kW.[6]

Table 3
Installed small hydropower capacity in Canada
(Megawatts)

Province/ territory	*AB*	*BC*	*MB*	*NB*	*NL*	*NS*	*NT*	*NU*	*ON*	*PE*	*QC*	*SK*	*YT*	*Total*
Capacity	424	568	23	43	803	469	67	..	498	..	345	7	127	3 372

Source: Statistics Canada[7]
Notes: AB – Alberta, BC - British Colombia, MB – Manitoba, NB – New Brunswick, NL – Newfoundland and Labrador, NS – Northwest Territories, NU – Nunavut, ON – Ontario, PE – Prince Edward Island, QC – Quebec, SK – Saskatchewan, YT – Yukon. Data from 2009.

Most small hydropower facilities provide decentralized power and are connected to local grids. These sites can respond quickly to demand fluctuations and are a reliable source of electricity for rural and remote communities. Small hydropower production also plays an important role in providing clean electricity to remote communities thus replacing costly and air-polluting diesel generation.

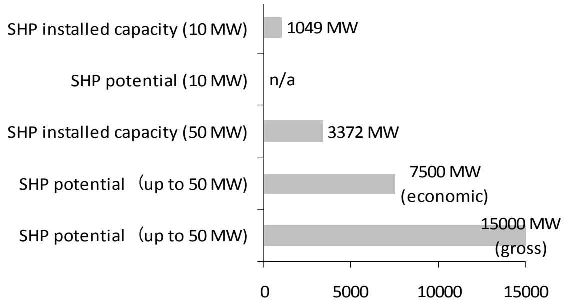

Figure 2 **Small hydropower capacities in Canada**
Note: Data from 2011.

The Canadian small hydropower industry includes around 20 equipment manufacturers and close to 70 engineering firms. Canada's small hydropower sector is fully developed, covering a wide number of technologies, products and services across the small hydropower value chain.

Canada's identified small hydropower potential is estimated at about 15,000 MW (figure 3 and table 4). Under the current socio-economic conditions, about 15 per cent of the identified small hydropower potential is expected to be attractive for development using currently available state-of-the-art technologies. Another 10-15 per cent of the feasible potential could be available with improved technologies (e.g. ultra-low-head new technology). Innovative technological advances are needed to improve the economic feasibility and address the high environmental/ecological requirements. Thus, the practical potential for additional capacity lies between 2,250 MW and 4,500 MW. The greatest potential for new small hydropower is located in British Columbia, where it is estimated that under half of the total potential could be developed for CAD$0.07 per kWh. The cost for the remaining sites in Canada is higher and varies from province to province.

There is significant potential for low-head hydropower in Canada, a portion of which could become economical viable with a reduction in equipment costs. A recent study of hydro potential in Ontario identified over 4,000 MW of low-head hydro potential, which includes some sites above 50 MW.[9] Outside of Ontario, at least 2,700 MW of low-head hydro potential has been identified in past studies (including only sites up to 25 MW). Low-head hydro potential mainly exists in sluice gates, irrigation canals, drinking water pressure-release valves, and municipal wastewater outfalls on numerous rivers. There are approximately 10,000 existing low-head dams and hydraulic structures for flood control and water supply or irrigation, which offer significant opportunities to add hydropower generation.[10] An overview on the overall small hydropower potential in Canada is given table 4.

Many existing sites require assistance or upgrade in maintenance and refurbishment. There are over 600 small and medium hydropower plants with units installed before 1965 which have a total refurbishment potential for increased capacity estimated at 1,000 MW, assuming an increase in plant production of 15 percent.[11]

Table 4
Small hydropower potential under 50 MW in Canada
(Megawatts)

Province/ territory	*AB*	*BC*	*MB*	*NB*	*NF*	*NS*	*NT*	*NU*	*ON*	*PE*	*QC*	*SK*	*YT*	*Total*
Potential capacity	200	3 529	309	614	1 200	164	106	129	3 699	3	4 387	575	57	14 972

Source: Canadian Hydropower Association [8]
Notes: AB – Alberta, BC - British Colombia, MB – Manitoba, NB – New Brunswick, NL – Newfoundland and Labrador, NS – Northwest Territories, NU – Nunavut, ON – Ontario, PE – Prince Edward Island, QC – Quebec, SK – Saskatchewan, YT – Yukon.

The estimated deployment of small hydropower in Canada by 2050 is given in table 5 according to Natural Resources Canada (NRCan), based on aggregated information from communication with various public and private utilities and companies across Canada. The installed capacity is expected to reach 7,700 MW in 2050, mostly due to developments carried out by independent power producers (IPP), provincial or municipal utilities, and remote communities.

Table 5
Estimated small hydropower deployment in Canada by 2050

Year	*Installed capacity (<50MW)*
Now	3 372
2015	4 792
2025	6 492
2050	7 742
	Additional MW
2005 to 2015 180 MW/year	1 620
2015 to 2025 170 MW/year	1 700
2025 to 2050 50 MW/year	1 250

Renewable energy policy

In Canada, incentives to develop clean, renewable or green power typically take one or more of the following forms: tax incentives, requests for proposal, standard offer programmes, net-metering and/or feed-in tariffs. The application and availability of these programs varies from province to province, and the schemes are subject to frequent amendments and adjustments.

Federal incentives and tax measures

The purchase of clean energy generation equipment, such as solar, wind and small hydro, qualifies for an accelerated capital cost allowance (Class 43.2). This allows a developer to write off 50 per cent of the cost of equipment per year (on a declining balance basis) against the tax liability.

Requests for proposal

A request for proposal (RFP) usually involves a specific acquisition target in terms of energy or power, a fixed term, minimum and maximum plant size restrictions and defined commercial operation dates. The proponent is expected to bid energy according to a fixed delivery schedule and defined tariff rates which may or may not include escalation.

Standard offer programmes

The standard offer programmes for renewable generation involve the purchase of energy using a guaranteed minimum price over a long-term contract. The price is often modified by technology and/or the size of the generator. Unlike the RFP, the standard offer price is available to all qualified proponents and may be modified by a defined escalation rate over its term. Typically, standard or standing offer programmes are aimed at small projects of less than 10 MW.

Net-metering

Net-metering allows small renewable generators to send electricity excess for their own use into the grid. This significantly reduces the costs associated with wind and solar applications as there is no battery or other storage device required. Small hydro with limited reservoir capacity could also benefit from net-metering. Net-metering is available in Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island.

Feed-in tariff (FIT) programmes

These programmes provide guaranteed grid access and stable prices under long-term contracts (up to 40 years for hydro, for example) for electricity generated from renewable sources. Ontario's FIT Programme is North America's first comprehensive guaranteed pricing structure for renewable electricity production and is offered for projects under 50 MW.

Other support

The Canadian federal government through NRCan has been supporting small-scale hydro technologies. The support of NRCan by the Canadian industry to develop and commercialize advanced small and low-head hydro and water current technologies with industry by:

- Engaging in demonstration and deployment;
- Fostering the commercialization of new technology;
- Developing infrastructure to support innovation such as standards and codes;

- Supporting the development of resource assessment data and tools;
- Supporting federal policy and programmes.

NRCan has actively cooperated with provinces, utilities, private industry, academic institutions and other organizations on key projects to reduce equipment and construction costs and increase turbine and site efficiencies as well as to support technology demonstrations at national and international level. This facilitates the realization of the additional capacities available within Canada, while at the same time helps the industry to strengthen its expertise in both products and services within Canada and abroad.

Barriers to small hydropower development

The above-mentioned incentives across Canada have helped to strengthen interest in small hydropower development. There has also been a positive policy shift to improve relations with First Nations[i] and to include them as active hydropower project partners. However, developers encounter long lead times required for approvals. Also, projects can be arbitrarily derailed by opposition during public participation processes. The most common concerns about small hydropower projects are the impact of civil works construction on stream flow, aesthetics and prevention of fish movement towards their natural habitat. In recent years, provincial governments have begun to address some of these issues and barriers using a more streamlined and sustainable watershed management approach. The federal government has recently joined this approach.

Note

i. First Nation is a term that came into common usage in the 1970s to replace the word ‘Indian’ in Canada. Although the term First Nation is widely used, no legal definition of it exists.

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2.4.2 United States of America

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Key facts

Population	313,847,465[1]
Area	9,826,675 km²
Climate	Mostly temperate, but tropical in Hawaii and Florida, arctic in Alaska, semi-arid in the great plains west of the Mississippi River, and arid in the Great Basin of the southwest; low winter temperatures in the northwest[1]
Topography	Vast central plain, mountains in west, hills and low mountains in east. Rugged mountains and broad river valleys in Alaska. Rugged, volcanic topography in Hawaii (Highest point: Mount McKinley, 6,194 m)[1]
Rain pattern	Variable, depending on location and elevation

Electricity sector overview

In 2011, the installed power generating capacity in the United States of America (USA) was 1,138 GW, and its net electricity generation surpassed 4,100 TWh.[2]

Fossil fuels and nuclear power account for 87 per cent of electricity generation in the USA (figure 1). According to the International Energy Agency (IEA), in 2009 the USA was the world's largest producer of nuclear power (830 TWh), and of electricity from natural gas (950 TWh).[3] It was also the world's second largest electricity producer from coal (1,893 TWh), and it accounts for the second largest hydropower capacity at 100 GW.[2]

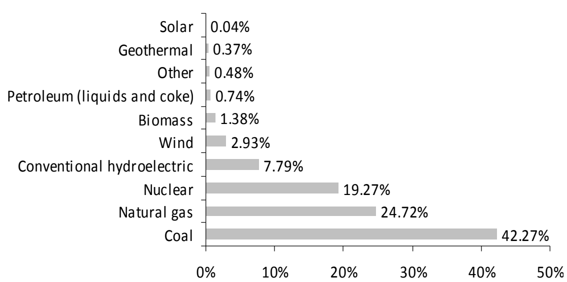

Figure 1 **Electricity generation in United States**
Source: DSIRE[2]
Note: Data from 2011.

An interim assessment of technically feasible hydropower potential by the U.S. Department of Energy (DOE) identified 372 GW undeveloped hydropower resources, divided between upgrades, retrofits, new projects, and pumped storage. The DOE Water Power Programme has set a goal of increasing U.S. hydropower capacity by 100 GW before 2050.[5]

Small hydropower sector overview and potential

The definition of small hydropower in the USA varies from state to state. It ranges from a capacity of 5 MW to a capacity of 100 MW. Currently, 92 per cent of existing turbines in the USA are classified as small or low power. These types of plants account for 20 per cent of the existing hydropower generation capacity, but they are part of a much larger proportion of the country's under-developed potential.[5] The installed capacity of hydropower plants up to 10 MW can only be estimated (table 1, figure 2)

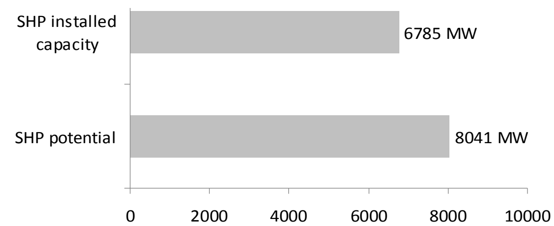

Figure 2 **Small hydropower capacities in the United States of America**
Source: Author's calculations, U.S. Department of the Interior, Bureau of Reclamation, Power Resources Office[9], Department of Energy[11]
Note: Data provided for plants up to 10 MW.

Small hydropower presents a significant opportunity for increased electricity generation in the USA. Several studies assessing the US small hydropower potential have been carried out, with varying results. The Electric Power Research Institute (EPRI) estimates that by 2025, some 2,700 MW could come from new small- and low-power hydropower projects, and a further 3,000 MW could be developed from in-stream hydro-kinetic projects.[7] [i]

An assessment by Idaho National Lab (INL) (2006) on the potential for development of small- and low-head hydropower generation in the USA identified around 5,400 of 100,000 sites. Small hydropower is defined as providing between 1 and 30 MW of annual mean power, while low-head hydropower usually refers to sites with a head i.e. elevation difference of less than five meters.[7]

A pilot study by the INL for the Northwest Region (i.e. Idaho, Oregon and Washington State), developed and demonstrated a methodology capable of comprehensively modeling sites in a large region using a stream-obstructing dam development model [8] The result shows 5,439 stream reaches with 15,140 MW total potential in the Northwest Region (small hydro definition of 1-50 MW). The candidate stream reaches are not located in the exclusion zones and have site characteristics within technically reasonable limits, however further detailed assessment of individual sites will be required to determine technical and economic feasibility.[8]

Table 1
Status of small hydropower in the United States of America

Installed capacity in range (MW)	*Number of plants*	*Estimated minimum capacity (MW)*	*Estimated maximum capacity (MW)*
<0.2	525	-	10.45
0.2 – 0.5	633	126.6	310.17
0.5-1	674	337.0	606.60
1-2	561	561.0	1 065.90
2-5	730	1 460.0	3 577.00
5-10	368	1 840.0	3 676.00
Total	**3 491**	**4 324.6**	**9 246.12**

Source: Based on Smith, with author's own calculations[6]
Note: Data from 2011.

Apart from the significant potential for new small hydropower plants, there is an untapped potential for small hydropower development on already existing infrastructure.

The U.S. Bureau of Reclamation (BR) is the largest water supplier in the USA, owning and operating 188 water projects across the western states which include dams, reservoirs, canals, diversion dams, pipelines, and other distribution infrastructure. BR also generates hydropower through 58 power plants and 194 generating units in operation at BR-owned facilities. It is the second largest producer of hydropower in the USA, after the U.S. Army Corps of Engineers. A resource assessment for non-federal hydropower development opportunities on existing non-powered BR dams (NPDs) has concluded that substantial hydropower potential exists in the five regions (i.e. Great Plains, Lower Colorado, Mid-Pacific, Pacific Northwest, and Upper Colorado) covering 17 western states under the jurisdiction of BR. More than 70 sites with small hydropower potential between 125 kW and 26 MW, with a total potential capacity of 225 MW (and 100,000 GWh/year) hold a benefit cost ratio of 0.75 (considering green incentives) and should be further considered. When only considering those sites in the capacity range up to 10 MW, there are 65 sites with a total potential capacity of about 170 MW. The results will be valuable for public municipalities and private developers seeking investment as they could add power to their load area.[9]

The National Hydropower Asset Assessment Programme (NHAAP) also analyzed a dataset of 80,000 NPDs.[10] Based on the underlying available data set, the author calculated that there are 397 NPDs with potential capacities between 1 and 10 MW, with an aggregated potential of about 1,306 MW.[11]

According to the World Energy Council, the economically exploitable potential for small-scale hydropower schemes (capacities up to 10 MW) in the USA is 198,151 GWh per year, as compared to the USA's 2008 small hydropower load factor of 47.82 per cent as a reference, this potential would equate approximately 10,808 MW of small hydropower capacity.[12]

Renewable energy policy

As of March 2009, the Renewable Portfolio Standard (RPS) requirements have been established in 33 states plus the District of Columbia (table 2). Eight states and two territories have concrete goals.[2] These states have tailored their RPS requirements to satisfy particular policy objectives, electricity market characteristics, and renewable resources potential. Consequently, there is a wide variation in RPS rules from state to state with regard to the minimum requirement of renewable energy, implementation timing, eligible technologies and resources, and other policy design details.[3] As shown in table 3, eligibility for new and existing hydropower plants can vary in time of construction, size, limits (of up to 1, 5, 10, 30, 60 and 100 MW) and environmental criteria.

The Database of State Incentives for Renewables and Efficiency also reports that 16 states, Washington DC and Puerto Rico offer rebate programmes for renewables.[2] Sales tax incentives for renewables are available in 28 states (and Puerto Rico). Tax credits for renewables are offered in 24 states.

Legislation on small hydropower

In 2010, a Memorandum of Understanding (MOU) for hydropower was signed between the Department of the Interior (DOI), the Department of Energy (DOE), and the Department of Army (DOA). The Federal agencies agreed to increase communication among each other and strengthen their long-term relationship to prioritize the generation and development of sustainable hydropower. They have also agreed to focus on increasing energy generation at federal-owned facilities and to explore opportunities for new development of low-impact hydropower.

The Federal Energy Regulatory Commission (FERC) is the primary federal agency responsible for licensing of non-federal hydropower projects. Under the Federal Power Act, FERC is authorized to issue licenses for construction, operation, and maintenance of hydropower projects. Original licenses can be issued

Table 2

Eligibility criteria for hydropower under the Renewable Portfolio Standard in the United States of America

State	*Hydropower Renewable Portfolio Standard*
Arizona	New hydropower (2006 and thereafter) is limited to 10 MW or less and may not require new dams. Incremental additional production at existing facilities (pre-1997) and hydro that balances intermittent renewables is also eligible.
California	In general, an eligible facility may not cause an adverse impact on instream beneficial uses or cause a change in the volume or timing of streamflow (exception for Fish Protection Act (FPA) license conditions). Eligible hydro includes:Small hydropower: Existing facilities (before 1 January 2006) of 30 MW or less under contract to a retail seller or municipal utility as of 1 January 2006 . New facilities (after 1 January 2006) of 30 MW or less, limit increased to 40 MW for a facility that is "part of a water supply or conveyance system". Conduit hydropower: Must use an existing pipe, ditch, flume, etc. Limits and existing or new distinctions are basically the same as for small hydropower above but do not contain existing contract requirements and additional details exist for conduit hydro in conjunction with a larger hydro facility. Incremental output/efficiency upgrades: Allowed without any capacity limit for facilities owned by a retail seller or municipal utility, in existence as of 1 January 2007, and improvements are made on or after 1 January 2008.
Colorado	Existing (as of 1 January 2005) must be 30 MW or less. New hydro must be 10 MW or less.
Connecticut	Only new (1 July 2003) run-of-river hydro of 5 MW or less. Must also be low-Impact hydropower.
Delaware	30 MW or less; must meet Delaware Department of Natural Resources and Environmental Control (DNREC) standards including Low-Impact Hydro standards.
Washington D.C.	No pumped-storage hydropower.
Hawaii	Hydropower is defined as 'falling water' without any clarification. All hydropower would presumably be eligible.
Illinois	No new dams; otherwise no specific size or other restrictions.
Iowa	Only 'small' facilities, but no explicit capacity limit. No hydropower is currently included in utilities designated capacities.
Kansas	Existing hydropower (as of 27 May 2009); new hydropower with a nameplate capacity of 10 MW or less.
Maine	Must be 100 MW or less and must meet all state's and federal's fish passage requirements.
Maryland	Less than 30 MW and there is a dam in operation as of 2004, otherwise no new dams may be built.
Massachusetts	New power facilities must meet environmental standards and be 25 MW or less. No new dams are eligible, but new production or incremental additions at existing dams is eligible. Pumped storage facilities are not eligible. Existing hydro facilities (12/31/1997) must meet environmental standards and be 5 MW or less. Pumped storage facilities are not eligible.
Michigan	Existing traditional; new run-of-river would appear to be eligible but no new dams. No size restrictions on otherwise eligible facilities.
Minnesota	Must be 100 MW or less.
Montana	Currently no new dams or diversions and hydropower must be 10 MW or less, except a facility up to 15 MW installed at an existing resevoir or irrigation system that did not have hydropower generation as of 16 April 2009 is eligible.
Nevada	Must be 30 MW or less. For any water impoundment, the dam must have been in existence as of 1 January 2003 and the water in a reservoir must be used exclusively for irrigation. No new impoundments or diversions are permitted.
New Hampshire	New renewable energy incremental production at existing facilities only; no explicit size limits but the implication would be that no new dams or impoundments are permitted. The existing small hydropower: includes only facilities placed in service prior to 1 January 2006 and facilities having met state water quality standards applicable to hydropower projects. Facilities may either be: (1) 5 MW or less and incorporate upstream and downstream diadromous fish passages approved by the Federal Energy Regulatory Commission (FERC), or (2) 1 MW or less, connected to the distribution system in New Hampshire, and meet applicable FERC fish passage restoration requirements.
New Jersey	Must be 30 MW or less; no apparent restrictions on new dams, but must meet Department of Environmental Protection (DEP) environmental standards and minimize any impacts to the environment and to the local communities. Facilities must be located in a place where retail competition is permitted.
New Mexico	No detailed definition, but hydropower must be placed in service after 1 July 2007.
New York	The main requirements are: -No new dams or impoundments but upgrades eligible. -Any run-of-river up to 30 MW that meets low-impact criteria is eligible. Existing small hydropower: No apparent limitations on existing hydropower resources. However, in order to be eligible for financial support through the Maintenance Resources Program, a facility must be 5 MW or less, run-of-river type.
North Carolina	Must be 10 MW or less; new or existing facilities are eligible (primary RPS).
Ohio	Significant environmental restrictions, but no size limits or limits on new dams or vintage.
Oregon	For pre-1995 facilities, eligibility includes post-1994 efficiency upgrades and low-impact hydro up to 50 MW per utility per year for utility-owned facilities. For non-utility owned, post-1994 facilities, up to 40 MW of low-impact hydro located in Oregon that is licensed by FERC or exempt from FERC licensing requirements is eligible. For post-1994 facilities, it includes only efficiency upgrades that meet certain geographic and environmental requirements.
Pennsylvania	Generally hydropower facilities must be low-impact and must meet other environmental requirements, but no apparent requirements on size or limitations have been given. Supplementing this is a separate statute listing certain other low-impact hydropower facilities that qualify as Tier I. One portion of this lists a maximum capacity of 21 MW and a pre-1984 FERC license requirement.
Rhode Island	30 MW or less; no new impoundments.
Texas	No restrictions. Double credit only for facilities certified after 1 September 2005.
Washington	Facility efficiency improvements after 31 March1999 and no new diversions or impoundments.
Wisconsin	All hydropower facilities of less than 60 MW are eligible.

Source: U.S. Department of Energy, Database for State Incentives for Renewables and Efficiency [2] for a term of up to 50 years. The licensee is given the authority of eminent domain to obtain lands or other rights needed to construct, operate, and maintain the hydropower project.[7 13] Licenses must be renewed.

There are very few hydropower projects that are not subject to FERC licensing requirements. These include projects on navigable waterways; projects on federal land; projects using surplus water or water power from a federal dam; and projects that will affect interstate commerce (being connected to a regional transmission grid).[7]

Two types of license exemptions exist for small hydropower projects and water transportation conduits. First, the 5 MW Exemption is issued with an indefinite validity. The project must be located at the site of an existing dam or use a natural water feature. It must propose increased capacity. The exemptee must own all land and facilities other than federal land to be eligible.[13] Second, conduit exemption is also issued with an indefinite validity; it must use the potential of a conduit (e.g. irrigation canal, aqueduct, water supply or effluent stream) constructed primarily for non-hydropower purpose. The exemptee must own the proposed powerhouse and the land upon which the powerhouse will be located. A conduit exemption may not use federal land.[13]

The Public Utility Regulatory Policies Act (PURPA) of 1978 requires States to implement utility conservation programmes and create incentive rates for eligible small power producers and cogeneration facilities. A small power production facility is defined as a power generating plant of 80 MW or less, whose primary energy source is renewable (hydro, wind or solar), biomass, waste, or geothermal resources. A small power production facility which meets PURPA's ownership, operating and efficiency standards is called a 'qualifying facility' (QF). States set the prices and mandatory purchase requirements under which utilities (under their jurisdiction) must buy from such facilities. Small hydropower facilities qualifying for QF status are eligible for such incentive rates.[14]

Barriers to small hydropower development

In 2009, the Small Hydro Council was established with the purpose of addressing barriers to the development of small projects with a particular focus on traditional hydro resources such as conventional hydro, development at non-powered dams, irrigation power, and conduit power. The Council coordinates activities on proposed initiatives for small hydro with the committees of the National Hydropower Association (NHA) and with the Ocean, Tidal and New Technologies Council.

According to the Small Hydro Council Initial Report (2010), the investment of time and money necessary to obtain a license for a small hydropower facility has become a significant burden, which has had an impact on the speed at which potential small hydropower is being developed.[15] Coordination between regulating agencies needs to become smoother and less duplicative, and other barriers to development need to be addressed, without compromising appropriate environmental protection.

Potential barriers to small hydropower development identified by NHA included the following:[5]

1. Complex regulatory processes. Project permitting/licensing/exemptions by the FERC are costly and time-consuming. Regulatory costs can exceed equipment costs.
2. Lack of integration and communication among agencies leads to redundancies. The consultation process takes too long – the studies needed to build new projects may take years.
3. Lack of standards. There are many standards and guidelines either available or in development for other renewables, especially wind and solar technologies. However, small hydropower has largely been ignored or the existing regulations and guidelines are not applicable. For standards development, it was recommended that the International Electrotechnical Commission (IEC) and European organizations be examined and possibly used as a model.
4. Some regulations hinder or block development. FERC did an analysis of the costs and resources associated with licensing, and found that Section 401 Water Quality Certification (under the Clean Water Act) was a major cost driver for projects. The Integrated Licensing Process (ILP) may not be useful for developing new projects.
5. Grid connection difficulties exist.
6. Limited incentives for development. The DOE application process is too complex for small hydropower projects, and the short window to submit paperwork can present difficulties. Financial companies do not fully understand hydropower attributes and lifetimes. Installed costs are only a part of the levelized cost of energy; financing, operations and maintenance, and other factors need to be considered. For example, the soft costs of small hydro project engineering, environmental analysis and permitting are much the same as for larger projects, driving the cost per kW/capacity for small projects significantly above the cost per kW/capacity of larger projects. In addition, financial institutions charge soft costs of project analysis and approval that are about the same regardless of the size of a project. These additional costs make the financing hurdle for small hydropower more difficult to overcome.[13] Furthermore, financial incentives are neither available for adding power to existing non-powered dams

involving certain low-impact situations or exemptions issued by FERC, nor available for rehabilitation of existing power projects unless the current incremental hydro criteria are met.
7. Absence of designs specific to small hydropower. Industry would benefit from new designs/materials for drop-in turbines.

Other research and development issues include a need for new technology that addresses the engineering and economics of small hydropower.[1] Such new technologies could minimize environmental impacts and could potentially lead to greater ease in obtaining regulatory approvals.

Note

i. Hydrokinetic technologies use the power of moving water, such as ocean waves or currents in canals, rivers, and tidal channels, to produce electricity.

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3. Asia
3.1 Central Asia
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Introduction to the region
Central Asia comprises five countries: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. These countries are landlocked with China to the west, Caspian Sea to the east, Iran and Afghanistan to the south and Russia to the north. Kazakhstan constitutes of 60 per cent desert and semi-desert and Turkmenistan is covered by about 80 per cent desert with little rainfall. Both Kyrgyzstan and Tajikistan are mountainous, while Uzbekistan contains mostly flat-to-rolling sandy desert with dunes and broad, flat intensely irrigated river valleys.

Until 1990, the Central Asia Integrated Power System (CAIPS) supplied electricity to the region and was in charge of resolving energy and water related problems in Central Asia.[1] The CAIPS generated electricity consisted of 30 per cent hydropower and 70 per cent thermal power, however, the economic and political disintegration of the Soviet Union resulted in the collapse of CAIPS. The current power network structure, therefore, dates back to the Soviet planning, where all five countries were treated as a single region. Post-Soviet disintegration led to divisions, the emergence of national borders and a lack of resources, resulting in a severe drop of electricity consumption. Hydropower resources are concentrated in Kyrgyzstan and Tajikistan; whereas Kazakhstan, Turkmenistan and Uzbekistan are concentrated with thermal resources such as fossil fuels.

Since this century, the urbanization of Central Asia is developing rapidly with urban populations increasing from 10-40 per cent, with Kazakhstan showing the highest urbanization level. However, in Uzbekistan and Tajikistan, the natural growth rate of the rural population is higher than the urban population; therefore, the urbanization level has dropped in recent years. The electrification rates are high in Kazakhstan, Turkmenistan and Uzbekistan, but information was not available for Kyrgyzstan and Tajikistan. The Government of Turkmenistan provides social protection through energy subsidies.

Table 1
Overview of countries in Central Asia

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Kazakhstan [ab]	17.55	41	98.0	18 735	78 090	2 260	7 990
Kyrgyzstan [ab]	5.49	65	..	3 640	11 186	2 910	10 604
Tajikistan [ab]	7.77	74	> 90.0	4 426	16 218	5 200	17 400
Turkmenistan [ab]	5.05	50	99.6	2 852	15 661	>1	3
Uzbekistan [ab]	28.39	64	100.0	11 600	49 150	1 730	6 396
Total	**64.25**	**-**	**-**	**41 253**	**170 305**	**12101**	**42 393**

Sources:
a International Journal on Hydropower & Dams[2]
b. EIA.gov[3]

Geographically, Central Asia has breathtaking mountain passes, vast deserts and grasslands. With regards to climate, Central Asia enjoys hot summers and mild to cold winters. In comparison, this region has lower greenhouse gas emissions than the more developed countries, but this is changing because of the economic growth fueled by abundant oil, gas and mineral reserves. The population in this region mainly relies on fragile land and water resources, and taps the region's river basins to the extreme—for agriculture and energy generation.[4]

Amu Darya and Syr Darya are the most important rivers of Central Asia and are transboundary in nature. Amu Darya is most prominent passing through all five nations and acts as an important source of hydropower. Amu Darya is essential for agricultural irrigation. In the Soviet Union period, natural resources were managed on a regional basis, thereby building cooperation between upstream countries (Kyrgyzstan and Tajikistan) which are hydropower rich and downstream countries (Kazakhstan, Turkmenistan and Uzbekistan) which are fossil-fuel rich. Following the Soviet Union break-up, regional exchanges declined as independent countries focussed on national economic interests. Kazakhstan has been the most successful in its reformation of the power sector.[5] Tajikistan is the most promising nation for hydropower development in Central Asia followed by Kyrgyzstan.

Small hydropower definition
Small hydropower in Central Asia is considered to be up to 10 MW or 30 MW in most countries (table 2). In 2008, the Government of Kyrgyzstan, for example, adopted a new Law on Renewable Energy, under

which hydropower plants under 30 MW are defined as small and receive a special feed-in tariff (FIT).[6]

Table 2

Classification of small hydropower in Central Asia

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*
Kazakhstan	..	..	..
Kyrgyzstan[a]	<30	-	-
Tajikistan[b]	≤10	≤.05	≤10
Tajikistan[c]	≤30	≤1	≤100
Turkmenistan	-	-	-
Uzbekistan	-	-	-

Sources:
a. Global Environmental Facility[6]
b. Tajikistan Ministry for Industry and Energy[7]
c. Tajhydro[8]

Regional overview and potential

Kazakhstan and Kyrgyzstan are currently undergoing reconstruction and restoration of small hydropower plants. Kyrgyzstan has a FIT for small hydropower plants, but accompanying by-laws and regulations are yet to be developed and adopted.[6]

Tajikistan experiences some micro-, mini- and small-hydropower plants in rural areas with low population densities, but it also has the prospective to grow its small hydropower development were it not for the fall back of a lack of local expertise and finance. Uzbekistan has a vast pool of unexplored small hydropower potential thanks to its 600 small river and water resources. Turkmenistan currently has a few implemented plants in addition to many plans at the proposal stage.

Overall the region experiences a vast reservoir of small hydropower potential, which is hampered by country specific disadvantages. Based on the small hydropower definition of up to 10 MW plant size, the small hydropower potential is estimated at 4,880 MW, while the total installed small hydropower capacity is approximately 183.5 MW (table 3).

Table 3

Small hydropower up to 10 MW in Central Asia

(Megawatts)

Country	*Potential capacity*	*Installed capacity*
Kazakhstan	2 707	78.00
Kyrgyzstan	at least 275	32.00
Tajikistan	115	12.18
Turkmenistan	23	5.00
Uzbekistan	1 760	56.32
Total	**4 880**	**183.50**

Sources: See country reports

Central Asia has an abundant small hydropower potential but only little has been developed. Prospects for tapping this potential in Central Asia are constrained by a number of barriers. These include:

- Low public awareness on renewable energy in rural communities;
- Inappropriate institutional and regulatory frameworks in the power sector that have not been designed with renewable energy in mind;
- Suitable technical and market conditions are not available to enable implementation and operation of small hydropower plants;[6]
- Inadequate access to bank credits and other sources of finance.

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3.1.1 Kazakhstan

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Key facts

Population	17,522,010[1]
Area	2,724,900 km^2.[1]
Climate	Continental, cold winters and hot summers, arid and semiarid[1]
Topography	Vast flat steppe extending from the Volga in the west to the Altai Mountains in the east and from the plains of western Siberia in the north to oases and deserts of Central Asia in the south (highest point: Mount Khan Tengry, 7,010 m)[1]
Rain pattern	Precipitation in the form of rain is insignificant, except for mountainous regions. In the zone of forest steppe precipitation is 300-400 mm per year, decreasing to 250 mm in the steppe zone; in the territory of the Kazakh rolling hills annual precipitation increases to 300-400 mm and in semi-deserts and deserts decreases to 200-100 mm. In the foothills and mountains precipitation varies from 400 mm to 1,600 mm per year[2]

Electricity sector overview

The power sector is one of the best developed sectors in Kazakhstan's economy. Only very small fractions (3.5 per cent) of the rural settlements do not have access to energy and electricity.[3] According to the *World Energy Outlook 2011*, the country's electrification access is 98 per cent.[4]

Electricity generation capacity was 18.7 GW in 2010. Electricity in 2011 was mostly generated by fossil fuels, given that Kazakhstan has rich gas, oil and coal reserves (figure 1).

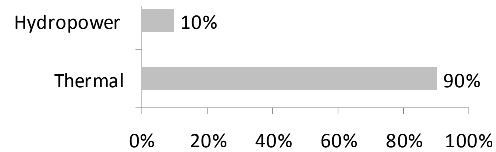

Figure 1 **Electricity generation in Kazakhstan**
Source: World Bank[5]
Note: Data from 2011.

The electricity market was privatized after the country gained independence from the Soviet Union. Electricity generation infrastructure is old and needs upgrading, as transmission and distribution lines are inefficient and cause losses around 15 per cent.[6]

Small hydropower sector overview and potential

Hydropower accounted for 3 per cent of total primary energy needs and contributed 10 per cent of the total electricity generated as per data of the Agency of the Republic of Kazakhstan on Regulation of Natural Monopolies (ANMR) in 2011.[7] There are seven small hydropower plants (with a capacity below 10 MW), with a total installed capacity of 78 MW (figure 2).

Kazakhstan has about 13 TWh of small hydropower economically developable potential, mainly located in East Kazakhstan, Zhambyl, Almaty and the southern Kazakhstani oblast/provinces (table).[3]

According to the European Bank of Reconstruction, many small hydropower projects in Kazakhstan are under reconstruction and renovation, some small hydropower plants are added to existing water management projects with small dams and reservoirs.[3]

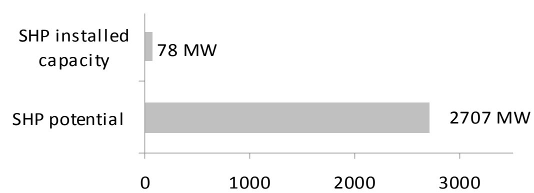

Figure 2 **Small hydropower capacities in Kazakhstan**
Source: German Agency for Technical Cooperation[3], Kazakhstan, Ministry of Environment Protection[8]

Small hydropower projects in Kazakhstan

Regions	*Number of projects*	*Projected installed capacity (MW)*	*Annual production (GWh)*
East Kazakhstani oblast	68	349	1 700
Almaty oblast	--	1 762	8 700
Southern Kazakhstani oblast	112	421	1 800
Zhambyl oblast	77	175	700
Total	**257**	**2 707**	**12 900**

Source: German Agency for Technical Cooperation[3]

Renewable energy policy

Rich gas and oil resources in Kazakhstan have largely prevented the development of a renewable energy market. However, the country has drafted strategy and legislation to encourage the development of renewable energy, with wind energy being the most promising. In 2009, the Parliament of Kazakhstan passed the Law on Use of Renewable Energy Sources establishing a regulatory framework in the country and commitment of achieving five per cent renewable share of total energy balance by 2024. The Authority plans to have 10 per cent of electricity generated from renewable energy.[9] Hydropower plants up to 35 MW are recognized under this Law. The remote rural areas are particularly interested in renewable energy projects because of energy shortage. For foreign investors, support from local law experts is necessary to attract their interests in Kazakhstan.[3]

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3.1.2 Kyrgyzstan

Yingnan Zhang, International Center on Small Hydro Power

Key facts

Population	5,496,737[1]
Area	199,951 km[2,1]
Climate	Dry continental to polar in high Tien Shan Mountains (highest point: Jengish Chokusu, 7,439 m); subtropical in southwest; temperate in northern foothill zone[1]
Topography	Peaks of Tien Shan and associated valleys and basins encompass entire nation.[1]
Rain pattern	Mean annual precipitation is 440 mm. Months with highest precipitation are April and May.[2]

Electricity sector overview

The total installed capacity in Kyrgyzstan is 3,713 MW, with hydropower dominating electricity generation (figure 1).[3] There are 18 power plants: 16 are hydro (79.5 per cent of total installed capacity: 2,950 MW) and 2 are thermal power plants (20.5 per cent of total installed capacity: 763 MW). The latter are fueled by gas, fuel oil and coal. All 16 hydropower plants are outdated and need refurbishing and/or upgrading.

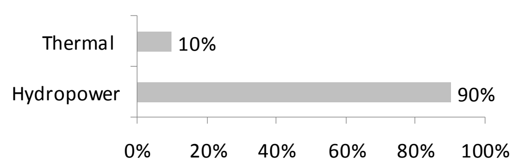

Figure 1 **Electricity generation in Kyrgyzstan**
Source: bishkek.usembassy.gov[4]

Small hydropower sector overview and potential

According to the National Energy Program of the Kyrgyz Republic for 2008-2010, 92 new small hydropower plants with a total capacity of 178 MW are to be constructed and 39 existing but abandoned small hydropower plants with a total output capacity of 22 MW were restored.[5] In addition, seven water turbines were installed onto existing irrigation reservoirs with a total output of 75 MW (figure 2).[6] In Kyrgyzstan, farmers living in mountain areas are still not grid-connected. Therefore, mini and micro hydropower projects are run by individual efforts in rural mountain areas.

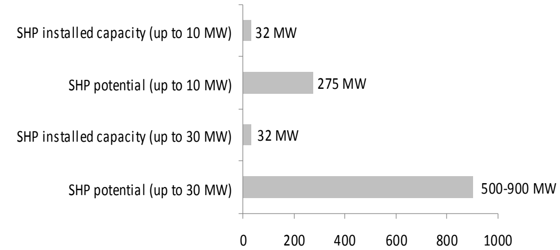

Figure 2 **Small hydropower capacities in Kyrgyzstan**
Source: National Energy Program of the Kyrgyz Republic for 2008-2010[5] and Global Environmental Facility[7]
Note: It cannot be confirmed that the 200 MW planned small hydropower capacity has been implemented therefore the installed capacity is reported as 32 MW only.

Renewable energy policy

The Government of Kyrgyzstan set up a Center on the Problems of Using Renewable Energy Resources (CPURER) that has developed a programme for the use of renewable energy, including biomass. Additionally, the Government also approved another two policies named National Energy Programme for 2008-2012 and Development Strategy of Fuel and Energy Sector until 2025.[6]

Barriers to small hydropower development

The Government of Kyrgyzstan promotes renewable energy development, but it still cannot attract sufficient interest of private investors to develop smaller projects. The main reason is the lack of legal and regulatory framework and insufficient data on existing potentials.

Specific barriers to small hydropower development are manifold. Due to seasonality, streams are more likely (than larger rivers) to freeze in winter. This could mean that facilities may not be operable during the winter, when power and heat are greatest in demand, and central grids are unable to compensate. Many communities are connected to the grid, therefore, during the summer, when power is relatively abundant, demand for off-grid power is not high. This leads to unfavourable economic conditions for commercial small hydropower plants.[8]

Streams during droughts are also more likely (than larger rivers) to suffer from low flow, thus reducing the generating capacity of the plant.[8] Furthermore, the small hydropower technical capacity in construction and maintenance (including spare parts) needs to be improved for local companies.[8]

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3.2.3 Tajikistan

Ugranath Chakarvarty, International Center on Small Hydro Power

Key facts

Population	7,768,385[1]
Area	143,000 km^2.[1]
Climate	Mid-latitude continental, hot summers, mild winters; semiarid to polar in Pamir Mountains[2]
Topography	Pamir and Alay Mountains dominate landscape; western Fergana Valley in north, Kofarnihon and Vakhsh Valleys in southwest (highest point: Qullai Ismoili Somon, 7,495 metres)[2]
Rain pattern	Average annual rainfall in lowland hot deserts of northern Tajikistan and cold high-mountain deserts of East Pamirs: 70-160 mm, while in Central Tajikistan it may exceed 2,000 mm.

Electricity sector overview

Electrification access in Tajikistan is more than 90 per cent, still the country faces severe shortages of electricity. Around 74 per cent of the population resides in rural areas, but represents merely 8-11 per cent of the country's total electricity consumption. The capital of Tajikistan, Dushanbe, and the aluminium industry consume most of the electric power in Tajikistan.[3]

With 8,476 km^2 of glaciers, 947 rivers stretching over 28,500 km and 1,300 freshwater lakes, landlocked Tajikistan is blessed with abundant water resources.[4] Hydropower contributed about 98 per cent of total electricity production in 2009 (16 TWh), clearly indicating the prominence of hydropower in Tajikistan (figure 1).[5] A large part of the generation comes from large-scale hydropower plants, however due to the sparsely distributed population, small hydropower and especially micro and mini hydropower have an invaluable impact on the socio-economic life of Tajikistan.

The State-owned company Barqi Tojik is the energy monopolist in the country and deals with maintenance of electric power stations and networks, manufacturing, transmission, distribution and selling of electric and heat power.[6]

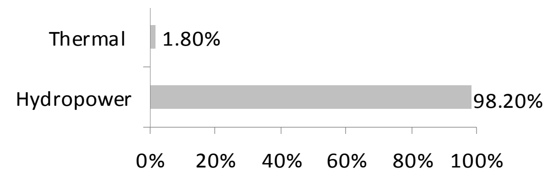

Figure 1 **Electricity generation in Tajikistan**
Source: Taj Hydro[6]

Small hydropower sector overview and potential

According to the Law of the Republic of Tajikistan on the Use of Renewable Energy Sources in 2010, hydropower is classified as micro, mini and small if the installed capacity is below 100 kW, 101-1000 kW, and 1001 kW-30 MW respectively. However, a document by the Ministry of Industry and Energy and UNDP Tajikistan from 2007 recommends that the classification be the following for micro <10 kW, mini 10-500 kW and small 500 kW-10 MW.[7]

According to Tajhydro, 155 small hydropower stations exist in Tajikistan within four regions with a total capacity of 12 MW (table 1 and figure 2). Technically small-scale hydropower in Tajikistan revolves around micro- and mini-hydropower, due to the low population density in rural areas.

Table 1
Installed small hydropower capacity in Tajikistan

Region	*Total SHP plants*		*Active SHP plants*			*Non-active plants*	
	Number	*Total capacity (kW)*	*Number*	*Capacity (kW)*	*Electricity generated (MWh)*	*Number*	*Capacity (kW)*
GBAO	35	3 432	15	725	497.8	20	2 707
Khatlon Oblast	8	2 185	-	-	-	8	2 185
Sughd Oblast	38	1 882	37	1 002	460.3	1	880
Districts of Republic Subordination	74	4 685	53	2 959	1 370.2	21	1 726
Total			**105**	**4 686**	**2 328.3**	**50**	**7 498**

Source: Tajjhdryo[8]
Note: GBAO - Gorno Badakhshan Autonomous Province

Most villages of the country are close to at least one water flow and thus of off-grid small to micro hydropower plants have been constructed and operated by local communities, providing electricity especially during winter when national electricity supply is mostly intermittent. Rivers in Tajikistan are characterized by high currents which make them freeze rarely. The associated equipments are made from spare parts, but are not periodically maintained and thereby inefficient, and break down with some frequency. At the same time, local communities use such off-grid schemes and pool their limited resources to cover operations and maintenance expenditure.

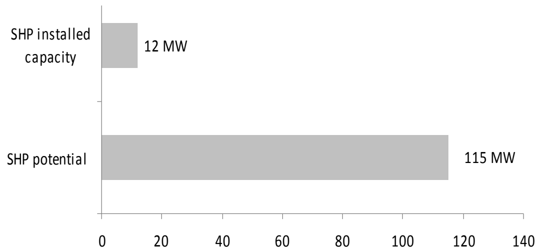

Figure 2 **Small hydropower capacities in Tajikistan**
Source: Tajhydro[8]

Since 2002, PamirEnergy has invested over US$37 million in maintaining the electrical infrastructure and developing small hydropower in the Gorno Badakhshan Autonomous Province (GBAO) region for a 25-year concession period. PamirEnergy has been providing electricity to 85 per cent of GBAO's population and is now managing all power generation, transmission and distribution in the region.[9]

The major part of Central Asia's water resources originates from Tajikistan (53 per cent), hence the country has one of the highest hydropower potentials in the world, estimated to be around 140 GW, with a potential annual electricity generation of 527 TWh and ranked second in the world by its per capita hydropower resources.[10] Technical hydropower potential amounts to 317.82 TWh and the total potential of small hydropower industry is 184.46 TWh per annum. All in all, Tajikistan is home to 4 per cent of the world's hydropower potential.[11]

In recent times, conditions for small hydropower have become favourable. According to Tajhydro's Small Hydro Power Development Center, preliminary researches show that 900 small scale schemes, each with output between 100-3,000 kW are technically feasible and economically efficient.[12] Use of small hydropower has been acknowledged by experts to be able to meet 50-70 per cent of rural areas energy demands and in some cases 100 per cent, based upon the presence of small rivers in predominantly mountainous areas.

In the long term, small-, medium- and large-sized hydropower stations in Tajikistan have the potential of boosting Tajikistan's economy by exporting electricity and meeting reliable domestic electricity needs for productive uses.

UNDP has been implementing several projects in collaboration with the Government of Tajikistan and has developed three strategic documents to confront poverty issues and development progress highlighting the use small hydropower, namely:[8]

- Intermediate Strategy for Renewable Energy Sources-based Integrated Rural Development (August 2010)
- National Program for Renewable Energy Sources-based Integrated Rural Development- National Scaling Up (October 2010)
- Energy Efficiency Master Plan (January 2011)

UNDP has also designed a National Trust Fund for Renewable Energy and Energy Efficiency in Tajikistan. Once the transmission networks to Afghanistan and Pakistan, which are under construction, have been completed, Tajikistan can enhance profitability by trading with these countries.

Table 2
Planned small hydropower plant capacity in Tajikistan, 2009-2020

Period	*Planned total installed grid connected capacity (MW)*	*Additional stand- alone capacity (MW)*	*Planned annual electricity production from the installed capacity (MWh/year)*	*Required money to incentivise newly installed capacity in given period (US$)*	*Total required money in the given period for incentives (US$)*	*Required money to cover investment costs of stand-alone plants (US$)*
2009-2011	43.53	5.00	280.84	5 616 868	5 616 868	5 000 000
2012-2015	32.85	18.62	185.07	3 701 344	9 318 212	18 620 000
2016-2020	26.80	73.20	175.74	3 514 706	12 832 918	73 199 000
Total 2009-2020	**103.18**	**96.82**	**641.65**	**12 832 918**	**27 767 998**	**96 819 000**

Source : United Nations Development Programme[13]

A preliminary assessment of finance required to incentivize small hydropower development for the period 2009-2020 is shown in table 2. Furthermore, UNDP's Energy and Environment Programme project 'Technology Transfer and Market Development for Small Hydropower in Tajikistan' in collaboration with the Global Environment Facility and UNDP, started in March 2012, will run until December 2015.[14]

Water infrastructure projects, including the development of hydropower capacity, are a complex issue related to the rights of downstream water users, especially in Uzbekistan and Turkmenistan. Both of these countries depend on water from Amu Darya for irrigation purposes. The Water Sharing Protocol of 1987 limits the use of water for hydropower during winter by Tajikistan.[10]

With the collapse of Soviet Union, the profitable relationship of Tajikistan along with Kyrgyzstan, providing hydropower in summer to Kazakhstan, Turkmenistan and Uzbekistan and in turn receiving gas and electricity during winters, has ended. In recent times, water rights have become an issue of tension in Central Asia.

Renewable energy policy

Electricity supply in Tajikistan is unreliable and power cuts often recur. However, the potential to utilize renewable energy is tremendous with small hydropower as top priority and solar and wind as other potential renewable sources. The Law of the Republic of Tajikistan on the Use of Renewable Energy Sources was established in 2010, regulating legal relations between public authorities and stakeholders in the area of priority and effective use of renewable energy with an emphasis on international cooperation. It also aims at increasing the level of energy conservation, reducing anthropogenic impact on environment and climate, saving and conserving non-renewable sources of energy. The Energy Law was amended in 2007. Both laws based on Energy (2007) and RES (2010) enable the selling of electricity generated from RES to the grid.[6]

Barriers to small hydropower development

- Lack of reliable data on high potential and use of renewable energy;
- Low electricity tariffs;
- Uncertainty in the legal and regulatory framework for private sector participation or independent power producers;
- Monopoly of energy sector;
- Lack of financing and underdeveloped mechanism to both attract and manage resources effectively from donors or state-funded support for decentralized renewable energy development;
- Lack of local expertise in project development and maintenance of small hydropower stations and equipment;
- Lack of awareness on the potential significance of small hydropower technology to reduce winter energy insecurity and correlation of social significance associated with depleting forest wood resources for heating purposes.

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3.1.4 Turkmenistan

Yingnan Zhang, International Center on Small Hydro Power

Key facts

Population	5,054,828[1]
Area	488,100 km^2.[1]
Climate	Subtropical desert[1]
Topography	Flat-to-rolling sandy desert with dunes rising to mountains in the south; low mountains along border with Iran (highest point: Gora Ayribaba, 3,139 m)[1]
Rain pattern	Annual average rainfall is 210 mm. Rainfall peaks in March with 44 mm, and reaches its lowest point in August with 1 mm, on average.[2]

Electricity sector overview

Electricity in Turkmenistan is mainly generated from natural gas, with a very small contribution from hydropower (figure 1). Electrification access is 99.6 per cent.[3] It has to be noted that Turkmenistan is the only country where households are provided with free electricity.

The installed capacity of the power grid of Turkmenistan is 4,151.7 MW. According to the World Bank, Turkmenistan generated 0.018 per cent of its total electricity in 2009 from hydropower, equivalent to 3 GWh.[4] The electricity sector in Turkmenistan is a monopoly and is managed by state-owned Turkmenenergo State Corporation which owns all electricity generating plants, along with transmission and distribution facilities.

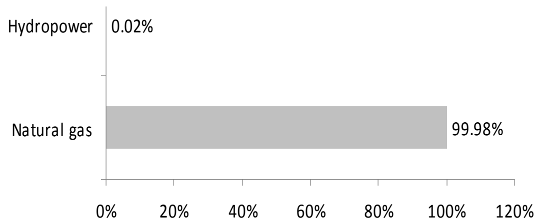

Figure 1 **Electricity generation in Turkmenistan**
Source: International Energy Agency[5]

Small hydropower sector overview and potential

The birth of Turkmenistan's power sector is considered to be in 1913, when the construction of the Hindu Kush hydropower plant was completed on Murghab River. Turkmenistan has a small installed (operating) capacity, approximately 5 MW (figure 2).[6] The Hindu Kush consisted of three hydraulic turbines manufactured by the Austrian-Hungarian Hans Company with a total installed capacity of 1.2 MW. The hydro station is in good technical condition and serves as a museum exhibit as well. With installed capacities of 0.6 MW and 3.2 MW respectively, Kaushut-Bent and Kolkhoz-Bent hydropower plants are currently being upgraded by an European Bank for Reconstruction and Development Renewable Energy Initiative.[6] Besides, there are many proposed small hydropower projects in Turkmenistan (table 1).

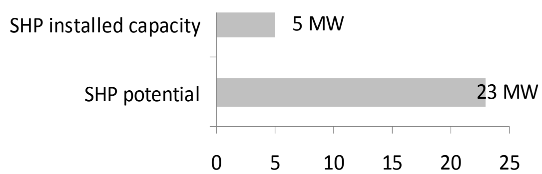

Figure 2 **Small hydropower capacities in Turkmenistan**
Source: Ebrdrenewables[6]
Note: Potential estimates vary.

In Turkmenistan, hydropower potential is mainly located on Murgab and Amu-Daria river basins. The largest small hydropower potential is concentrated in the southern part of the Republic on the Murgab and Tejen rivers and Karakumy canal (figure 2).[6]

Renewable energy policy

Turkmenistan has abundant wind and solar power potential. The Law of Turkmenistan on Energy Saving was issued to protect the environment. In September 2008, a Law on Hydrocarbon Resources was revised and approved to encourage foreign investors to buy property in Turkmenistan.[3] The Renewable Energy Development Strategy plans to develop renewable energy frameworks.[7]

Table 1
Proposed programme for small hydropower development in Turkmenistan

Type of construction	*Quantity*	*Potential capacity (MW)*	*Note*	*Region*
Reconstruction and rehabilitation of existing hydro plants	3	4.7	Mostly former rural hydro plants of capacity between 0.8 and 2.7 MW	Iolontan region on Murgab river
Adding hydro plants to water management projects	6	52.3	Hydro plants of capacity between 2.6 and 15 MW	South Turkmenistan. Karakumy canal, Murgab and Tenjen Rivers
Total	**9**	**57.0**		

Table 2
Priority small hydropower projects in Turkmenistan

Projects	*Potential installation capacity (MW)*	*Location*
Adding to water management projects		
Hauznan reservoir HPP	11.7	Karakumy Canal, Mary Oblast
Kopetdag reservoir HPP	15.0	Karakumy Canal, Ashkhabad oblast
Saryyazin reservoir HPP	12.0	Murgab River, Mary Oblast
Tashkeprin HPP	7.0	Murgab River, Mary oblast

Note: HPP – hydropower plant

Barriers to small hydropower development

The population of Turkmenistan obtains free-of-charge the following: 45 kWh electricity per month per person, 600 m^3 of natural gas per year per person, and 1,500 liters of gasoline per year for car owners.[7] Therefore the population does not use solar, wind or hydropower and investment in these renewable energy sources by private companies is not followed or promoted.

Currently, due to an absence of a specific policy for promotion of renewable energy, there is also no regulatory framework related to renewable energy.

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3.1.5 Republic of Uzbekistan

Yingnan Zhang, International Center on Small Hydro Power

Key facts

Population	28,394,180[1]
Area	447,400 km[2].[1]
Climate	Mostly midlatitude desert, long, hot summers, mild winters; semiarid grassland in east[1]
Topography	Mostly flat-to-rolling sandy desert with dunes; broad, flat intensely irrigated river valleys along course of Amu Darya, Syr Darya (Sirdaryo), and Zarafshon; Fergana Valley in east surrounded by mountainous Tajikistan and Kyrgyzstan; shrinking Aral Sea in west[1]
Rain pattern	Annual average rainfall is 417 mm. Rainfall peaks in March with 81 mm, and reaches its lowest point in August with 3 mm, on average.[2]

Electricity sector overview

The electrification rate of Uzbekistan is approximately 100 per cent, and all connections are metered and billed according to tariffs set for consumer categories. However, the electromechanical devices were mostly manufactured during 1960-1990 and are generally old and unreliable.[3]

The installed power generation capacity in Uzbekistan exceeds 12 GW, of which 1.7 GW from hydropower and 10.6 GW from thermal power plants (fueled by natural gas, mazut[i] and oil).[4] The 2011 electricity generation figures are depicted in figure 1 below.

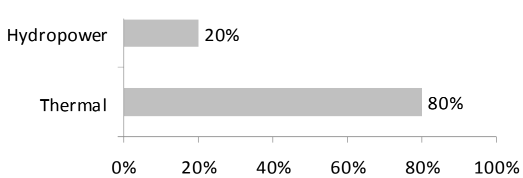

Figure 1 **Electricity generation in Uzbekistan**
Source: US Energy Information Administration[5]

Small hydropower sector overview and potential

Hydropower in Uzbekistan is mostly located on the River Syrdarya and its tributaries. Around 30 per cent of hydropower energy derives from small hydropower plants (510 MW).[7] According to a report of the Asian Development Bank, in many remote rural areas, small hydropower plants are responsible for the electricity generation, which offers a competitive and environmentally friendly option for addressing electricity shortages.

In Uzbekistan there is largely unexplored hydropower potential in 600 small rivers, irrigation canals and water reservoirs. The total small hydropower potential is estimated at 1,760 MW (figure 2) with annual output of 8,000 GWh, only 3.2 per cent of which has been developed.[8]

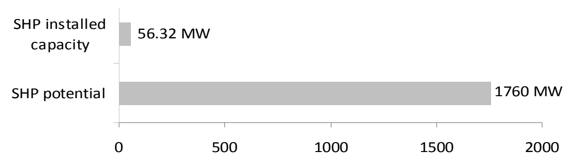

Figure 2 **Small hydropower capacities in Uzbekistan**
Source: German Agency for Technical Cooperation[8]

Renewable energy policy

Uzbekistan has abundant oil and gas resources. Therefore, the Government spends little to develop renewable energy except hydropower and solar. The Government has plans to construct small hydropower plants and develop the country's vast solar power potentials.[8]

Note

i. Mazut is a heavy, low quality fuel oil, used in generating plants and similar applications.

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3.2 Eastern Asia

Heng Liu, International Center on Small Hydro Power

Introduction to the region

Eastern Asia comprises five countries: China, Japan, Democratic People's Republic of Korea (North Korea), Republic of Korea (South Korea) and Mongolia. It is a sub-region of Asia that can be defined in either geographical or cultural terms. More than 1.5 billion people, about 38 per cent of Asia's population or more than 22 per cent of the world's population live in this region (table 1). The region is one of the world's most populated areas, with a population density of 133 inhabitants per square kilometre, about three times more than the world average of 45 per square kilometre. Mongolia has the lowest population density among the five.

Table 1

Overview of countries in Eastern Asia

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
China[ac]	1 339.61	53	99.4	962 190	3 759 000	213 400	662 200
Japan[ad]	127.37	33	100.0	281 099	91 823	27 571	74 175
DPRK[a]	24.35	40	26.0	..	22 520	4 780	13 000
Republic of Korea[a]	48.88	17	100.0	75 416	417 300	1 530	34 731
Mongolia[ab]	2.75	38	67.0	923	3 896	28	18
Total	**1 542.96**	**-**	**-**	**1 319 628**	**4 294 539**	**247 309**	**784 124**

Sources:

a. Central Intelligence Agency World Factbook[1]

b. Energy Regulatory Commission Mongolia[2]

c. International Center on Small Hydropower[3]

d. Ritsumeikan University[4]

e. Basandorj[5]

Note: DPRK – Democratic People's Republic of Korea

The climatic conditions of these countries mirror those of the northern hemisphere with cool winters and warm summers. Precipitation occurs during the warmer period borne by the monsoon winds.

The majority of electricity in Japan, Republic of Korea, China and Mongolia is derived from conventional thermal sources. Hydropower also contributes significantly to the electricity mix in Japan and China, but not in the Republic of Korea. As for Democratic People's Republic of Korea, such information was not available, it has the lowest electrification rate in the region (table 1).

Small hydropower definition

Both Japan and Mongolia do not have any official definition of small hydropower. The Republic of Korea had a small hydropower definition up till 2005 based on a capacity of 10 MW, but in 2007 capacity regulation as a means to define small hydropower was removed and altered to a converting system from flow of water to electricity due to enforcement of a regulation by Development and Utilization of New and Renewable Energy Supply. China has different definitions for small, mini and micro hydropower. A small hydropower definition of Democratic People's Republic of Korea was not available (table 2).

Table 2

Classification of small hydropower in Eastern Asia

Note: DPRK - Democratic People's Republic of Korea

	Small (MW)	*Mini (MW)*	*Micro (kW)*
China	≤50	≤2	≤100
Japan	-	-	-
DPRK	..	..	..
Korea (Rep.)	-	-	-
Mongolia	-	-	-

Note: DPRK - Democratic People's Republic of Korea

Regional overview

All five countries in Eastern Asia have adopted small hydropower. Small hydropower serves as an important livelihood facilitator particularly in remote mountainous rural areas. It provides a practical solution for rural electrification, poverty alleviation and economic growth in developing countries. China has been especially active in realizing rural electrification through small hydropower.

Based on the 10-MW definition, the small hydropower potential of the region is 75.31 GW and the installed capacity is 40.48 GW (table 3). This does not include information on installed and potential small hydropower resources from the Democratic People's Republic of Korea, since they are unknown.

Table 3

Small hydropower in Eastern Asia

(Megawatts)

Country	*Potential capacity*	*Installed capacity*
China	63 429	36 889
Japan	10 267	3 503
Korea (DPR)	..	..
Korea (Republic)	1 500	65
Mongolia	53	< 28
Total	**75 312**	**40 485**

Source: See country reports

China ranked first in the world for small hydropower potential (both on its own and the 10 MW small hydropower definitions). The Government sees small hydropower as a great opportunity for future development hence it includes it in its mid- and long-term renewable energy planning as well as rural electrification programmes. Japan and Republic of Korea also have large small hydropower potentials as compared to other countries, while Mongolia has a relatively small hydropower potential due to the seasonality of its limited water resources.

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3.2.1 China

Heng Liu, Xiaobo Hu and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	1,343,239,923[1]
Area	9.6 million km[2]
Climate	Extremely diverse; tropical in the south to subarctic in the north
Topography	Mostly mountains, high plateaus, deserts in west; plains, deltas, and hills in east
Rain pattern	Given the country's vastness, many degrees latitude and complex terrain, it has a variety of precipitation levels including continental monsoon areas. Annual mean range is high from zero mm in the deserts to 1,500 mm on the East coast. The highest level of rain is in the summer for most areas.

Electricity sector overview

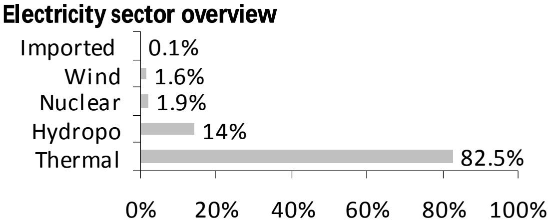

Figure 1 **Electricity generation in China**
Source: China Electricity Bulletin[2]
Note: Data from 2011.

By 2010, the total electricity installed capacity in China reached 970 GW, ranking second in the world. Of the installed capacity, 710 GW are thermal power and 220 GW hydropower, it is the country with the largest installed hydropower capacity.[3]

In the next 20-30 years, hydropower will remain the second most important component in China's energy mix, after coal. It is estimated that China's hydropower installed capacity will reach 400 GW by 2030 and 450-500 GW by 2050.[4]

Rural electrification in China has increased from 94.5 per cent at the county level, 86.83 per cent at township level and 61.05 per cent at the village level in 1978 to 100 per cent, 99.68 per cent and 99.74 per cent, respectively in 2008.[5]

Small hydropower sector overview and potential

In China, small hydropower refers to capacities of up to 50 MW (table 1).

Table 1
Classification of small hydropower in China
(Megawatts)

Definition	*Installed capacity*
Small	≤50
Mini	≤2
Micro	≤0.1

Thanks to the 1,500 rivers with each a drainage area of over 1,000 km[2] and China's technological maturity, the small hydropower potential of the country is significant. Small hydropower is an abundant resource in China, widely distributed in more than 1,700 counties in over 30 provinces, regions and municipalities – principally in the Western regions and mainly among remote mountainous areas, minority groups' territories and revolutionary sites. Featuring vast areas, sparse populations and decentralized energy demand, these regions can neither be served by the state grid nor are appropriate for long distance power-supply to the grid. Because of the development of small hydropower, more than 300 million people in one third of all the counties, and covering half of all the territories in China, have access to electric power.

A total small hydropower potential of 128 GW (using the country's definition of 50 MW), China is ranked as the first in the world's small hydropower potential (figure 2). To date about 40 per cent of China's small hydropower resources have been developed. However, approximately 62.3 GW of small hydropower potential remains under developed. From 2000 to 2009, 30,271 MW of rural hydropower plants were added, with an average annual growth rate of 13.53 per cent that represented an energy generation of 767,200 GWh (average annual growth rate of 10.66 per cent). By 2012, the country had approximately 45,799 small hydropower stations with a total installed capacity of about 65.68 GW and an annual output of over 217,300 GWh.[6]

Over the past decades, the development, investment and asset management of Chinese small hydropower have changed. During the pre-1990 period, the Chinese small hydropower plants were mainly funded by the central and local governments. After late 1990s, due to a rapid development of the Chinese economy, the gap between power supply and demand has dramatically intensified and has caused power supply shortages in most provinces. During this period, the Chinese investment system started to be reformed through a combination of government guidance and market mechanisms. A variety of economic entities were encouraged to invest in and develop small hydropower, with the hope of narrowing the gap between power supply and demand and the shortfall in government funds (table 2).

In addition to the investment made by the Chinese Government, over time many private investors have become more involved in hydropower development. Over a 10-year period, small hydropower investment specifically experienced a gradual transition away from central and local governments and towards corporate enterprises (including those of foreign), with joint ventures and private hydropower plants accounting for an increasing proportion of the newly installed capacity.

Moreover, a set of technical standard systems, including a small hydro programme encompassing design, construction, installation, experiment, operation and equipment manufacture was set up to provide technical support and service for small hydropower development.[7]

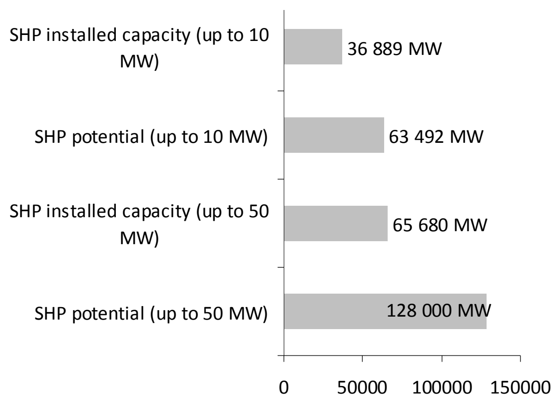

Figure 2 **Small hydropower capacities in China**
Source: China Ministry of Water Resources[6]

Table 2
Ownership of rural hydropower units in China

Type	*Number of SHP units*	*Proportion (%)*
Non-enterprise	2 217	8.94
Enterprise (all)	22 585	91.06
Wholly state owned	1 972	7.95
Holding state owned	1 003	4.05
Joint venture state owned	213	0.86
Collective	2 702	10.89
Private and others	16 695	67.31
Total	**24 802**	**100.00**

Source: Ministry of Water Resources[11]
Note: Data from 2009.

In 2012, the unit cost of building new small hydropower stations was about 8,000-10,000 yuan/kW (about US$1,305 to US$1,630/kW) while the unit cost of refurbishment and efficiency expansion of old stations was only one third at about 3,000 yuan/kW (about US$489/kW). The refurbishment and efficient expansion of old stations generally do not take longer than one year and do not cause migration or environmental problems, hence they bring technical, economic and environmental benefits.

Further progress can be made in the field of water resources planning to maximize the use rate of hydropower, to enhance the protection of the environment, to minimize any negative impact caused by hydropower development and to establish a benefit-sharing mechanism for the displaced population as well as by accelerating the development of pumped storage stations.

Renewable energy policy

Under the 12th Five-Year-Plan (FYP) there are aims to achieve an 11.4 per cent share in non-fossil fuel consumption and a 30-per cent share in non-fossil fuel installed capacity by 2015. The hydropower installed capacity will reach 290 GW, a 5.7-per cent increase from 2010, wind to reach 100 GW, a 26.4-per cent increase; solar energy to reach 21 GW, a 89.5-per cent increase from 2010.[3]

Legislation on small hydropower

The Chinese Government has passed a series of policies to support and encourage local governments and local people to develop their nearby, rich small hydropower resources. 'Self-construction, self-management and self-consumption' has been a well-known policy guiding small hydropower development in China since the early 1970s. As for the taxation policy, value added tax for small hydropower has, since 1994, stood at 6 per cent – much more favorable than the 17 per cent tax on large hydropower stations. The relevant Chinese authority is working to promulgate a specialized regulation on rural hydropower development and management in China.

The Chinese Government continues to support the small hydropower sector in its 12th FYP (2011-2015). The first objective is to fully complete the National Planning of New Rural Electrification i.e. to invest 43.52 billion Yuan (about US$7 billion) to build small hydropower plants in 300 new rural electrification counties, with a planned new installed capacity of 5,156 MW. This is expected to provide an energy output of 19.16 TWh.[8]

The second objective of the 12th FYP is the wider implementation of the tasks covered by Hydropower for Fossil Fuel Power Plan 2009–2015 which aims to solve, through firewood substitution, the fuel concerns of 6.78 million rural residents and to protect a forest area of 1,593,333 hectares, by constructing 1,022 small hydropower stations with an installed capacity of 1,705.6 MW.[9]

The third objective of the 12th FYP is to carry out small (rural) hydropower efficiency and capacity expansion projects. A total investment of 3.75 billion yuan (about US$600 million) has been planned for the refurbishment of 620 rural hydropower stations with a total capacity of 880 MW within a two-year period

(2011-2012). The implementation will consolidate, recover and renew some 1.1 GW of generation capacity.[10]

Barriers to small hydropower development

While much progress has been made in small hydropower development, the current energy macro-policy environment in China is not conducive to the development of small hydropower and there are several issues expected to be improved, such as the barrier in obtaining bank loans and/or financing; relatively low tariff for small hydro to be sold to grids; small hydropower also faces harsh competition when sold to the grid and the compensation for its external benefits, among others.

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3.2.2 Japan

Motoyuki Inoue, Ritsumeikan University and Tokyo Metropolitan University, Japan

Key facts

Population	127,368,088[1]
Area	377,737 km[2]
Climate	Changes from tropical in the south to cool temperate in the north[1]
Topography	Approximately 70 per cent of the land is mountainous, and dividing mountain ranges cut across the land like a backbone. This produces steep-gradient rivers with plentiful flow volumes that stream from the mountains into the sea through alluvial fans and l plains.
Rain pattern	Japan lies in the Asian monsoon region and has ample precipitation.

Electrical sector overview

Japan's energy self-sufficiency ratio is merely four per cent, making hydropower generation a valuable, purely domestic electricity source. In 2011, hydropower accounted for 35 per cent of Japan's domestically produced energy. In proportion to the total electric power generation, hydropower accounts for under 10 per cent (figure 1).

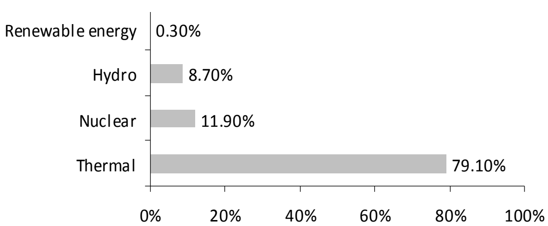

Figure 1 **Electricity generation in Japan**
Source: Energy White Paper 2012[2]

Many existing hydropower plants are ageing and the number of these has increased, deterioration is accelerating and many facilities are in need of being modernized.

According to a 2012 survey by the Agency for Natural Resources and Energy, there were 2,708 technically untapped hydropower sites with a total potential power output of approximately 12 GW and potential annual electricity production of approximately 45.8 GWh.[3] These values which concerned untapped hydropower were based on the result of the fifth hydropower research conducted by Ministry of Economy, Trade and Industry in 1980. Approximately 98.6 percent of untapped hydropower sites have power outputs of less than 30 MW and an average output of around 4.5 MW. There is a sharp decrease in the number of untapped sites with power output of less than 1 MW, as many are located in remote areas and suffer unfavourable conditions, such as relatively high construction cost. However, since the survey excludes mountain streams and small rivers, presumed economically inefficient, it is possible that many small-scale sites are not covered by the survey.

Japan enjoys a large gross theoretical hydropower potential (718 TWh) as it has high rate of precipitation and mountainous terrain. However, Japan's proportion of technically exploitable capability to gross theoretical capability stands at a value of 19 per cent.

Small hydropower sector overview and potential

There is no official definition of small hydropower according to installed capacity in Japan. Following the small hydropower definition of below 10 MW, there were 1,369 operational small hydropower plants in 2012 (total installed capacity 3,518 MW, annual generation 18,802 GWh).[3] And there are 2,476 untapped hydro sites with a total power output of approximately 6,749 MW (figure 2) and annual electricity production of approximately 27,449 GWh.[3]

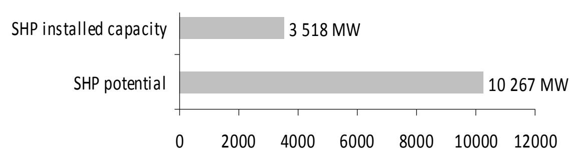

Figure 2 **Small hydropower capacities in Japan**
Source: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry[3]

In addition to the above, surveys on the untapped heads of small hydropower are recently being tried by various organizations. For example, according to the results of a survey by the New Energy Foundation (March 2009) on the untapped heads arising from using existing structures such as dams, conduit, etc., which were not covered in the surveys described above, analyzed that there were 1,389 sites of power generation using untapped heads, with a combined power output of approximately 330 MW and annual electricity production of approximately 1.7 GWh.[4]

Japan's agricultural waterways have a total length of approximately 400,000 km, and their gross theoretical potential is estimated at 5.7 TWh.[5] The technically exploitable capability of irrigation channels will improve further with the use of power generation through run-of-river units.

In recent years, small-scale hydropower development has been conducted by various operating bodies other than electricity utilities, such as municipalities, public corporations for land improvement, private enterprises, specified non-profit corporations and individuals. Following the establishment of various programmes promoting small-scale hydropower, efforts to introduce small-scale hydropower using various untapped water heads in existing infrastructure facilities such as intake weirs, check dams, water-supply facilities, etc. and in relatively small-scale rivers are gradually taking place.

Legislation on small hydropower

The Act on the Promotion of New Energy Usage 1997 was passed with the aim of accelerating the promotion of new energy usage. Initially, hydropower was not included but in April 2008, hydropower of 1 MW or less was incorporated, such as facilities that are used non-exclusively for hydropower, such as serving as subsidiary power generation combined with irrigation, water use, erosion-control facilities, etc.

The Act on the Promotion of New Energy Usage as a feed-in tariff (FIT) scheme started in July 2012. Under the FIT scheme, if a renewable energy producer requests an electric utility to sign a contract to purchase electricity at a fixed price and for a long-term period guaranteed by the Government, the electric utility is obligated to accept this request. In regard to hydropower, this system is applied to small- and medium-scale. Tariff for hydropower is sorted in three procurement categories according to scale: between 1 MW and 30 MW (24 yen/kWh, tax exclusive), between 200 kW and 1 MW (29 yen/kWh) and less than 200 kW (34 yen/kWh). Power purchase agreements (PPAs) are for 20 years.

The Japanese Government ministries and agencies are promoting small-scale hydropower as a form of renewable energy from such standpoints as CO_2 reduction, diversification of energy sources, reduction of maintenance costs of facilities and revitalization of local communities. Efforts toward increased hydropower generation have been undertaken, such as institutional reforms, consideration of a relaxation of regulations, and subsidies on survey, design and construction expenses.

Barriers to small hydropower development

In order to further support the use of small hydropower, the following will be necessary. [6]

Re-evaluation of the potential capacity of small-scale hydropower generation and common understanding of hydropower use:

Extensive discussions should be held on the possibility of expanding the use of various untapped heads in existing infrastructure facilities, such as dams, weirs, irrigation channels, water-supply and sewerage systems, existing hydropower-generation facilities, and small rivers, without being bound by past preconditions and constraints. In doing so, it is necessary to re-evaluate Japan’s technically developable hydropower capability. In addition, a common understanding needs to be established among the parties involved, regarding the possibility of further using hydropower as a renewable energy source and regarding the issues to be resolved from technical, cost, environmental and institutional perspectives.

Technological development of using various untapped heads economically:

In actively utilizing various untapped heads as a new means for hydropower generation, it is necessary that they are in line with current facilities’ flood-control and water use functions and with the surrounding environment. At present, the efforts of concerned parties and studies are being conducted on power generation facilities that are suitable for the installation site based on conventional technologies. In the future, it will be necessary to systematically promote the development of new hydropower technologies that match the actual situation depending on the type of untapped head, by clearly defining the development goals of technological issues.

Hydropower development led by local residents:

In order to expand the use of small hydropower, local residents are advised by the Government to take the initiative to promote small hydropower development by taking advantage of the characteristics of each area. Local residents are asked to think about measures to promote comprehensive development of hydropower, together with solar power and wind power, as renewable energies. In promoting community-based hydropower development in the future, local governments need to consider how to use water resources in various ways, not only for hydropower generation but also for tourism and other purposes, and, to this end, a system that enables flexible hydropower needs to be developed. In addition, the Government commented that steps should be taken to simplify application procedures and speed up processing for small hydropower generation with regard to the River Act and the Natural Parks Act, as well as to create support systems that enable the easy use of nationwide hydrological and terrain data for development purposes, and maintenance and management support systems of the power plants once the project has been completed.

Development of environmentally friendly technologies for sustainable hydropower generation:

In order to realize greater sustainable hydropower use, researchers need to analyze the extent of environmental and social impacts. Based on their findings, the national and local governments need to establish rational countermeasures. When newly building or expanding small hydropower facilities,, it is necessary to establish detailed criteria (such as minimum flow discharge) and methodologies matching the actual river and facility conditions, in order to balance the use of renewable energies and river environment preservation. In terms of measures to release sediment from dams, it is difficult for the dam administrator alone to resolve the problem. Joint efforts are required by the Government, local population and researchers from interdisciplinary fields, covering disaster prevention, environment and resource management to find a consensus on sustainable hydropower generation and measures to mitigate negative impacts from hydropower development.

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3.2.3 Democratic People's Republic of Korea

Kai Whiting and Lara Esser, International Center on Small Hydro Power

Key facts

Population	24,589,122[1]
Area	122,538 km[2]
Climate	Temperate, with all four seasons
Topography	Mountainous areas in 80 per cent of the country, especially in the northern and eastern coastline
Rain pattern	Average annual precipitation: 1,000-1,200 mm

Electricity sector overview

The national electrification rate is low, currently at 26 per cent.[2] In 2000, electricity shortages, blackouts and rationing were reported due the lack of fuel and transmission network failures. Some of the causes were a major flooding in 1996 which rendered some hydropower plants inoperable, and operation under capacity at coal-fired stations due to problems with train-based coal transportation.[4] Energy shortages also stem from the reduction in energy imports as a result of the import sanctions and less financial aid.

All energy infrastructures are state-owned, and state sources report a total installed capacity of 7 GW, with an average annual power generation of 51,000 GWh.[3] Data on the share of different energy sources to the annual power generation is inconclusive. It is known that the country relies on two main sources of electricity: hydropower (60 per cent) and coal (40 per cent).[3]

Much of the infrastructure is outdated, poorly maintained or based on obsolete technology. It is considered unlikely that the network is robust enough to manage electricity imports.

There are five thermal power plants and over 700 hydropower plants, including medium- and small-sized plants. While there is no plan to construct more thermal power plants, it was reported in 2005 that new hydropower plants and tidal power plants were under construction and that they are to be finished by 2012.

A Sustainable Rural Energy Development Programme was operating from August 2006 until March 2007, when United Nations Development Programme operations were suspended. In January 2011 the project resumed activities with the aim 'to strengthen the sustainable and efficient use of conventional energy and improve accessibility of alternative energy sources for local communities and households'. This includes renewable energy pilot demonstration schemes.[5]

As of year 2000, a total of 4.2 GW hydropower potential had been developed. Another 22.36 GW is its theoretical potential and another 12.38 GW is the untapped potential.[3]

Small hydropower sector overview and potential

Information on the small hydropower situation is not comprehensively known. A national report from year 2000 stated that the existence of some 250 small and medium power plants with a generating capacity of 50,000 kWh would facilitate electricity of self-sufficiency in the Jagang Province.[6]

Many rivers, reservoirs, irrigation canal networks and tidal dykes along the West coast are favorable for large-, medium- and small-sized hydropower development. The sites suitable for small hydropower vary in heads. Almost 80 per cent of the estimated sites have a head lower than 15 m, and among those 50 per cent have a head of 5 m. However, the total small hydropower potential was not clearly stated in the available documents.

The general future plan for hydropower in the Democratic Republic of Korea is to rehabilitate and refurbish old turbines, which have been in operation for more than 30 years. The plan is to increase the installed hydropower capacity by 1,117 MW (table 1).

In 2005, for example 20 Francis turbine units and 10 Kaplan and/or Propeller units needed replacement to gain 2-3 per cent higher efficiency. Their refurbishment cost will be equivalent to building a new hydropower plant of 110 MW installed capacity.

Table 1
Planned hydropower in the Democratic People's Republic of Korea
(Megawatts)

Basin	*Capacity*
Huichon	644
Kumya	329
Ryesong	144
Total	**1 117**

Source: Jin and Chol[3]

Table 2
Planned medium- and small-hydropower in the Democratic People's Republic of Korea

River Basin	*Number*	*Capacity (MW)*
Daedong No. 5	4	10.0
Dokji	4	3.2
Chongchon	3	15.0
Jangja No. 2	3	6.0
Total	**14**	**34.2**

Source: Jin and Chol[3]

Renewable energy policy

The policy orientation of the Government is towards non-fossil fuel options, solving the issue of ageing infrastructure and of the transmission and distribution network.[7]

In fact, since the Fukushima nuclear incident in March 2011, the Democratic People's Republic of Korea's state media have reported widely on renewable energy development with leader Kim Jong Il inspecting a newly constructed experimental solar water heating facility in Pyongyang, and stating his approval to 'aggressively develop and utilize renewable energy sources, such as solar heating'.[8] There are recent indications of the nation's desire to increase bi-lateral agreements and technology transfers within the renewable sector.[9]

According to Korean Central News Agency, the Democratic People's Republic of Korea has, in addition, revised its environmental protection law in late 2011 to promote the development and use of renewable energy sources.[8]

Legislation on small hydropower

The Democratic People's Republic of Korea has set a policy to develop small hydropower, however no further information is available.

Barriers to small hydropower development

Financial challenges are the main barrier to develop the small hydropower potential. Remaining problems include the lack of generation equipment including turbines and power system, as well as automation.

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3.2.4 Republic of Korea

Young Joon Kim, K-water Institute, Republic of Korea

Key facts

Population	48,860,500[1]
Area	99,434 km^2
Climate	Temperate climate. Distinct seasons, with dry, cold continental air masses during the winter, and humid, warm air masses from the ocean during the summer. Temperature varies widely between summer and winter, and there is great regional diversity.
Topography	Mostly hills and mountains; wide coastal plains in west and south
Rain pattern	Average annual precipitation: 1,283 mm, of which 70 per cent falls during the rainy season (June-September), and about 18 per cent during the dry season (October to March).

Electricity sector overview

Republic of Korea remains one of the top energy importers in the world with an energy import dependency at 97 per cent.[2] In the electricity sector, most gross generation (93.4 per cent as of 2007) comes from plants operated by utilities—over 95 per cent of which are operated by the South Korea Electric Power Corporation (KEPCO) and its subsidiaries. The remaining 6.6 per cent of generation comes from combined district heat and power plants (0.9 per cent) and non-utility generation (5.7 per cent). The electricity generation is dominated by fossil fuels, followed by nuclear power (figure 1).[3]

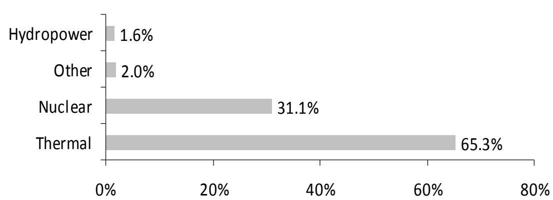

Figure 1 **Electricity generation in Republic of Korea**
Source: Korean Electric Power Corporation[4]
Note: Data from 2011.

Small hydropower sector overview and potential

Until 2005 the small hydropower classification was based on an installed capacity of up to 10 MW. However, through the enforcement of a regulation on Development and Utilization of New and Renewable Energy Supply (2007), the small hydropower definition was unified based on water flow.

The total installed capacity of small hydropower in Republic of Korea is 65.4 MW, developed at 51 sites (figure 2). This is only 4.3 per cent of the 1,500 MW that is as evaluated as potential of small hydropower in Republic of Korea (table 1).

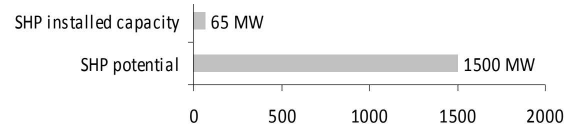

Figure 2 **Small hydropower capacities in the Republic of Korea**

Installed small hydropower in the Republic of Korea

Owner	*Locations*	*Capacity (kW)*	*Share (%)*
Private operators	16	28 609	43.8
K-water	16	15 434	23.6
Korea Electric Power Corporation	8	14 145	21.6
Korea Rural Community Corporation	6	6 749	10.3
Local governments	5	475	0.7
Total	**51**	**65 412**	**100.0**

The small hydropower potential of domestic rivers is 1,412 MW. Adding the small hydropower potential in existing water-related facilities like sewage treatment plants, water treatment systems, irrigation reservoirs, multi-purpose dams and irrigation dams, the total small hydropower potential could reach up to 1,500 MW. Annual power generation could reach 5,256 GWh (assuming a 40-per cent operation ratio).

Renewable energy policy

The Government of Republic of Korea enacted the Alternative Energy Development Promotion Law and started the commercialization and spread of solar and waste energy after two oil crises with the aim to diversify energy production and consumption. Successive plans have increased the renewable energy share targets. The third plan (2009-2030) has set the renewable energy supply share to 6.1 per cent.

Barriers to small hydropower development

- Limited economic feasibility of small hydropower projects. The topography of the country does not allow using high head turbines.
- The local small hydropower industry has not yet been fully developed.

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3.2.5 Mongolia

Dursan Basandorj, Mongolian University of Science and Technology, D. Sod, Mon-Energy Consult Co., Ltd, Mongolia

Key facts

Population	3,179,997[1]
Area	1,564,116 km[2]
Climate	Hot in summer and extremely cold in winter, with January averages dropping as low as −30°C (some areas are at -45°C)
Topography	Varied geography, with mountainous forests, vast steppes and the Gobi Desert (highest point: Khüiten Peak, 4,374 m)
Rain pattern	Annual rainfall can be as low as 100 mm in the desert and even the maximum of 360 mm in the north is little. Lakes, rivers and glaciers are thus integral to the water supply

Electricity sector overview

The electricity consumption of Mongolia in 2010 was 4.22 TWh, and the total installed capacity in 2011 was 923 MW.[2] Mongolia is a net electricity importer (i.e. from Russia) with fossil fuels dominating the generation mix (figure 1).[3]

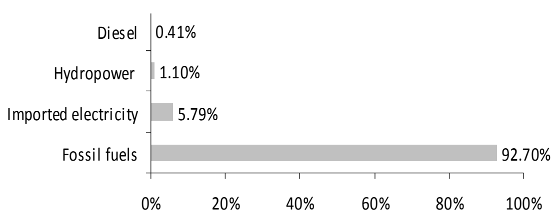

Figure 1 **Electricity generation in Mongolia**
Source: Energy Regulator's Regional Association[3]
Note: Data from 2011.

Mongolia's Aimag centres are the largest permanent settlements in the rural areas and are divided into Soums. The electrification in cities, Aimag and Soum centres is 100 per cent. However, 10.6 per cent (17,000) of the 160,000 herd families who led a nomadic life had no access to electricity as of 2011. Among the nomadic households that do have access to electricity, most have a small 50-100 W solar (PV) supplied under the '100 000 solar homes' project or small wind systems. Some (less than 10 per cent) own small imported electricity generation engines.

There are four integrated power grids in Mongolia: Central Energy System (CES), Western Energy System (WES), Eastern Energy System (EES) and Altai-Uliastai. An overview of installed capacity in each grid is shown in table 1 below.

Table 1
Overview of energy systems in Mongolia

Grid	*Electric power plants*	*Installed capacity (MW)*
CES	5 coal fired TPPs	814
WES	12-MW Durgun HPP and some diesel generators	12 + (1.9 +0.5 + 2.7)
EES	isolated coal-fired TPP	36
Ulistai-Altai	11 MW Taishir HPP and 2 MW SHPP, some diesel generators in reserve	13 + (5 + 8)

Note: TPP – thermal power plant, HPP – hydropower plant, SHPP – small hydropower plant.

Additionally, the South-Gobi province has a 6 MW isolated thermal power plant. Apart from this, Ukhaa Khudag, a coal mining site in the Umnugovi province, has its own 18 MW thermal power plant with 12 MW diesel generators in reserve. All provincial and Soum centres have electricity supply of some sort. Oyutolgoi is the largest mine in Mongolia, which owns 26 MW capacity of diesel generators, however the mine needs a 60-MW power source for its operation.

The hydropower potential was estimated to be 6,417.1 MW or 56.2 TWh per year. Identified hydropower sites include 220 MW Egiin hydropower plant, as well as hydropower pump storage such as 100 MW Orkhon site, 150 MW Artsat site, 300 MW Shuren site and a 50 MW pump-storage plant at the Tuul river at Ulan Bator.

Small hydropower sector overview and potential

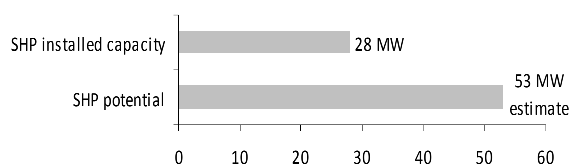

Figure 2 **Small hydropower capacities in Mongolia**

Table 2
Classification of small hydropower in Mongolia
(Megawatts)

Definition	*Installed capacity*
Small	1-10
Mini	0.1 – 1
Micro	0.05-0.1
Pico	< 0.05

All small hydropower plants in Mongolia are government-owned because the private sector has insufficient resources for small hydropower development. The capacities of existing small hydropower plants (see table 2 for classification) are from several hundred kW and above. The total installed capacity of small hydropower is 28.40 MW (figure 2). Most small and mini hydropower schemes have capacities ranging between 90 kW and 2,000 kW, scattered around the country and far from energy

grids. They are of seasonal importance and operate only in warm months of the year.
Some feasibility studies have been prepared by local engineers. Estimated potential of Yoroo small hydro scheme is 9 MW, Zeergenet is 5-6 MW and Maikhan Tolgoi is 8-12 MW. However, a comprehensive potential estimate is lacking.

Renewable energy policy

Mongolia has abundance of renewable energy sources such as water, solar and wind.. It has over 3,800 rivers and rivulets, however approximately 2,000 are dried out due to change in climate, mainly in the northern half of the country.

Approved by the Mongolian Government in 2005, the National Renewable Energy Programme includes plans to increase renewable energy share of the electricity system up to 20-25 per cent from 2005 to 2020. This programme includes the construction of 12 MW Durgun and 11 MW Taishir hydropower plants and other mini hydropower plants. There are also plans to carry out feasibility studies of other small hydropower plants to supply 16 Soum centres with electricity and to build a 100-MW Orkhon hydropower plant and a 50-MW Salkhit wind farm, both to be connected to the CES grid.

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3.3 Southern Asia

Arun Kumar, Indian Institute of Technology Roorkee, India

Introduction to the region

Southern Asia comprises Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan and Sri Lanka. All the countries have substantial large and small scale hydropower potential, except for Maldives and Bangladesh, the latter having limited hydropower potential. India, Nepal, Bhutan, Pakistan, Afghanistan and Iran are part of the Hindu Kush Himalaya region which is rich in steep slopes, moderate rainfall, high snowfall and biodiversity. However for various reasons, the majority of the countries in the region (except Iran) have limited access to electricity.

Table 1
Overview of countries in Southern Asia

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Afghanistan[abcd]	30.00	77	15.5	820	843	400	802
Bangladesh[ab]	142.00	72	41.0	6 100	37 000	230	1 200
Bhutan[b]	0.71	65	-	1 506	7 320	1 489	>7 304
India[b]	1 155.00	70	75.0	173 626	811 104	33 606	114
Iran (Islamic Rep. of)[be]	73.00	29	-	62 000	220	8 488	17 900
Nepal[be]	29.00	81	43.6	641	3	664	2 410
Pakistan[be]	170.00	64	62.4	22 263	105 000	6 555	28 000
Sri Lanka[b]	20.00	86	76.6	2 684	9 882	1 357	5 634
Total	**1 619.71**	**-**	**-**	**269 640**	**971 372**	**52 789**	**63 364**

Source:
a. International Energy Agency[1]
b. International Journal on Hydropower and Dams[2]
c. Afghanistan Energy Information Center[3]
d. Afghanistan, Ministry of Energy and Water and Ministry of Rural Rehabilitation and Development[4]
e. United States Energy Information Administration[5]

Small hydropower definition

The classification of small hydropower varies from country to country, ranging from an upper limit of 10 MW to 50 MW (table 2).

Table 2
Classification of small hydropower in Southern Asia

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*
Afghanistan	1-10	0.100-1	5-100
Bangladesh	..	..	..
Bhutan	1-25	up to 1	up to 100
India	2-25	0.101-2	up to 100
Iran (Islamic Rep. of)	1-10	0.101-1	up to 100
Nepal	1-10	0.100-1	up to 100
Pakistan	up to 50	0.150-5	up to 150
Sri Lanka	1-10	0.101-1	up to 100

Source: See country reports

Regional overview

All countries except Maldives have developed small hydropower. The policies relevant for small scale hydro-power development and ministries/ organizations dealing with the subject of small scale hydropower development in different countries are summarized below (table 3).

In Afghanistan, substantial reconstruction and expansion of transmission and distribution systems are carried out. General surveying and potential assessment of mini and micro hydropower sites are underway.

Bangladesh is dominated by flat land hence its potential in hydropower development is limited. Bhutan has developed only a limited small hydropower capacity. For Bhutan, no study has been conducted to assess the small scale hydropower potential even though the mountainous region has an excellent setting for small hydropower development.

Even though India has targeted an ambitious hydropower development programme, its pace has recently slowed down. It has achieved less than half of target set for its 10^{th}- 11^{th} plan due to various delays. Regulatory framework, encouragement and support for renewable energy have been a moving factor for the recent interest in small hydropower development, especially in the private sector.

Iran has an ambitious hydropower development plan and has developed 8,488 MW mostly during the recent years. Even though the country has substantial potential due to its mountainous terrain and its large irrigation canal network, it has developed only limited small hydropower potential. Iran's efforts to involve the private sector, especially in small hydropower, are relatively low. Feasibility studies for small hydropower projects have been completed and several schemes are at different stages of development, but mainly pending government agencies' approvals.

Table 3
Policies relevant to small hydropower in Southern Asia

Country	*Policy*	*Ministry/organization*
Afghanistan	Not available	Ministry of Energy and Water (MEW), Ministry of Economy and Ministry of Rural Rehabilitation and Development (MRRD)
Bangladesh	Renewable Energy Policy – 2008	Bangladesh Power Development Board (BPDB)
Bhutan	Sustainable Hydro Power Development Policy – 2008	Department of Energy (DOE)
	No specific policy for small hydropower	Druk Green Power Corporation (DGPC)
India	Hydro Power Policy – Nov 2008	Ministry of New and Renewable Energy (MNRE) and State Nodal Departments
Iran (Islamic Republic of)	Not available	Iran Water & Power Resources Development Company (IWPCO)
Nepal	Hydropower development Policy (2001)	Nepal Electricity Authority (NEA)
Pakistan	Policy for Development of Renewable Energy for Power Generation (2006)	Alternative Energy Development Board (AEDB), Water and Power Development Authority (WAPDA)
Sri Lanka	Sustainable Energy Authority Act 2007 – On grid renewable Energy Project Regulation 2009	Sustainable Energy Authority (SEA)

Source: See country reports

Pakistan is yet to develop small hydropower to an appreciable scale, given its small hydropower potential in hilly areas as well as on its extensive irrigation barrage/canal network. Low small hydropower development to date can perhaps be attributed to the lack of policies, capacity and private sector involvement.

Sri Lanka's small hydropower development in the last 15 years can be attributed to its conducive policy and proper regulatory support. The small hydropower potential on irrigation dams and canals and low head run-of-river schemes has not been developed to its available potential but is receiving substantial attention from the private as well as the government sector. Small hydropower has been quite successful in Sri Lanka for rural electrification.

Furthermore, Pakistan, Afghanistan, India, Iran and Sri Lanka have high possibilities of adding small hydropower to existing water resources projects built for irrigation, drinking water, sewage out fall and industrial water conduits. Some of the existing channels and natural rivers may also have kinetic turbines. However, the assessment of such potential is yet to be assessed in the region.

As the region has favourable climatic and physiographic settings for hydropower development, substantial potential of hydropower exists in the region. Only 15 per cent of the small hydropower potential has been developed, hence the region has a vast opportunity for further development.

The total small hydropower potential (up to 10 MW) is more than 18.03 GW, of which a capacity of approximately 3.56 GW has been developed so far (table 4).

Table 4
Small hydropower in Southern Asia
(Megawatts)

Country	*Potential*	*Installed capacity*
Afghanistan	1 200.00	75.14
Bangladesh	at least 0.15	0.01
Bhutan	..	8.80
India	15 000.00	3 198.00
Iran (Islamic Rep. of)	at least 38.23	16.50
Nepal	1 430.00	70.25
Pakistan	..	..
Sri Lanka	400.00	194.00
Total	**18 077.18**	**3 562.70**

Source: See country reports
Notes: Data is for plants up to 10 MW. The small hydropower potential of Iran is reported as 1,260 GWh/year.[2] The small hydropower potential of Pakistan for plants up to 50 MW is estimated at 2,265 MW.

As seen above, the region has substantial small scale hydropower potential.

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3.3.1 Afghanistan

Lara Esser, International Center on Small Hydro Power

Key facts

Population	30,419,928[1]
Area	652,000 km^2
Climate	Arid to semiarid; cold winters and hot summers[1]
Topography	Mostly rugged mountains (highest point: Noshak peak, 7,485 m); plains in north and southwest[1]
Rain pattern	Average annual rainfall: 285 mm. Dry and wet season vary according to location.[2]

Electricity sector overview

The power sector infrastructure in Afghanistan is in dismal condition as a result of unrelenting conflict over the past three decades. Afghanistan's annual electricity consumption per capita is among the lowest in the world, according to the Power Sector Strategy at about 27 kWh or even lower at 18.50 to 19.25 kWh per capita according to other sources.[3 4]

The Government of Afghanistan seeks to reconstruct the ruined electricity infrastructure to meet the demands of its growing population. The Government and multilateral and bilateral donors (United States Agency for International Development, Asian Development Bank and the World Bank) have planned to import electricity from Central Asia in order to increase domestic supply by about 300 MW by the end of 2015. This electricity will be carried by the new transmission system known as the Northeast Transmission Power Systems (NEPS) under construction.

The ultimate goal of the Afghan Ministry of Energy and Water's (MEW) Power Sector Plan is to become a net power exporter from 2022 onwards, since Afghanistan possesses natural gas resources, oil and condensate reserves, and coal reserves.

The Power Sector Strategy (2007) indicates a country-wide electricity access rate of 6 to 10 per cent in 2007, to be increased to almost 25 per cent by 2010 and to 33 per cent by 2015. In urban areas the Strategy plans to increase the access rate from an estimated 27 per cent in 2007, to 77 per cent by 2010, and almost 90 per cent by 2015. Figures for electricity access vary widely. The Power Sector Strategy estimates power coverage to be over 70 per cent in urban areas, including privately owned diesel-powered generators. Twenty per cent of the population has access to public power (grid-supplied) on certain days for a limited number of hours.

Nationally, seven grids distribute power, with supply coming from domestic hydropower generation, imported power and thermal generation. The plan includes the installation of diesel generators in various cities, where no alternatives to electricity are available. In the long term, however, most diesel generation should be replaced with other less costly alternatives.

The Inter-Ministerial Commission for Energy (ICE) Capacity Building Strategy (February 2011) announced the following goals to be pursued at the national level:

- By end 2011: electricity will reach at least 65 per cent of households and 90 per cent of non-residential establishments in major urban areas and at least 25 per cent of households in rural areas.
- By end 2011: at least 75 per cent of the costs will be recovered from users connected to the national power grid.
- By 2013 to 2015: energy supply of 1,800 MW (of which 1,200 MW are from domestic production), 85 per cent urban and 40 per cent rural coverage (both commercial and households), 95 per cent collection rate and 45 per cent reduction in technical losses
- Note: These targets may change with the drafting of the Energy Sector Master Plan.

The total installed electrical capacity was more than 840 MW in 2010 for the country including National Solidarity Programme projects. The installed capacity in rural areas is estimated at roughly more than 100 MW, most of which is mini and small hydropower as well as diesel generators. Not included are private diesel generators that are not registered within the MEW or other databases.

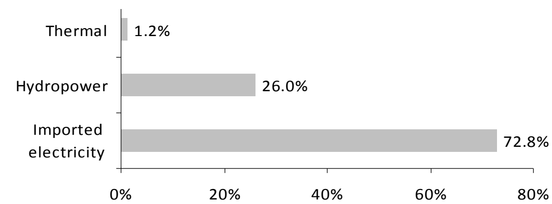

Figure 1 **Electricity generation in Afganistan**
Source: Farhad[5]

Historically, most power generation in Afghanistan has been based on hydropower (figure 1), and the rest from thermal sources (e.g. coal and natural gas). While large hydropower plants are on-grid in Afghanistan, micro hydro and solar based power systems also provide off-grid supply.[4] Sources of energy in the villages further from the grid include micro hydropower, diesel generation, candles, batteries, solar lanterns, and hurricane lamps for light and biomass for cooking.

Selected small hydropower projects and programmes

Rural donor projects	*Description*
USAID funded by the Alternative Development Programme — Eastern Region (ADP/E)	Support of the construction of the Dodarak micro hydro (60 kW) – approximately US$107,000—including US$17,000 for local labour—to engineering and construction works. The plant was opened in April 2009 and is expected to remain functional for the next 40 years. The Community Development Council (CDC) of Dodarak village has implemented a transparent system for managing electricity accounts. Each family pays Af 3 and each business Af 5 for one kilowatt hour of electricity. The CDC collects the money, which is used to pay the power plant technicians and maintain the plant. If revenue exceeds regular expenses, the CDC can allocate funds for other development projects in the village.[6]
U.S. Army Corps of Engineers (USACE) Since 2006	Project aims to train, manufacture and install micro hydropower plants in isolated Afghan villages and connect the villages to the grid. The construction of 105 units in seven of 34 Afghan provinces until July 2011 was planned. The average system has a capacity of 10 kW, but the largest one, Daste Riwat plant has a capacity of 130 kW. All the components of this project were fabricated locally, apart from the imported alternators.[7]
Financed by Japan Fund for Poverty Reduction (JFPR)	Development of four mini hydro plants in Bamyan and Badakhshan Provinces, each about 500 kW, of a total capacity of 2 MW. The micro hydropower plants are expected to provide basic infrastructure in support of improving services, increasing productivity, facilitating income generation, and contributing towards improved health and environmental protection through increased access to electricity.[3]
National Solidarity Program (NSP) funded by World Bank	Together with local CDCs, over 500 micro hydro projects were built between 2003 and 2007. CDCs participation has involved operations and maintenance, established viable systems of cost-recovery, in return providing sustainability[4]

Source: DAI-International Development Company[6], Sgt. O' Connor[7], Asian Development Bank[3] and Ministry of Energy and Water, Afghanistan[4]

Small hydropower sector overview and potential

The 2011 draft Afghanistan Power Sector Strategy classified hydropower into the following capacity ranges: large >10 MW, small 1 to 10 MW, mini 100 kW to 1 MW, micro 5 kW to 100 kW and pico <5 kW.

Official information on the age, number and status of small and micro hydropower plants is not available. For 2010, the National Rural Power Strategy reports that 75.14 MW of small hydropower was installed (figure 2). DAI – an international development company (2009) reported that about 160 micro hydropower plants have been installed in Afghanistan in recent years.[6]

The small hydropower potential in Afghanistan is estimated to be 1,200 MW. New capacity for small hydropower is expected to reach 615 MW by the end of 2014.[8]

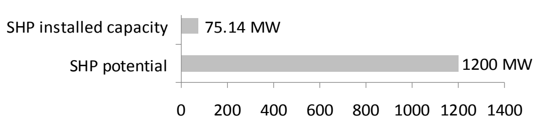

Figure 2 **Small hydropower capacities in Afghanistan**
Source: Akbar[8]

The Government recognizes the importance of economic growth in reducing poverty and averting future conflicts. In Afghanistan National Development Strategy (ANDS), the Government emphasized the importance of "enhancing access to cost-effective and uninterrupted power". Specifically, the Government's draft Power Sector Strategy recognized the importance of enhancing rural energy availability and imposed an ambitious target of delivering 100 MW to electrify 25 small towns and rural villages by 2013 through micro hydropower and decentralized stand-alone systems.

Afghanistan has projected, that it will need a minimum of 330 MW of new installed power by 2020. Based on informal assessments, it is assumed that around 30 to 40 per cent of the installed micro hydropower stations are not operational. Therefore, if taking into account the possible failure rate of 20 per cent, approximately 400 MW of new operational capacities will be needed by 2020.[9]

The National Priority Program One (Component D) Energy for Rural Development in Afghanistan (ERDA) aims to support rural communities not only to install energy systems, such as micro hydropower plants, but also to foster productive use of electricity for generating employment in rural areas. Besides micro hydropower and biogas that have been promoted, improved water mills to replace less efficient traditional water mills, solar photovoltaic and thermal systems, will be also included (ANDS Priorities and Implementation Plan, Vol. II).

A robust micro hydropower industry already exists in Afghanistan. It has at least six turbine manufacturers.[9]

Renewable energy policy

The MEW as well as the Ministry of Rural Rehabilitation and Development (MRRD) are the governmental focal points for rural energy development. MEW has the mandate to develop renewable energy in urban areas, as well as plan for rural energy supply on the provincial level and implement it at the provincial and district centre-level. The MEW created a Renewable Energy Directorate (RED) in July 2009. At the provincial level, MEW is represented by the Water Department until full restructuring of Da Afghanistan Breshna Sherkat (DABs).[i]

The MRRD uses rural energy supply as a means for community development. It started with a Rural

Livelihoods and Energy Department, which was mainly implementing the National Solidarity Programme's rural energy projects. After the set-up of the Energy for Rural Development in Afghanistan (ERDA), the department has been transformed into the Rural Energy and Enterprise Department (REED). MRRD has the mandate to plan and implement rural energy supply at the village level.

Renewable energy offers great hope for Afghanistan, especially for its rural electrification. Since the rural population is dispersed, renewable energy offers the best solution for electrification for the majority of Afghanistan's rural population.[9] However, at the moment, there is no renewable energy policy in place yet. The ICE appointed a sub-committee that was being advised in technical and administrative terms by the German Agency for Technical Cooperation's Energy Programme in Afghanistan. A draft version of 'Afghanistan Rural Renewable Energy Strategy Action Plan until 2014 and Development Objectives until 2020' was finalized in September 2010.

Solar power is another option as Afghanistan is a country with one of the highest irradiation values on earth. Solar photovoltaic (PV) can be the most economic for small loads, such as lighting in the absence of a connection to the main power grid and/or mini grid. A solar home system to provide basic lighting may cost up to US$7,000 per kW, whereas a micro hydropower station, which can supply household and productive uses may only have investment costs around US$3,000 per kW. However, construction time and investment costs are also factors to consider.

The Afghanistan National Rural Renewable Energy Strategy (2010) focuses on economic development in rural areas through the provision of high quality electricity based on renewable energy technologies, including micro hydropower. It aims to be less of a master plan, and more of an adaptable work plan. It foresees increasing energy needs and possible insufficient electricity production from PV systems or isolated wind operations and suggests the use of base load power plants such as mini hydropower to improve the energy access situation in rural zones of the country.

Legislation on small hydropower

The National Rural Energy Strategy (2010) includes an Action plan until 2014, with the following actions:

- Training the private sector (hydropower turbine manufacturers, operators and hydropower engineering companies) on the delivery of high quality energy services in rural areas.
- Creating guidelines for operation and maintenance (O&M) of small hydropower plants (more than one MW) and basic electrification schemes (below 100 kW).[8]
- Adapting international standards in rural renewable energy to Afghan National Standards via the Afghan National Standards Authority.

Barriers to small hydropower development

Barriers to small hydropower in Afghanistan should be seen in the wider context of barriers to rural renewable energy expansion, since micro to small hydropower is mostly used in rural areas:

- Weakness of the private sector for investment in rural energy, despite an increase in companies and entrepreneurs in the last years.
- Lack of important data for Afghanistan. For example, figures like the total number of urban households, total number of non-residential establishments, and total number of rural households, as well as total cost of power import, generation, transmission, distribution, operation, maintenance and administration for the entire country, were not available in 2007.[4] The demand for data such as the total actual electricity generation and the electricity generated based on renewable energy was reiterated in the National Rural Renewable Energy Strategy (2010) under objectives and indicators until 2020.
- Lack of involvement of international financial institutions with regard to support to the private sector in this area.[9]
- Lack of concessionary loans (with sovereign guarantees) provided for rural electrification projects and major organizations with international involvement in infrastructure development, environmental protection and support for private sector development.
- Deficits in cash-flow: The Draft Electricity Law includes the agreed principle that the main instrument for financing operation and maintenance (including mini repairs of key components) should be cash-flow finance. Retail tariffs for electricity supply need to cover all O&M costs, but in reality, consumers are either unwilling or unable to pay for the full cost of supply, resulting in cash-flow deficits, and often a critical financial position of the utility or operator of an isolated mini-grid.[8]
- Instability in the country, that has been mentioned as a constraint to the timely implementation of the Power Sector Strategy in some places.[8]
- Limited technical human resources capacity (i.e. not enough trained personnel able to produce improved units from standard technical drawings).[10]
- Licensing requirements: The draft Rural Renewable Energy Strategy requires operators of isolated mini-grids to be licensed, while considering affordability and financial requirements of the licensee, and the costs of

energy supply based on the type of source. According to the Draft Electricity Law (2008), Article 13.9, there are no license requirements for the establishment/construction of electricity supply infrastructure. Furthermore, according to Article 14.3.3, electricity service companies that do not serve more than 1,000 customers and do not own more than 2 MW of installed capacity, based on their own sources of generation, do not require a generation or distribution licence.[8]

Note

i. Da Afghanistan Breshna Sherkat (DABS), has replaced Da Afghanistan Breshna Moassessa (DABM), the former national electric utility in Afghanistan. DABS engages in the generation, import, transmission and distribution of power. The company is an independent and autonomous corporation, owned by the government of Afghanistan.

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3.3.2 Bangladesh

Md. Abdul Wazed, Chittagong University of Engineering and Technology, Bangladesh

Key facts

Population	161,083,804[1]
Area	147,570 km[2]
Climate	Tropical; mild winter (October to March); hot, humid summer (March to June); humid, warm rainy monsoon (June to October)[1]
Topography	Mostly flat alluvial plain (80 %); terraces (8 %) and hilly in southeast (12 %).[1]
Rain pattern	Average annual rainfall: 2,499 mm.[2] Dry season: November to May. Rainy (monsoon) season: June to October

Electricity sector overview

The electrification rate in the country was 41 per cent in 2009 and population without electricity was about 95.7 million.[1]

The installed capacity of power plants in Bangladesh (end of 2011) was 6,693 MW. The breakdown per unit type is shown in figure 1. The Kaptai hydropower scheme on Karnafuli River, with a generating capacity of 230 MW by five units, is the only hydropower plant operated by Bangladesh Power Development Board (BPDB).

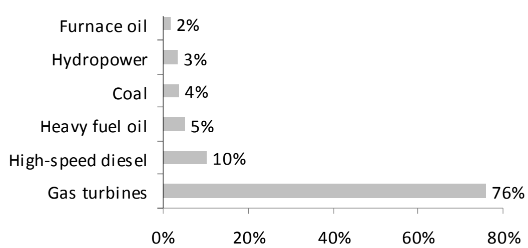

Figure 1 **Electricity generation in Bangladesh**
Source: Bangladesh Power Development Board[3]

Small hydropower sector overview and potential

The first micro hydropower unit of 10 kW has been installed in a village of Bandarban through private initiatives. The project is providing electricity to 140 families in the village and to a Buddhist temple. A relatively small potential of mini hydropower generation can be found in the hill tracts area of Bangladesh.

Several studies on the feasibility of hydropower in Bangladesh have been released over the past decades, revealing that most of the potential sites are micro- and pico-scale.

Several initiatives had been launched by the engineers of the BPDB and the Bangladesh Water Development Board (BWDB) in association with foreign experts to investigate the potential for mini or micro hydropower utilization in Bangladesh.[3] They identified 12 potential sites for the development of mini hydropower plant in 1984. Out of these 12 sites, only the Mahamaya Chara was taken up for development of an integrated project for flood control, irrigation and power generation and accordingly, a working group was formed by the engineers of BPDB to carry out groundwork of the project. The project has not been commissioned yet.[3]

In 1992, under the Flood Action Plan (FAP), Northeast Regional Water Management Project (FAP-6) conducted a preliminary assessment of selected rivers in the Northeast Region. The investigation on the most promising rivers and sites shows their suitability for development of run-of-river low head schemes.

Based on mean monthly discharges and an assumed five metres head, the hydro potential of the 10 major and medium perennial rivers (with sufficient flow for power generation throughout the year) of the Northeast Region is estimated at 161 MW, with an annual energy production of about 1,410 GWh.

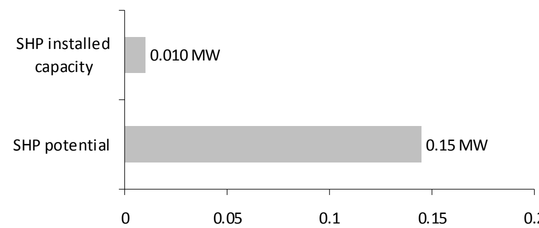

Figure 2 **Small hydropower capacities in Bangladesh**
Source: Local Government Engineering Department, Institute of Fuel Research Development

There are rivers carrying high discharges during the monsoon season and very low discharges during the dry season. They have relatively high longitudinal slope across alluvial fans close to the Indian border. Most of the rivers have low flows in the winter months and sometimes they dry out completely. Nine rivers were identified in a study. The potential of these rivers is estimated at 35 MW with an annual energy production at 307 GWh, however the estimated plant capacities are not available

Some other potential sites identified by researchers would be economically viable if projects combine small hydropower with measures such as flood control, irrigation and tourism. For example, there are at least 19 potential sites of hydropower generation in the Teesta barrage project, the largest irrigation project of the country having 10 sites with more than two-metre head. The constructions of these regulating structures have been completed and most of them are in operation. These sites can be investigated for development of small hydropower projects.

Local Government Engineering Department (LGED) has implemented the Bamer Chara Irrigation Project in Banskhali Thana under Chittagong district with an intention to provide irrigation facilities to 355 hectares of land. A large reservoir has been built in this project for dry season irrigation. Water enters the project area through a gated spill way and flow is controlled downstream by a conventional regulator. Currently LGED is examining the flow rate in the spillway and exploring the scope for installing a micro hydropower plant at the site.

Some studies have been conducted on a channel in Halda River near Madhunaghat Bridge on the Chittagong – Kaptai road in the Chittagong district as a possible site for micro hydropower. The average flow velocity is 0.75 m/s, average flow rate is 787 m^3/s and average available water head is 3.28 m. The monthly average flow rate and available head in Mohamaya chara, Bamerchara, Sapchari and flow rate in Sailopropat, and Bandarban have been reported.

The results of the studies conducted by LGED and by the Institute of Fuel Research Development (IFRD) of Bangladesh Council of Scientific and Industrial Research (BCSIR) are shown in table 1 and 2 respectively.

Table 1

Potential micro-hydropower sites in Bangladesh

(Kilowatts)

Name of the canal with location	*Power potential*
Nunchari Tholi Khal in Khagrachari	5
Sealock Khal in Bandarban	30
Taracha Khal in Bandarban	20
Rowangchari Khal in Bandarban	10
Hnara Khal in Kamal Chari, Rangamati	10
Hnara Khal in, Hang Khrue Chara Mukh, Rangamati	30
Monjaipara micro hydropower unit	10
Bamer Chara irrigation Project	10

Source: Local Government Engineering Department

Note: Sites identified by local government engineering department officials.

Three potential sites (Sitakunda, Richang and Toibang of greater Chittagong, Bangladesh) for installation of micro hydropower plants are reported. It is mentioned that with the available head and flow rate a cross flow turbine or a waterwheel will be the best option for the electricity production and the generator would be flexible enough to cover the range 500 to 3,500 W in these sites.

Renewable energy policy

The Bangladesh government approved its first Renewable Energy Policy on 6 November 2008, encouraging investment in this sector to generate electricity from renewable sources to meet an ever-growing demand. The main renewable energy sources are solar energy, wind energy, biomass, biogas and hydropower. To achieve the objectives of its Renewable Energy Policy, the government has set a target of meeting five per cent of the electricity demand by 2015 by utilizing renewable energy, and 10 per cent by the year 2020. Currently, renewable energies contribute to less than one per cent of the country's total electricity generation.

Legislation on small hydropower

Pico/micro/mini/small hydropower sites and plants in Bangladesh are situated in hilly areas (where there are natural falls), on the canal drops or at the dam-toe. Very often, hydropower requires dam or some sort of obstacle and thereby hampers the natural flow. Environmental impact assessment is mandatory for site selection and erection of such hydropower plant.

Barriers to small hydropower development

Some of the major barriers to small hydropower development in Bangladesh are:

- Installation of hydropower plants requires land acquisition. It is often delayed due to litigation, poor maintenance of land records, etc. Reservoir schemes could result in displacement of families.
- Most of the untapped hydropower potential is located in the remote areas of the country for which access roads will have to be constructed before work can commence.
- Furthermore, power would have to be transmitted over long distances to load centres from these remote areas requiring construction of long transmission lines. Low load factor of hydropower reduces firm power due to strong rainfall seasonality and plants have low output during the dry season.
- The process for getting clearance from the environment and forest agencies is cumbersome and involves inputs from many other agencies. Inter-State water disputes have come in the way of developing projects.

Table 2

Potential hydropower sites in Bangladesh

Name of Water Fall	*Average discharge (Litre/s)*	*Electrical power (kW)*	*Annual energy production (kWh)*
Sailopropat, Banderban	100	5	43 800
Madhobkundu, Moulvibazar	150	15	131 400

Source: Institute of Fuel Research Development (IFRD) of Bangladesh council of Scientific and Industrial Research (BCSIR)

Note: Sites identified by Institute of Fuel Research Development

- Hydropower projects, until recently, have been funded mainly by Government Agencies and hence only a limited number could be realized so far. Bank-lending to hydropower is low due to liquidity issues and due to the banking sector's lack of understanding of small hydropower and its benefits. Interest rates are too high and loan tenure is short, hindering private small hydropower development.

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3.3 Bhutan

Tandin Jamtsho, Druk Green, Bhutan; Ugranath Chakarvarty, International Center on Small Hydro Power

Key Facts

Population	716,896[1]
Area	38,394 km[2]
Climate	Varied climate; tropical in southern plains; cool winters and hot summers in central valleys; severe winters and cool summers in Himalayas
Topography	Mostly mountainous with some fertile valleys and savannah
Rain pattern	Average annual rainfall: 1,793 mm. Rainy season: April to October (monsoon season)[2]

Electricity sector overview

The rich hydropower resource has spurred hydropower development along with proving its prominence in Bhutan's economic development. The country has not been fully electrified and the electrification rate remains 60 per cent. This is primarily due to lack of transmission and distribution facilities. Bhutan generates more electricity than it actually needs and therefore exports power, primarily to India.

According to Druk Green Power Corporation, the total installed capacity of all power plants is 1,504 MW.[3] Hydropower is the main source of electricity in Bhutan with an installed capacity of 1,488.8 MW, generating annually 7,304 GWh according to the World Bank statistics on 2010 (table 1).

Table 1
Installed hydropower capacity in Bhutan
(Megawatts)

Project name	*Installed capacity*
Chukha	336.0
Kurichhu	60.0
Basochhu Upper Stage	24.0
Basochhu Lower Stage	40.0
Tala	1020.0
Small/Mini/Micro plants	8.8
Total	**1488.8**

Source: World Bank[2]
Note: Only operational plants listed.

Diesel generator constitutes the remaining installed capacity. Hydropower provides more than 99 per cent of electricity needs of the country (figure 1).

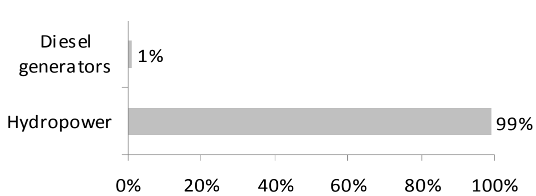

Figure 1 **Electricity generation in Bhutan**
Source: Druk Green Power Corporation Limited[3]

Harnessing hydropower in Bhutan offers sustainable socio-economic development potential; in fact it is widely accepted as a backbone of the Bhutanese economy. Being located on the Southern slope of Eastern Himalayas, its rugged terrain and well conserved dense forests, covering 72.5 per cent of total territory, provide swift water flow offering immense opportunity for hydropower development.[4] However, Bhutan is prone to earthquakes and landslides; therefore planning of hydropower development and other infrastructure must involve essential consideration in this regard.

According to Druk Green, Bhutan has a theoretical hydropower potential of 30,000 MW out of which 23,760 MW is technically and economically feasible.[3] Only 4.96 per cent of this vast potential has been harnessed as of 2010.[3] The potential of hydropower to provide electricity to country's domestic population and exporting this energy to India makes it an attractive sector to develop.

Small hydropower sector overview and potential

Bhutan has set its small hydropower standard as 25 MW. There are 21 operational small/mini hydropower plants (up to 10 MW) at the moment (figure 2). These small hydropower plants, totalling an installed capacity of 8.8 MW, generated 25.58 GWh of electricity in 2010. All small hydropower plants are under the public sector and there is no private sector participation, although it is encouraged.

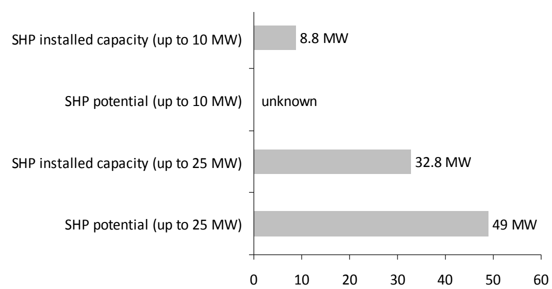

Figure 2 **Small hydropower capacities in Bhutan**

Table 2
Operational small hydropower plants in Bhutan

Capacity	*Number of plants*
> 1 MW	3
> 100 kW <= 1 MW	9
<= 100 kW	9
Total plants	**21**

Two proposed small hydropower plants, Begana (12 MW) and Druk Bindu (13 MW), can be identified as per Power Transmission Infrastructure Map, prepared by Engineering, Design and Contracts Department, Bhutan Power Corporation in July 2008.

Renewable energy policy

The Renewable Energy Policy draft was submitted to Gross National Happiness Commission (The Planning Commission of Royal Government of Bhutan) in April 2011. Gross National Happiness (GNH) has been the country's development philosophy. It affects the country's Renewable Energy Policy that is also, based on the promotion of sustainable development, preservation of cultural values, conservation of natural environment and establishment of good governance. This policy would cover solar power, wind power, bio-energy, geothermal, micro/mini/small hydropower and waste-to-energy renewable energy sources.[5] Objectives of this policy are to:

- Initiate exploration and development of renewable energy sources;
- Institutionalize development of national and local capabilities for enhanced use of RE sources;
- Promote efficient and cost effective based commercial application by providing fiscal and non-fiscal incentives;
- Mobilize funds and attract private investment;
- Contribute to socio-economic development;
- Enhance energy security;
- Establish institutional framework to promote renewable energy (includes setting up a Department of New and Renewable Energy under the Ministry of Economic Affairs, as a nodal agency).

However, the date of implementation of Renewable Energy Policy 2011 depends on its time of approval, after which all projects awarded in the renewable energy category will be governed by this policy.

As hydropower development is a major driver of economic growth, it finds a prime focus in the government's 5 year plan. Bhutan has no specific small hydropower policy but it's Economic and Hydropower related policies well complement its development. The policy initiatives supporting hydropower development in Bhutan include Bhutan Sustainable Hydropower Development Policy 2008 and Economic Development Policy 2010.

The Sustainable Hydropower Development Policy 2008 has been introduced to attract public, private and foreign investment, to ensure development of hydropower resources in accordance with sustainable development policy of the Government, to contribute towards development of clean energy, to contribute to socio-economic development and thereby to enhance revenue contribution to the Government.

According to Economic Development Policy 2010, energy is the main driver of Bhutan's economy. It puts strong focus on hydropower's ability to boost sustainable and equitable socio-economic development, and on environmental conservation. It aims to support the government to achieve 10,000 MW target by 2020 by promoting construction of projects and interlinking transmission grids to ensure energy security and reliability.

Another policy under formulation in support of hydropower includes Captive Power Generation Policy under which industries shall be permitted to develop hydropower plants for industrial consumption. Bhutan truly has several forms of policy in support of hydropower, and pays strict adherence to environment conservation making hydropower as a long term sustainable development strategy.

Barriers to small hydropower development

Several barriers exist to small hydropower development. Market related barriers include the power system that is not yet competitive and the lack of private sector participation. Due to terrain and topographic conditions, providing electricity to remote rural household and institutions through grid extensions is not always economically possible. Furthermore conservative environmental laws apply. In addition to its challenging terrain, Bhutan is located in Himalayan Hindu-Kush region widely considered a region of unmatchable biodiversity with Bhutan having several bird areas and protected areas. Attentive measures are therefore required to develop hydropower sites.

For mini hydro, difficulties are exacerbated by the costs of developing suitable sites, the absence of technical support and assistance for operation and maintenance, the large variations in water flows between the dry and wet seasons, and the very low electricity demand by households.[6]

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3.3.4 India

Arun Kumar, Indian Institute of Technology Roorkee , India

Key facts

Population	1,205,073,612[1]
Area	3,287,263 km^2.[1]
Climate	Varies from tropical monsoon in south to temperate in north[1]
Topography	Upland plain (Deccan Plateau) in south, flat to rolling plain along the Ganges, deserts in west, Himalayas in north (highest point: Kanchenjunga 8,598 m)[1]
Rain pattern	Average annual rainfall: 1,074 mm. Monsoon season: June to September[2]

Electricity sector overview

Electricity is a concurrent subject in India, meaning that the Central (Federal) Government and the State Governments have responsibility to promote this sector and authority to make necessary laws and regulations and to formulate and implement policies and programmes. Indian States function under the guidance of the Central Government.

The total installed capacity of the country is 211,766 MW as on 31 January 2013. The break-up of the total installed capacity from different energy sources is shown in figure 1 (renewables include small hydropower, biomass, urban and industrial waste-to-energy and wind energy). The power generation infrastructure is owned by the Indian Government as well as by the private sector.

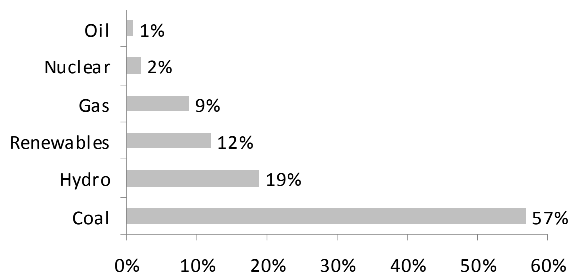

Figure 1 **Electricity generation in India**
Source: Ministry of Power[3]

Small hydropower sector overview and potential

The classification of small hydropower in India can be seen in table 1 below.

Table 1
Classification of small hydropower in India
(Kilowatts)

Type	*Station capacity*
Pico/watermill	Up to 5
Micro	Up to 100
Mini	101 - 2000
Small	2001 - 25000

The state-wise details on installed small hydropower capacity in India are provided in table 2. As of end of 2012, the aggregated small hydropower capacity in India was 3,496 MW.

In India the potential of small hydropower projects (less than 25 MW) is estimated at about 20,000 MW (these estimates are under upward revision). As of December 2012, 6,474 small scale sites with 19,749 MW aggregated small hydropower potential have been identified in the country, out of which 4,143 sites (of 15,151 MW capacity or 76.7 per cent of the total small hydropower potential) are located on small streams (run-of-river), 379 sites (of 1,645 MW capacity, 8.3 per cent of the total small hydropower potential) are located on the toe of existing irrigation dams, and 1,952 sites (of 2,953 MW capacity, 15 per cent of the total small hydropower potential) are located on existing canals, falls and barrages. Efforts are underway for potential assessment on facilities like, pipelines for drinking water and industrial use, effluent outfall at water treatment plants and sewage treatment plants, outlets of small dams and hydro kinetics in flowing channels/streams. In the deregulated environment small scale pumped storage plants are being contemplated in the future.[4]

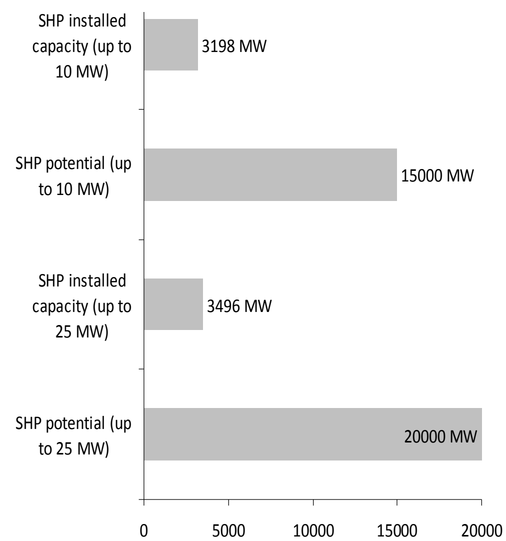

Figure 2 **Small hydropower capacities in India**

The Indian Ministry of New and Renewable Energy (MNRE) that is in charge of small scale hydro up to 25 MW, is contemplating a small hydropower assessment programme in its 12th plan period (2012–2017). The target is that out of the total grid interactive power generation capacity that is being installed, two per cent should come from small hydropower. Today, the small hydropower programme is essentially driven by private investment. The focus of the programme is to lower the cost of equipment, to increase its reliability and

Table 2
Small hydropower in India

State	Projects installed: Number	Projects installed: Capacity (MW)	Projects under implementation: Number	Projects under implementation: Capacity (MW)
Andhra Pradesh	66	217.830	15	35.25
Arunachal Pradesh	143	101.510	65	30.97
Assam	5	31.110	4	15.00
Bihar	29	70.700	5	17.70
Chhattisgarh	8	27.250	5	140.00
Goa	1	0.050	-	-
Gujarat	5	15.600	-	-
Haryana	7	70.100	2	3.35
Himachal Pradesh	142	536.905	47	182.45
J&K	35	130.530	9	34.65
Jharkhand	6	4.050	8	34.85
Karnataka	132	915.395	41	322.03
Kerala	25	158.420	11	52.75
Madhya Pradesh	11	86.160	3	4.90
Maharashtra	47	295.525	20	80.60
Manipur	8	5.450	3	2.75
Meghalaya	4	31.030	3	1.70
Mizoram	18	36.470	1	0.50
Nagaland	10	28.670	4	4.20
Orissa	9	64.300	4	3.60
Punjab	46	154.500	12	21.15
Rajasthan	10	23.850	-	-
Sikkim	17	52.110	1	0.20
Tamil Nadu	21	123.050	-	-
Tripura	3	16.010	-	-
Uttar Pradesh	9	25.100	-	-
Uttarakhand	98	170.820	47	178.04
West Bengal	23	98.400	17	84.25
A&N Islands	1	5.250	-	-
Total	**939**	**3 496.145**	**327**	**1 250.89**

Note: Data as of December 2012.

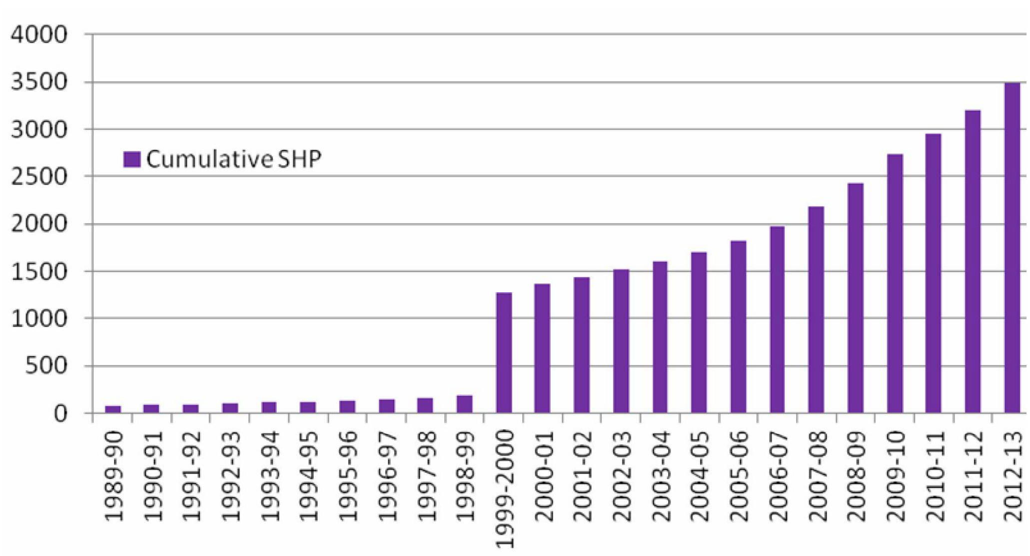

Figure 3 **Small hydropower capacity addition in India**

to set up projects in areas which give the maximum advantage in terms of capacity utilization.

India has developed small hydropower on its existing irrigation dams and irrigation canal falls. From 1997 to 2008, about 500 MW have been developed on these existing facilities and are the first choice for development by IPPs.[5]

Year-wise capacity addition from small hydropower projects is shown in figure 3. A target of adding about 2,100 MW during the 12th Plan (2012 to 2017) has been fixed.

To make small hydropower cost effective and reliable, 31 supporting documents (standards, guidelines and manuals) covering the entire range of small hydropower activities have been developed by the Indian Institute of Technology (IIT) Roorkee, through a consultative process and are available for the use of developers, manufactures, consultants, regulators and others.[6]

Legislation on small hydropower

In August 1998 and thereafter in November 2008, the Government of India announced a Policy on Hydro Power Development. People adversely affected by hydropower have been made long term beneficiary stakeholders in the hydropower projects by way of one per cent of free power on recurring basis with a matching one per cent support from State government for local area development, as well as annual cash benefits, ensuring a regular stream of benefits.

To enable the project developer in the hydropower sector achieve a reasonable and quick return on investment, merchant sale of up to a maximum of 40 per cent of the saleable energy has been allowed. The Government of India provides subsidy for development of small hydropower both for government, society and private sector in different proportions depending on the location, degree of difficulty and installed capacity.

Water is a state government subject in India, and hence hydropower development is the responsibility of state governments. Central government advises on the hydropower matters and plays the role of an overall river basin planner and arbitrator. The MNRE has issued guidelines to the State Governments for developing policies for renewable energy development, and especially for small hydropower. The Indian Electricity Act 2003 has special provisions for encouragement of the development of renewable energy and rural electrification.

The main features of the small hydropower policies of the State government are summarized below:

- 24 States namely Arunachal Pradesh, Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh and West Bengal have announced policies for setting up commercial small hydropower projects through private sector participation. The facilities available in the States include wheeling of power produced, banking, buy-back of power and facility for third party sale.
- Over 6,500 MW capacity small hydropower sites have been allotted to private sector for their development.
- Power banking (a concept of utilising the electricity from the grid by the independent Power Producer for its use from one season rainy period) to other seasons i.e. dry period) is permitted by many for a period of one year but in some cases only for six to eight months.
- Buy back of small hydropower is generally based on the guidelines issued by the Central Electricity Regulatory Commission (CERC), with variations given by the State Electricity Regulatory Commissions (SERCs) of many states.
- Some states provide other concessions such as lease of land, exemption from electricity duty and entry tax on power generation equipment.
- Some States do not levy any water charges while some levy it as a percentage of electricity tariffs.
- Some States have prescribed the minimum quantum of power produced from renewable sources, renewable purchase obligation to be purchased by State Distribution Licensee varying from 1 to 10 per cent in incremental manners.

Barriers to small hydropower development

There are several barriers for small hydropower development in India that vary from state to state, depending on the preparation for data, site, feasibility reports and clearance. These barriers may be summarized as follows:

- Lack of availability of discharge data.
- Lack of availability of qualitative geological and sedimentation data.
- Lack of availability of manpower for small hydropower plants planning and design.
- Long time in getting project clearances, in obtaining permissions or licences.
- Lack of involvement of local people.
- Lack of awareness and legal tools with state government to regulate minimum flows in the streams.

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3.3.5 Islamic Republic of Iran

Ugranath Chakarvarty, International Center on Small Hydro Power

Key facts

Population	78,868,711[1]
Area	1,648,195 km[2]
Climate	Mostly arid or semiarid, subtropical along the Caspian coast[1]
Topography	Rugged, mountainous rim; high, central basin with deserts, mountains; small, discontinuous plains along both coasts.[1]
Rain pattern	Annual average rainfall is 300 mm in the plains but only 130 mm in the desert areas.[2]

Electricity sector overview

The Islamic Republic of Iran (hereafter Iran) enjoys a strategic location, acting as a pathway for crude oil transport. In 2010, Iran was the world's fourth largest gas and oil producer and in 2009, Iran was the world's third largest net exporter of oil and it ranked sixth among the[3] world's top electricity producers from natural gas. Electrification in the country amounts to 98 per cent, wherein a population of 1.2 million lacks electricity.

Electricity generation capacity reached 56 GW in 2009. Iran is a net exporter of electricity to its neighbouring countries. However, rollout blackouts are not uncommon in summer months owing to the instability of the grid and the consequent great losses, which may reach 19 per cent.[4]

Electricity generation in 2009 exceeded 221 TWh and was mostly from fossil fuels (natural gas, gas oil and furnace oil), as can be seen from figure 1 below.[5] In September 2011, Bushehr, a 1,000-MW nuclear power plant was commissioned in Iran.

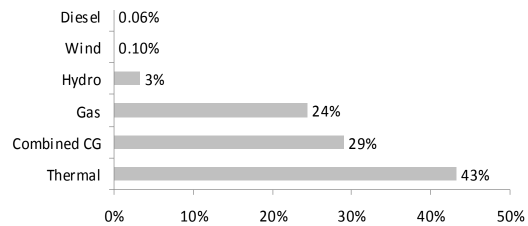

Figure 1 **Electricity generation in the Islamic Republic of Iran**

Source: Electric Power Industry in Iran[5]

Note: Data from 2009. CG – cycle gas

Small hydropower sector overview and potential

Government-owned Iran Water and Power Development Company (IWPCO) is responsible for hydropower development projects, its operation and the development of facilities to secure water supply. However, Iran Water Resources Management (IWRM) provides administrative support to operate water resources effectively and develop hydropower potential. There is no clear information on small hydropower classification in Iran. However, information was available for medium and small hydropower projects (table 1).

Table 1

Installed medium and small hydropower projects in the Islamic Republic of Iran

Project name	*Installed capacity (MW)*	*Scale of project*	*Status*
Ardeh Power Plant	0.125	Micro	In operation
Darre Takht 1 Power Plant	0.680	Mini	In operation
Darre Takht 2 Power Plant	0.900	Mini	In operation
Gamasiab Power Plant	2.800	Small	In operation
Kuhrang Power Plant	35.000	Medium	In operation
Lavarak Power Plant	47.000	Medium	In operation
Micro Power Plant	0.227	Micro	In operation
Piran Power Plant	8.400	small	In operation
Sarrud Power Plant	0.065	Micro	In operation
Shahid Azimi Power Plant	1.000	Small	In operation
Shahid Rajaee Power Plant	13.500	Medium	In operation
Shahid Talebi Power Plant	2.250	Small	In operation
Yasuj Chain Power Plants	16.800	Small	In operation
Tarik Power Plant	2.800	Small	Under construction

Source: Water and Power Development Company[6]

Note: Data as of June 2012.

There are nine small hydropower plants in table 1 that primarily fall under the category of small hydropower as defined by Iran (Installed capacity <10 MW), with an aggregated small hydropower capacity of 16.5 MW (and additional 2.8 MW are under construction). Yasuj Chain Project consists of six run-of-river hydro schemes which include Polkolu 1, Polkolu 2, Kokhdan, Karick1, Karick2, and Karichi 3. The Tarik Power plant project is under construction by Tehran Berkeley Consulting Engineers in 2007 as Engineering, Procurement and Construction (EPC) method of implementation.

According to the Ministry of Energy, Iran has a hydropower potential of 35,427 MW. Economist Intelligence Unit (EIU) estimates that 5,065 MW of hydropower resources have been utilized in 2009.[7] Table 2 shows an overview of small hydropower potential sites as per a study from 2005.[8]

Table 2
Small hydropower potential in the Islamic Republic of Iran

Basin	*Preliminary Study*				*Updated preliminary study*				*Total (MW)*
	Run Off		*Storage*		*Run off*		*Storage*		
	Qty.	*Capacity (MW)*	*Qty.*	*Capacity (MW)*	*Qty.*	*Capacity (MW)*	*Qty.*	*Capacity (MW)*	
1	2	3	4	5	6	7	8	9	10
Khazar Area	5	57.67	9	114.2	108	1 145.0	-	-	1 438.87
Talesh	-	-	7	117.0	18	214.9	7	64.9	428.80
Urumieh	-	-	4	56.0	6	71.3	7	100.2	2 44.50
Mond	-	-	7	136.0	2	21.0	9	163.1	329.10
Gorgan & Dasht	-	-	3	17.0	6	53.5	3	37.6	120.10
Aras	1	5.93	6	67.9	12	168.0	2	12.5	275.33
Dez	-	-	-	-	15	1 118.0	2	65.0	1 200.00
Karun	-	-	-	-	6	380.0	3	746.0	1 135.00
Karkheh	-	-	-	-	4	425.0	-	-	429.00
Total	**6**	**63.60**	**36**	**508.1**	**177**	**3 596.7**	**33**	**1 189.3**	**5 600.70**

Source: Kumar[8]
Note: The total in column 10 is derived from adding column 3,5,7 and 9. Qty – quantity.

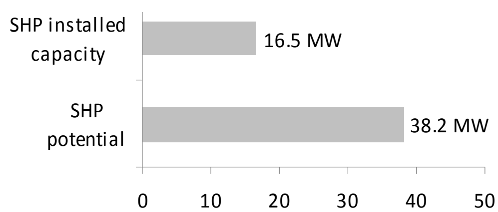

Figure 2 **Small hydropower capacities in the Islamic Republic of Iran**
Source: Water and Power Development Company[9]

As per IWPCO, table 3 indicates the medium and small hydropower plants which are now available to be constructed and has been advertised for tendering and execution as of June 2012.

Table 3
Planned medium and small hydropower plants in the Islamic Republic of Iran

Project name	*Capacity (MW)*	*Scale of project*
Ardal Package	21.000	Medium
Zivakeh Power Plant	15.400	Medium
Dez Power Plant	28.000	Medium
Yasouj development	4.800	Small
Zayanderood Regulator Dam	8.500	Small
Pichab Power Plant	3.915	Small
Joobkhal	4.516	Small

Source: Water and Power Development Company[9]
Note: All projects are ready for construction.

IWPCO has also introduced ready-for-investment projects. There are four prepared small hydropower projects, with an aggregated capacity of 33 MW.[5]

Legislation on small hydropower

The fourth five year national development plan (2005 to 2009) of Iran includes renewable energy policies.[10] The private sector should be supported to disseminate renewable energy applications that are approaching economic viability, such as wind, geothermal and biomass energy. Manufacturers should be supported for transferring and localizing renewable energy technologies which are expected to become competitive in medium terms, such as photovoltaic (PV) systems and solar thermal power plants. Research centres should expand their research programmes for renewable energy technologies that are becoming competitive in longer than 10 years period. Sustainable and accessible energy to the poor and in isolated areas should be provided.

In this context, the Government purchases the electricity produced by the private sector from renewable energy power plants at a price three times higher than the amount paid by consumers. Iran aims to produce 10 per cent of its required electricity from renewable sources by 2025. Fiscal incentives for renewable energy include investment/production tax credits and energy production payment.[10]

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3.3.6 Nepal

Madhu Prasad Bhetuwal, Department of Electricity Development, Ministry of Energy, Nepal

Key facts

Population	26,494,504[1]
Area	147,181 km[2]
Climate	Varies from cool summers and severe winters in north to subtropical summers and mild winters in south.[2]
Topography	Tarai or flat river plain of the Ganges in south, central hill region (lowest point: 64 m), rugged Himalayas in north (highest point: Mount Everest, 8,850 m).[2 3]
Rainfall pattern	Two rainy seasons, one during summer from June to September that brings around 80 % total annual rainfall and the other in the winter. Most part of the country experiences annual rainfall in the range of 1,500 mm to 2,500 mm. The rainfall variations in the different areas of the country ranges <250 mm in the Northern central portion near the Tibetan Plateau and 6,000 mm along the southern slopes of the Annapurna Himalayan ranges.[3]

Electricity sector overview

The Nepal Investment Board (NIB), the Ministry of Energy (MoE), the Department of Electricity Development (DoED), Nepal Electricity Authority (NEA), and the Alternate Energy Promotion Centre (AEPC) are responsible in the development of electricity sector. The NIB deals with hydropower project (HEP) with installed capacity of 500 MW or more. The DoED is a regulating and promotional body under the MoE that deals with projects having an installed capacity between 100 kW and 500 MW. The AEPC deals with projects less than 100 kW. The NEA, a government owned enterprise, is the main responsible organization for generation, transmission and distribution of electricity. Electrification rate in the grid connected area is 14.46 per cent.[4] As of 2011, the NEA has more than 2.32 million consumers, out of them 94.94 per cent are domestic consumers.[4] It is estimated that 42 per cent of the population have access to electricity in the grid connected areas.[4] In off-grid areas, small hydropower and micro hydropower projects are the primary source of electrification. A recent survey revealed that the main source of lighting (67.26 per cent) of households is electricity.[1] Some of small and micro hydropower projects are constructed and operated by the NEA and private sector.

Nepal is blessed with an enormous hydropower potential of 83,000 MW but less than one per cent of its potential has been harnessed for generating electricity so far.[5] The power demand has remarkably grown at an average annual growth rate of 8.5 per cent.[4] Despite the growing electricity demand, the per capita electricity consumption is very low (86 kWh/year).[4] The total installed capacity of electricity is merely 750 MW of which 746 MW is grid connected.[6] The estimated grid connected energy demand in fiscal year 2011/12 was 5,194.78 GWh, out of which 3,041.93 GWh energy was sold. With system loss of 26.43 per cent, the total volume of supplied energy in the integrated Nepalese Power Supply (INPS) grid was 4,178 GWh energy in fiscal year 2011/12.[4] In order to manage exceeding power demand with limited supply, 746.07 GWh (17.8 per cent) energy was imported from India in the fiscal year 2011/12 and power cuts as well as rationing resulting in nearly 12 hours load shedding per day in the winter season have occured.[4]

Small hydropower sector overview and potential

Nepal adheres to the generally accepted small hydropower definition of an upper capacity limit of 10 MW. There are 20 small hydropower projects in Nepal with an aggregated installed capacity of nearly 70 MW (figure). The total annual energy generated from these projects is about 490 GWh. Out of these 20 small hydropower plants, 12 plants were built on a BOOT (Build-Own-Operate-Transfer) basis and are operated by Independent Power Producers (IPPs).

Table 1
Installed small hydropower capacity in Nepal

Ownership	*Number of projects*	*Installed capacity (MW)*
By private sector on a Build-Own-Operate-Transfer basis	12	49.850
By public sector	8	20.062
Total	**20**	**69.912**

There are no small hydropower potential studies so far for Nepal. The theoretically and techno-economically viable hydropower potentials for Nepal have been estimated at 83,290 MW and 42,110 MW respectively. The summary of the same in various major basins is given in table 2 below.

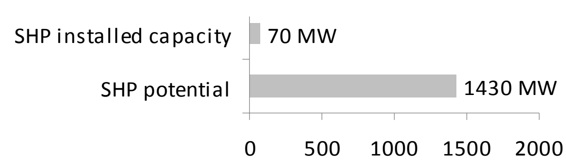

Figure 1 **Small hydropower capacities in Nepal**
Source: Nepal Electric Authority[7]

Table 2

Hydropower potential in Nepal

(Megawatts)

Name of basin	*Theoretical potential*	*Technically feasible*
Sapta Koshi	22 350	10 860
Sapta Gandaki	20 650	5 270
Karnali-Mahakali	36 180	25 100
Southern Rivers	4 110	880
Total	**83 290**	**42 110**

Keeping in mind increasing competency, effectiveness, managerial capacity and financial resources of the private sector and the country's urgency to divert financial resources to other non-commercial sectors (e.g. health, education, social, security etc.), the Government of Nepal has adopted a liberal economic policy. As a consequence, Hydropower Development Policy (HDP), 1992 was approved and accordingly Electricity Act (EA), 1992 and Electricity Rules (ER), 1993 were enacted to motivate national and foreign private sector investment for the development of hydropower. Consequently, the private sector has become interested in the development of small hydropower and the previously active role of the public sector in the construction of small hydropower has been reduced. 22 small hydropower projects with a total installed capacity of 98.344 MW are currently being built by private developers.[6] Similarly, in various parts of the country, several private companies currently are investigating and preparing feasibility studies of 155 small hydropower projects with a total estimated installed capacity of about 878.992 MW.[6] With the expansion of infrastructure facilities (road and transmission lines), emergence of domestic developers as well as commercial banks in the power sector and a conducive environment to small hydropower development, the number of small hydropower projects is expected to increase in the near future.

Renewable energy policy

The Government of Nepal approved a new Hydropower Development Policy in 2001.[5] Some of its objectives are:

- To develop hydropower projects on a competitive basis with the BOOT scheme (e.g. provision for generation license for 35 years for domestic project);
- To follow a transparent process in attracting national and foreign investment (e.g. Guidelines and directives have been prepared and published);
- To provide appropriate incentives (e.g. exemption of Value Added Tax (VAT) for machines, equipment, spare parts and penstock pipe, custom duty reductions for imported small hydropower related machinery or equipment, income tax holidays for first 10 years from project commissioning date and thereafter 50 per cent for next five years);
- To mitigate or avoid possible adverse environmental impacts and to make appropriate provisions to resettle the displaced families (for instance enactment of Environmental Act, Land Acquisition Act);
- To encourage local level participation in small and mini hydropower projects for electrification of remote rural areas;
- To establish a Rural Electrification Fund (REF) in order to make electric service available to many people;
- To control unauthorized leakage of electricity with necessary technical measures and appropriate legal provisions;
- To encourage the utilization of electric power during low demand hours;
- To provide appropriate benefits at the local level while operating hydropower projects;
- To make proper provisions to cover risks likely occurring in hydropower projects;
- To restructure the existing institutions in the public sector to create a competitive environment, by encouraging the involvement of community/cooperative institutions, local bodies and the private sector in the generation, transmission and distribution of hydropower in order to extend a reliable and qualitative electricity service throughout the country at a reasonable price;
- To safeguard the consumers' interests by providing reliable and qualitative electricity service to the consumers at a reasonable price;
- To make rational and transparent process for electricity tariff fixation for reasonable electricity price;
- To give more priority to utilize national labour and skills in the implementation of hydropower projects.
- To establish an institution to impart training within the country to produce skilled human resources for the development of hydropower, to enhance the capability of those involved in this sector and to carry out studies and research works related to hydropower development.

Legislation on small hydropower

The Electricity Act (EA) and Electricity Rules (ER) are the prime Acts and regulations. There is a two-stage licensing system in the power sector. In the beginning an applicant gets Survey License for Electricity Generation (SLEG) on the basis of first come first served basis, provided the applicant submits all the requirements in the stipulated time and carries out field investigation to prepare feasibility and environment study reports. After completing necessary studies, the applicant then applies for a Generation License within the valid SLEG period.

Besides, EA and ER, there are Environment Protection Act (EPA), 199; Income Tax Act, 2058; VAT, 1996; Foreign Investment and Technology Transfer Act, 1992; Forest Act, 1993, Water Resources Act, 1992; Bonus Act, 1974; Land Acquisition Act, 1977; Local Governance Act, 1999; Company Act, 2006 and their corresponding rules also relevant for the development and operation of the small hydropower.

Barriers to small hydropower development

There are numerous barriers constraining hydropower development in Nepal. A lack of political stability, good governance and law and order issues are important factors hindering progress and economic growth. Besides these, lack of firm transmission development plan, frequent changes of ministers and the government, frequent changes of working guidelines, lack of inter-governmental agency co-ordination, overlapping job responsibilities among various government intuitions, prolonged processes and procedures for environmental clearances from the government and a long list of excessive local demands have been posing a major threat to small hydropower development in Nepal.

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3.3.7 Pakistan

Mariam Gul, NED University of Engineering and Technology, Pakistan; Ugranath Chakarvarty, International Center on Small Hydro Power

Key facts

Population	190,291,129[1]
Area	796,095 km^2.[1]
Climate	Mostly hot, dry desert; temperate in northwest; arctic in north[1]
Topography	Flat Indus plain in east; Balochistan plateau in west; mountains in north and northwest (highest point: K2 /Mount Godwin-Austen 8,611 m)[1]
Rain pattern	Mean annual rainfall varies from 0 mm in the desert areas of the country and up to 1,800 mm in the north[2]

Electricity sector overview

The electrification access in Pakistan was 62.4 per cent in 2009, leaving more than 63.8 million inhabitants without access to electricity. Electricity consumption per capita is estimated at 465 kWh per year.[3] Major energy resources in the country include natural gas, oil and hydropower (figure 1). The total electricity generation capacity in Pakistan is 23,412 MW (as of 2010).

Electricity generation in Pakistan is carried out by the public sector and independent power producers. The electricity market restructuring and liberalization processes have been difficult, resulting in unpaid bills and sub-marginal electricity tariff. According to an Asian Development Bank (ADB) Pakistan suffers power shortages, estimated at over 4,200 MW during peak demand, leading to worsening brownouts and blackouts across the country, and necessitating power rationing.[5]

Pakistan is blessed with a hydropower potential of more than 40,000 MW. However, only 15 per cent of total hydropower potential has been harnessed so far. The total installed capacity of the hydropower stations in the country is about 6,595 MW, out of which 3,767 MW is in Khyber-Pakhtunkhwa, 1,698 MW in Punjab, 1,036 MW in Azad Jammu and Kashmir and 93 MW in the Northern Areas. The hydropower sector in Pakistan is mainly owned and managed by Water and Power Development Authority (WAPDA) which is also the largest electric power producer in Pakistan owning more than 55 per cent of total electric power generation and serving 88 per cent of Pakistan's electricity consumers.

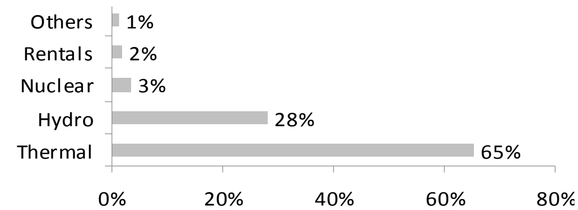

Figure 1 **Electricity generation in Pakistan**
Source: Private Power and Infrastructure Board[4]

WAPDA has however been working on its ambitious plan called National Water Resource and Hydropower Development Programme Vision 2025 with an objective to develop 16,000 MW of hydropower for providing cheap electricity to consumers along with preventing water shortages in future, compensate/adjust for predicted climate changes, protection of agriculture from drought and increasing reservoir capacities.[6]

Small hydropower sector overview and potential

In Pakistan the small hydropower definition is up to 50 MW upper capacity limit. Table 1 below shows small hydropower resources by province.

Coincident with the precipitation pattern in Pakistan, hydropower has been harnessed in the northern part of the country and small hydropower resources are scarce in the southern part (Sindh and Balochistan provinces) due to its desert climate. The majority of these projects are public sector-based. A further summary of micro hydropower plants in Pakistan can be seen in table 2 below.

Table 1
Small hydropower up to 50 MW in Pakistan

Province	*Operation*		*Construction*	
	Number of plants (n)	*Installed capacity (MW)*	*Number of plants (n)*	*Installed capacity (MW)*
Gilgit Baltistan	78	44.275	15	49.83
Khyber Pakhtunkhwa	8	125.800	7	115.68
Azad Jammu & Kashmir	8	38.800	11	25.47
Punjab	5	64.00	6	30.31
Total	**99**	**272.875**	**39**	**221.29**

Source: Farooq[7]

Table 2
Installed micro hydro plants up to 150 kW in Pakistan

Region	*Plants installed (Number)*	*Installed capacity (kW)*	*Households*
Khyber Pakhtunkhwa and FATA	470	6 790.5	59 437
Gilgit Baltistan	22	401.5	4 010
Balochistan	3	80.0	800
Azad Jammu and Kashmir	43	592.0	3 915
Total	**538**	**7 864.0**	**68 162**

Source: Farooq[7]
Note: FATA – Federally administered tribal areas

Table 3
Small hydropower potential in Pakistan

Province	*Capacity (MW)*	*Completed feasibility study*		*Raw sites*	
		Number (n)	*Capacity (MW)*	*Number (n)*	*Capacity (MW)*
Gilgit Baltistan	764	-	71.50	136	814.15
Khyber Pakhtunkhwa	564	-	143.00	78	426.41
Azad Jammu & Kashmir	337	9	78.10	24	177.00
Punjab	409	6	131.28	306	349.00
Sindh	191	5	69.05	3	48.55
Balochistan	..	..	..	..	..
Total potential	**2 665**	**20**	**492.93**	**547**	**1815.11**

Northern Pakistan boasts about an estimated potential of 300 MW for micro hydropower projects.[8] Aga Khan Rural Support Programme (AKRSP) has provided electricity to Gilgit Baltistan and Chitral, a district in Khyber Pakhtunkhwa. In fact, 50 per cent of Chitral's population receives electricity from over 180 micro hydropower plants now being managed by the local communities.[9] The ADB has co-financed the Malakand Rural Development Project in the Khyber Pakhtunkhwa province to build 76 micro hydropower schemes ranging 5-50 kW of capacity in the Malakand division.[10]

According to WAPDA, Pakistan is endowed with a total small hydropower potential of 2,265 MW. Table 3 below shows its geographical division.

Balochistan is a mineral rich province boasting iron and hydrocarbon resources. There is no potential for small hydropower development due to unavailability of required head to generate electricity; however, the National Water Resources Development Programme has included eight sites for irrigation facility.

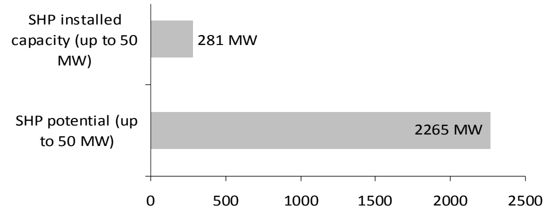

Figure 2 **Small hydropower capacities in Pakistan**
Note: Data on installed capacity and potential for small hydropower up to 10 MW is not available.

The Pakistan Environmental Protection Act of 1997 mandates the provision of environmental assessment for approval of development projects, including small hydropower. An Environmental Impact Assessment is compulsory.[11]

Renewable energy Policy

The Alternative Energy Development Board (AEDB) is the focal centre for preparing policy for promotion of alternative renewable energy in Pakistan. The policy takes four key aspects into consideration which include energy security, economic benefits, social equity and environmental protection as policy objectives with an evolutionary nature.[12] In 2006, the Government of Pakistan approved Policy for Development of Renewable Energy for Power Generation (short phase/introduction of the first phase) prepared by AEDB which includes development of the following renewable resources:

- Small hydropower;
- Solar photovoltaic and thermal energy for power generation;
- Wind power generation.

The second phase of the policy introduced the ARE Policy 2011 and recognized three categories:[13]

- Alternative fuels (biogas, bio-fuel, hydrogen and fuel from waste);
- Renewable energy (geothermal, small hydro, marine, solar, wind, energy from waste);
- Fossil Fuel Hybrids Systems (at least 70 per cent renewable sources)

The third phase or maturity phase for competitive growth would commence 2015 onwards.[14] Moreover, the Government of Pakistan aims at achieving 15 per cent of its Total Primary Energy Supply (TPES) by renewable sources and to further increase its role to 20 per cent by 2020.[15] Pakistan's total and per head CO_2 emissions remain well below developed countries and the main focus of ARE Policy 2011 is to reduce Pakistan's dependence on imported fossil fuels.

Barriers to small hydropower development

- Long gestation period;
- Small/micro hydropower schemes are generally constructed in remote off-grid areas with poor infrastructure;
- Lack of trained local staff for operation and maintenance;
- Restricted optimal usage due to off-grid nature;
- Lower interest by private sector due to lacking proper tariff structure;
- Difficult socio-economic conditions and generally weak implementation and coordination capacity.

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3.3.8 Sri Lanka

Nimashi Fernando, Harsha Wickramasinghe, Wimal Nadeera, Sustainable Energy Authority

Key Facts

Population	21,481,334[1]
Area	65,610 km^2.[1]
Climate	Tropical monsoon; northeast monsoon (December to March); southwest monsoon (June to October)[1]
Topography	Mostly low, flat to rolling plain; mountains in south-central interior[1]
Rain pattern	Mean annual rainfall varies from under 900 mm in the driest parts (south-eastern and northwestern) to over 5,000 mm in the wettest parts (western slopes of the central highlands).[2]

Electricity sector overview

The installed electricity generation capacity in Sri Lanka reached 3,141 MW in 2011, where 66 per cent is owned by the state and 34 per cent is in possession of independent power producers.[3] Gross electricity generation in Sri Lanka was 11,528 GWh in 2011.[3] Figure 1 below depicts the breakdown of the different energy sources used.

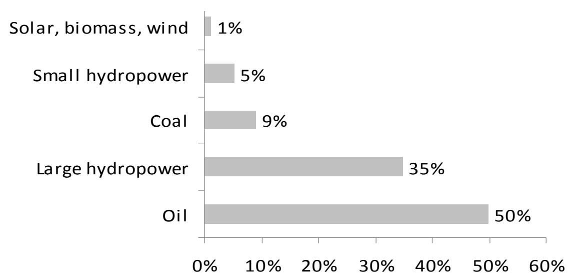

Figure 1 **Electricity generation in Sri Lanka**
Source: Ceylon Electricity Board[3]

Small hydropower sector overview and potential

Sri Lanka adheres to the small hydropower definition of 10 MW upper capacity limit. There are 90 small hydropower plants in Sri Lanka, with an aggregated installed capacity of 194 MW, most of which are owned by Independent Power Producers (IPPs).
According to Sri Lanka's Sustainable Energy Authority (SEA), the total economically feasible small hydropower potential in Sri Lanka is 400 MW (figure 2).[4]

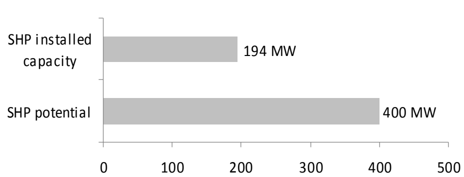

Figure 2 **Small hydropower capacities in Sri Lanka**
Source: Ceylon Electricity Board[4]

The chart below indicates the development of New Renewable Energy (NRE), of which the major share comes from small hydro plants.

According to figure 3, the rate of increase in capacity additions, especially small hydro, accelerated after year 2007 with the establishment of SEA in 2007. The acceleration can be attributed to the transparent resource allocation process introduced by SEA which is based on a 20-year permit to use a particular new renewable energy source granted to private sector developers through a 'first come first served' principle.

Renewable energy policy

The Government of Sri Lanka envisages developing NRE technologies to reach a 10 per cent target in power generation by 2015. The Mahinda Chintana Idiri Dekma, the Government's vision for national development, envisions further extending this goal to reach 20 per cent by 2020.

Standardized Power Purchase Agreements (SPPA) are considered the key driver of the early success of the small hydropower sector in Sri Lanka, also applicable to other renewable sources and waste or co-generation facilities with capacities up to 10 MW. Main features of the SPPAs include:

- A complete avoidance of market risk: the Ceylon Electricity Board assures the purchase of all that is produced by a small hydropower project.
- A floor price of 90 per cent of the tariff: ensuring a steady and predictable cash-flow.
- A long term commitment: the SPPA lasts 15 years and is based on sound legal provisions.

The SPPA was well received due to its relative simplicity. It was also acceptable to banks and had low transition costs.[6]

The Sri Lankan small hydropower sector followed a natural evolution until year 2005, with no formal policy framework. The tariff on offer was based on avoided costs, and escalating oil prices forced the small hydropower tariff to climb up towards an almost unsustainable level.[6] Furthermore, the loosely regulated resource allocation process has left many good sites in the hands of non-serious licensees where their licences have yet to be cancelled and transferred to the more premium developers.[6] Although the small hydropower in Sri Lanka has created a conducive investment environment with the necessary legal framework and financing mechanisms in place, a too expeditious development could create harm by connecting more small generators to the grid in an unregulated manner, potentially warranting a number of technical issues.[7]

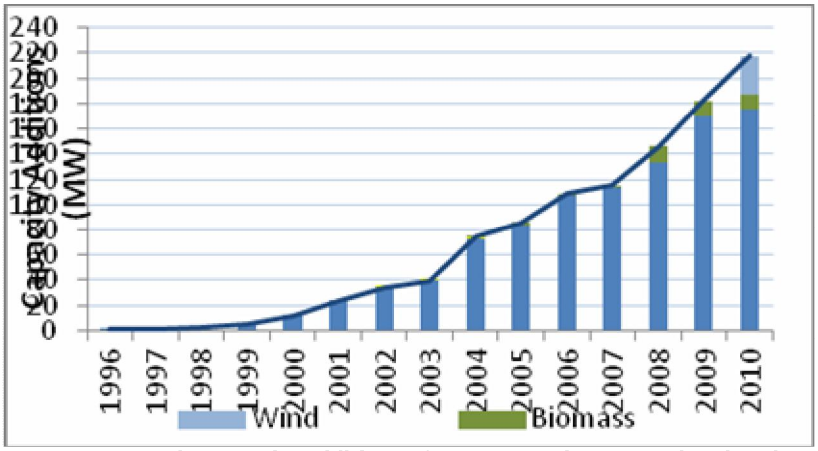

Figure 3 **Cumulative capacity additions of new renewable energy in Sri Lanka, 1996 – 2010**
Source: Sri Lanka Energy Authority[5]

To address this issue, the Sri Lankan Government proposed an adjusted a three-tiered, technology-specific, cost-based tariff for NRE developers, eliminating the drawbacks of the previous tariff based on avoided cost. [6,8]

In general, the Sri Lankan Government has successfully provided policy support to the industry over the past years, creating a conducive environment for the development of small hydropower in the country.

Currently, the leading Sri Lankan small hydropower businesses are very active in the African continent in consulting and project development. The country has a well-developed small hydropower value chain.

Legislation on small hydropower

The primary legislation on small hydropower sector in Sri Lanka is Sustainable Energy Authority Act No.35 of 2007. The provisions of this act are resource neutral and apply not only to small hydropower, but equally on all renewable energy resources. The primary legislation is supported by subsidiary legislation identified as 'regulations' with the publication of *Energy Development Areas* through a regulation where the SEA can exercise control over the hydropower resource, land requirement for the project and access. The applications received to develop any small hydropower site are treated in the first come, first served basis, as detailed out in another subsidiary legislation. The detailed information on the project development process is contained in a publication titled *A Guide to the Project Approval Process for On-Grid Renewable Energy Project Development* and is cited in the subsidiary legislation as a binding acceptance, making the guide a part of the small hydropower legislation.[9]

Barriers to small hydropower development

The small hydropower sector in Sri Lanka has reached its maturity state, however the industry is still experiencing barriers to implementation in the following areas:

- Absence of a dedicated transmission solution for uptake of power from small hydropower plants;
- Limitations at local grid sub-station level and at national power system level for adding more small hydropower to the grid;
- Public opposition at regional level arising out of conflicting use of water resources;
- Absence of dispatch control strategies such as advance forecasting and on-line monitoring and regression.

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3.4 South-Eastern Asia

Lara Esser, International Center on Small Hydro Power

Introduction to the region

South-Eastern Asia (hereafter SEA) comprises 11 countries, 10 of which are independent members of the Association of Southeast Asian Nations (ASEAN) and the newly independent Timor-Leste.[1] For the ASEAN-6 region (i.e. Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam), nearly 85 per cent of electrical power is generated from fossil fuels. The renewable mix relies almost exclusively on hydro and geothermal electricity generation (12 per cent and 3 per cent respectively).[2] Hydropower development in the region can help ASEAN achieve its target of 15 per cent of renewable energy in the total ASEAN power supply by 2020.

A predominantly tropical climate subjects the inhabitants to a range of natural hazards including annually occurring monsoon floods, droughts and tropical cyclones. Manmade disasters are also a feature of SEA due to its burgeoning population, thus increasing the its vulnerability to the impacts of climate change, especially to those living below an income of US$1-US$2 a day.[1] In addition, the combination of rapid economic development coupled with the very rapid urbanization rate globally has led SEA to emit greenhouse gas (GHG) emissions twice as fast as the global average.[1] Yet SEA does have one of the greatest potentials for mitigating carbon dioxide through the reduction of deforestation and improved land management practice. Meanwhile its vast untapped opportunities in renewable energy development and energy efficiency should play an integral role in curbing future emissions.

Table 1
Overview of countries in South-Eastern Asia

Country	*Population (million)*	*Rural Population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Cambodia[adej]	14.14	80	29.0	538	2 330	13.3	50.0
Indonesia[afg]	239.87	56	67.2	35 313	177 883	4 519.0	11 000.0
Laos[acf]	6.48	67	55.0	742	1 553	2 000.0	10 000.0
Malaysia[acf]	28.40	28	99.4	22 973	101 100	1 910.0	4 950.0
Myanmar[acf]	47.96	66	13.0	2 256	6 426	1 541.0	7 830.0
Philippines[acf]	93.26	51	89.7	13 459	59 190	3 291.0	6 432.0
Thailand[acfh]	69.12	66	99.3	30 920	139 000	3 424.0	5 314.0
Timor-Leste[acf]	1.20	72	22.0	45	..	0.3	1.5
Viet Nam[abcfi]	86.93	70	97.6	16 048	97 300	5 500.0	24 000.0
Total	**587.36**	**-**	**-**	**122 294**	**584 782**	**22 198.6**	**69 577.5**

Sources
a. Central Intelligence Agency[3]
b. Reegle[4]
c. International Energy Agency[5]
d. World Bank[6]
e. Cambodia Ministry of Industry, Mines and Energy[7]
f. *International Journal on Hydropower and Dams*[8]
g. Indonesia Agency for the Assessment and Application of Technology[9]
h. Thailand Department of Water Resources[10]
i. Viet Nam Institute of Energy[11]
j. Cambodia Deputy Office of General Department of Energy[12]

Small hydropower definition

Table 2
Classification of small hydropower in South-Eastern Asia

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*	*Pico (kW)*
Cambodia	--	0.5–10	up to 500	--
Indonesia	5–10	0.2–5	1–200	up to 1
Laos	1-15	0.1-1	5–100	up to 5
Malaysia	1-10	--	up to 1 000	--
Myanmar	--	--	--	--
Philippines	--	0.1–10	1–100	up to 1
Thailand	6–15	0.2–6	up to 200	--
Timor-Leste	--	--	--	--
Vietnam	1-30	0.001-1	0.2–1	--

Source: See country reports

The SEA region experiences various small hydropower definitions, including pico-hydro. Classification by various countries within the region can be found in table 2.

Regional overview and potential

Small hydropower has been adopted by -9 of the 11 countries in the region (table 3). Hydropower plays an important role in electricity production both in Vietnam as well as the Philippines.

The largest installed small hydropower capacity can be found in Viet Nam (622 MW), followed by the Philippines (248 MW), Thailand (146 MW) and

Indonesia (99 MW). Viet Nam (2,205 MW) has the largest small hydropower potential (defined as up to 10 MW), followed by the Philippines (1,876 MW) and Indonesia (1,267 MW). In the Philippines, all of the run-of-river small hydropower plants are privately owned, while in Thailand, all small hydropower development responsibility lies in the hands of its Government (i.e. Department of Alternative Energy Development and the Electricity Generating Authority of Thailand. The German Government, through the German Agency for Technical Cooperation (GTZ), has been providing long-term support to the development of mini hydropower in Indonesia since 1991, hence this area has been developed slowly overtime.

Among the countries with lesser small hydropower potential, Malaysia has some known small hydropower (116 MW) including an estimated micro hydropower potential of 28.8 MW, yet implementation has been slow. It is predicted that by year 2020, most rivers and waterways will be fully utilized for electricity generation. Cambodia still has a large small hydropower potential of 300 MW, but currently it has only one mini hydropower (1 MW) in operation with another two micro plants (370 kW installed capacity).

Myanmar has abundant renewable energy resources and small hydropower potential (170 MW) and will continue to develop small hydropower as a power source for small village electrification. Laos is a mountainous country with impressive excess of electricity generation. Currently several funding programmes from international donors are in place to develop its pico hydropower. Few small hydropower development opportunities exist in Timor-Leste due to its steep topography, yet the State Secretary for Energy Policy along with the Norwegian Water Resources and Energy Directorate are implementing Hydropower Master Plan which was expected to take place in 2012.

Table 3

Small hydropower up to 10 MW in South-Eastern Asia

(Megawatt)

Country	*Potential*	*Installed Capacity*
Cambodia	300.0	1.9
Indonesia	1 267.0	99.4
Laos	50.2	10.5
Malaysia	116.6	87.7
Myanmar	167.4	36.0
Philippines	1 876.0	248.0
Thailand	700.0	146.3
Timor-Leste	at least 0.3	0.3
Viet Nam	2 205.0	621.7
Total	**6 682.5**	**1251.8**

Source: See country reports

Brunei has plans on developing its small hydropower potential in the near future, while Singapore's geography does not present opportunities to harness renewable energy from hydro technologies.[13] [14] The two countries are not covered in this chapter due to the lack of development in this area.

The total installed capacity in the region is approximately 1.25 GW. Apart from Timor-Leste, which small hydropower status is largely unknown, all other countries have a relatively high small hydropower potential. In general, the future of small hydropower looks very promising within the region having a potential of approximately 6.6 GW.

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3.4.1 Cambodia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	14,952,665[1]
Area	181,035 km[2]
Climate	Tropical and rainy, with little seasonal temperature variation
Topography	Mostly low, flat plains; there are mountains in the southwest and north.
Rain pattern	The monsoon season is from May to November, the dry season is from December to April.

Electricity sector overview

According to the Cambodian Ministry of Energy and Mines, the country has an installed capacity of 537 MW. However, it remains heavily dependent on imported electricity from Vietnam and Thailand as well as on fossil fuel imports for electricity generation (figure 1). Électricité du Cambodge is a fully state-owned limited liability company.

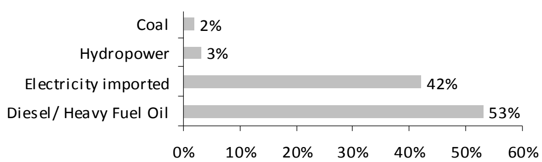

Figure 1 **Electricity generation in Cambodia**
Source: Ministry of Industry and Mines and Energy[2]

The national electrification rate in 2010 was 29 per cent.[2] Urban areas are 100 per cent electrified, as compared to only 12.3 per cent in the rural areas.[2] Approximately 11.3 million people had no access to electricity in 2009. Four per cent of the population is served by off-grid sources, including mini grids or household systems. The Royal Government of Cambodia has formulated a Rural Electrification Strategy with the target to provide 70 per cent of rural households with electricity by 2030. Electricity shortage facing the remaining rural households (30 per cent) is expected to be solved by a Renewable Energy Development Program which will provide quality renewable energy services in remote regions mostly via solar applications (solar lanterns, solar home systems -SHS). The main components of the Rural Electrification Strategy are as follows: expansion of the existing grids, up-scaling of power generation (hydro, oil, coal) and cross border power supply from neighboring countries (Thailand, Vietnam and Lao People's Democratic Republic), creation of mini grids (diesel, biomass especially gasification, micro hydropower and battery lighting with solar and wind).[3]

Small hydropower sector overview and potential

See table 1 for the classification of small hydropower in Cambodia.

Table 1
Classification of small hydropower in Cambodia
(Megawatt)

Definition	*Installed capacity*
Small	not applicable
Mini	>0.5–10
Micro	≤ 0.5

Sources: Association of Southeast Asian Nations[3], Cambodia Ministry of Industry, Mines and Energy[4]

The present installed capacity of mini and pico hydropower is 1.87 MW. There is one mini hydropower plant with a 1-MW installed capacity and two micro hydropower plants with a combined capacity of 370 kW under the responsibility of Provincial Electricity Unit of Électricité Du Cambodge.

There are also privately-owned micro- and pico-hydropower plants imported from Viet Nam or China located in the Northern provinces with an installed capacity ranging between 1 kW to 30 kW.[4] The theoretical potential of mini-, micro- and pico-hydropower has been assessed at around 300 MW (figure 2), and 30 possible small hydropower sites have been identified (table 2).[4]

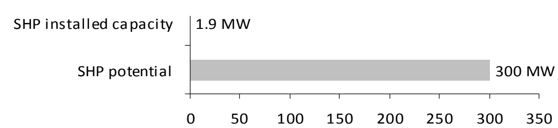

Figure 2 **Small hydropower capacities in Cambodia**

The Government's small hydropower promotion involves:

- An aim to scale up electricity access in rural areas in order to tackle poverty and foster economic development.
- Private sector participation and encouragement.
- Identifying technical assistance and financial support.
- Making electricity affordable in rural areas.
- Reduction or exception on import tax.

Renewable energy policy

The country targets to achieve 15 per cent of electricity generation from renewable sources by 2015.[3] The Cambodian Government has set in its Renewable Electricity Action Plan (REAP, 2002-2012) the objective of providing cost-effective and reliable electricity to rural Cambodia through the use of renewable energy technologies.[4]

Table 2
List of mini and micro hydropower projects to be developed in Cambodia

Project name	*Capacity (MW)*	*Location*	*Remark*
O'Chum II	1.0	Ratanakiri Province	Completed in 1993
O'Mleng	185.0	Mondul Kiry	Completed in 2008, Japan Grand Aid
O'Rimis	185.0	Mondul Kiry	Completed in 2008, Japan Grand Aid
Stung Sva Slap	3.8		On the list of priority mini hydropower projects
Upper St. Siem Reap	0.6.0	-	On the list of priority mini hydropower projects
Lower St. Siem Reap	1.5.0	-	On the list of priority mini hydropower projects
Upper O Sla	2.0	-	On the list of priority mini hydropower projects
Lower O Sla	4.5.0	-	On the list of priority mini hydropower projects
Sre Cheng (St. Daunpe)	130.0	-	On the list of priority mini hydropower projects
O Samrel	33.0	-	On the list of priority mini hydropower projects
Ta Taok (O Chum)	38.0	-	On the list of priority mini hydropower projects
Kompong Lpov (O Doeum Chek)	32.0	-	On the list of priority mini hydropower projects
Bu Sra (O Por)	56.0	-	On the list of priority mini hydropower projects
Bey Srok (O Sien Ler)	78.0	-	On the list of priority mini hydropower projects
Ta Ang (O Cheng)	10.0	-	On the list of priority mini hydropower projects
Dakdeur/Romis	0.2	-	On the list of priority mini hydropower projects
O'Turou Trao	1.1	Kampot	Desk Study
Stung Siem Reap 3	1.7	Siem Rap	Desk Study
O'Katieng	1.0	Rattanak Kiry	Desk Study
O'Sla Up Stream	1.9	Koh Kong	Desk Study
Stung Chikreng	0.8	Siem Reap	Desk Study
Stung Kep	4.1	Kep City	Desk Study
O'Phlai	3.4	Mondul Kiry	Desk Study
Prek Por	4.8	Mondul Kiry	Desk Study

Sources: Cambodia Ministry of Industry, Mines and Energy[4], Lor[5]

In 2007, the Rural Electrification Fund created as per the Royal Decree of the Kingdom of Cambodia (NS/RKT/1204/048) came into existence. Not under jurisdiction of any specific Ministry, it has relations with the Ministry of Industry, Mines and Energy, the Ministry of Economy and Finance and the Electricity Authority of Cambodia. The grants available under the scheme target private rural operators (Rural Electrification Enterprises, REE). Out of the 200 REEs active in Cambodia, 178 are off-grid enterprises.[6]

Barriers to small hydropower development

- High associated costs for distribution networks connecting mountainous areas, where most economically viable small hydropower sites are located, to consumption areas.
- Lack of small hydropower-related capacities and field expertise.
- Lack of finance for plant development.[4]

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3.4.2 Indonesia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	248,645,008[1]
Area	1,904,569 km[2]
Climate	Tropical, hot and humid, but more moderate in the highlands. There are two discernible seasons, both of which are hot. The coastal regions, however, are often cool, and in the mountains the air is chilly.
Topography	Mostly coastal lowlands, but the larger islands have interior mountains.
Rain pattern	Dry season: June to October. Rainy season: November to March.

Electricity sector overview

The total installed capacity of Indonesia was 35,313 MW in 2011.[2] Indonesia does not import any electricity. Thermal sources are dominant contribution to electricity generation (figure 1). In 2010, most of the electricity (83 per cent) was produced by the state-utility PT Perusahaan Listrik Negara's (PLN), 6.4 GW off-grid, half of which from renewable sources and half from diesel.[3]

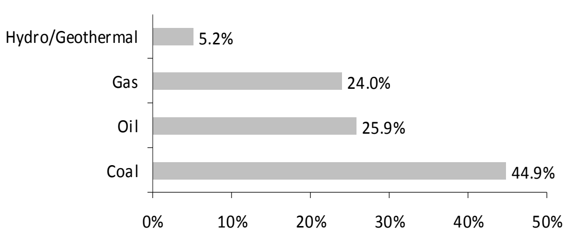

Figure 1 **Electricity generation in Indonesia**
Source: Differ Group[3]
Note: Data from 2010.

In Indonesia, only 67.2 per cent of households have access to electricity.[2] Indonesia has a rural electrification programme included in its Renewable Energy Development Program, where the Government has taken measures to replace diesel-based power plants with renewable energy ones.[4] Access to electricity, particularly in rural areas is still a challenge where increased use of hydropower potential is considered an appropriate solution.[2] The Government targets an electrification rate of 90 per cent by 2020.[4]

Small hydropower sector overview and potential

In Indonesia there is no agreed general consensus on the small hydropower definition, with the terms small, mini, micro and pico hydropower used interchangeably. Current installed small hydropower capacity is about 100 MW, however, the potential is much higher (figure 1).

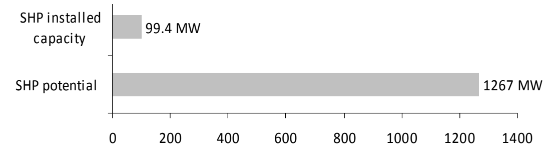

Figure 2 **Small hydropower capacities in Indonesia**

Germany has provided long-term support to the development of mini hydropower in Indonesia. A cooperative called Mini Hydro Power Project (MHPP) was carried out by the Directorate General of Electricity and Energy Utilization, Ministry of Energy and Mineral Resources and the German Technical Cooperation (GTZ). The first phase of the MHPP project (1991-1996) had focused on the introduction of technology to local institutions and individuals thar were already active in micro hydropower project development. In the second phase (1999-2002), the scope of intervention was broadened to include policy dialogue, scaling-up of technology packages, and improving operation and management. The project has developed a variety of mini hydropower technology packages transferring knowledge and expertise to local manufacturers in Java and Sumatra. Over the past decade, such packages have been applied in more than 100 installations. These schemes presently supply over 20,000 families with clean and sustainable energy.[5]

As part of the global Energizing Development Program, MHPP has, since 2006, been scaled-up to further enhance sustainable access to energy in rural Indonesia. Between 2006 and 2009, over 90 additional schemes went into operation. By 2009, these schemes supplied 68,000 individuals, 427 social infrastructures, and 2,020 small businesses with clean energy. In 2010, a monitoring survey visited 20 mini hydropower sites built in Sumatra and Sulawesi under MHPP. The survey mission found 19 out of the 20 visited mini hydropower sites were still operational and in overall good condition. Only one was temporarily out of operation due to land conflicts. On average about 240W is available for each of the 1,638 households supported by the 19 MHPP investigated. Additionally, 88 per cent of the social infrastructure buildings in the communities are supplied by the installation, meaning that small businesses can also benefit. All sites are looked after by trained operators who receive a regular salary. All communities individually defined a tariff system, where the rules for customer and social infrastructure tariffs were set; five communities even have special tariffs for productive use. Each has an established technical and financial management system. All villages use the collected tariff for future maintenance and repair of the systems hence they do not require any further external support.[6]

The ASEAN Hydropower Competence Centre (HYCOM) in Bandung facilitates ASEAN-wide knowledge exchanges on mini and micro hydropower (1 kW to 1 MW). The objective of HYCOM is to provide an ASEAN-wide competence centre, offering training as well as facilitating research and development to the small hydropower sector. It has implementing partners (i.e. PT Entec Indonesia and Technical Education Development Centre, Bandung) and supporting partners i.e. the Swiss Renewable Energy and Energy Efficiency Promotion in International Cooperation, the Renewable Energy Support Program for ASEAN, the ASEAN Centre for Energy and Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ).[7] It is involved in training activities on standards, laboratory testing of micro hydropower equipment with regard to reliability, safety and efficiency, support for the development of mini hydropower sites and networking and exchange of micro hydropower related information.[7]

Renewable energy policy

The renewable energy target of the country is 25 per cent. The Government pays attention to its development and has passed laws and regulations to prioritize and promote it. These include the National Energy Policy 30/2007, the Electricity Law 30/2009 and the ministerial decrees on Distributed Power Generation and Renewable Energy and Energy Conservation.[5]

Legislation on small hydropower

The electricity generated using renewable energy, especially small hydropower, is to be bought by the state-electricity company at an agreed fix price.[2]

Barriers to small hydropower development

- Structural and policy-related barriers: lack of standardization of procedures and technical codes, non-standardized procedures to obtain power purchase agreements, lack of technical support to interconnect small hydropower to the grid. No consistent and transparent governmental policy supporting renewable energy development in place. Absence of subsidies or any other financial incentives supporting renewable energy development.
- Barriers related to technical and institutional capacities: insufficient stakeholder involvement during project selection, planning, and implementation. Lack or poor quality of pre-investment financial evaluations. Technical problems resulting from poor design and construction quality (civil, mechanical, and electrical) are also common. Local equipment design and manufacturing capability is limited, and is mostly concentrated on Java. Imported small hydropower equipment is expensive and spare parts are often difficult to obtain. There are no mechanisms in place (i.e. product liability, quality assurance, technical control institution) that warrant the quality of small hydropower equipment.
- Plant operation and maintenance is often haphazard, with little preventative action.
- Financing mechanisms are either unavailable or difficult to locate.
- Barriers related to awareness and dissemination of information: many institutions and decision makers are not aware of the possibilities for small hydropower development. As a result, conventional energy options are preferred. Basic data (maps, surveys, hydrology, and geology) needed for project evaluation is often missing or difficult to obtain, especially for more remote regions. A frequently updated and easily accessible inventory with potential small-scale hydropower sites was inexistent in 2012. Potential project developers therefore often have to take a lengthy way through many institutions to identify investment opportunities. At the same time, attractive sites may remain undeveloped, because they are unknown.

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3.4.3 Lao People's Democratic Republic

Lydie Mateo, Gregoire Pelletreau and Aurelie Phimmasone, Laos Institute for Renewable Energy, Lao People's Democratic Republic

Key facts

Population	6,586,266[1]
Area	236,800 km[2]
Climate	Tropical monsoon[1]
Topography	Mountainous landscape
Rain pattern	Rainy season: May to November. Dry season: December to April[1]

Electricity sector overview

The responsibility for the energy sector is divided among various organizations with the Ministry of Energy and Mines or MEM (formerly the Ministry of Industries and Handicrafts or MIH), being the most prominent as it manages the electricity sector through the Department of Electricity (responsible for power sector development) and Electricité du Laos (EDL), which is a state owned enterprise responsible for electricity supply to the domestic sector. Under the Electricity Law (Article 43), MEM has the primary responsibility for policy formulation and strategic planning, jointly undertaken with the Science, Technology and Environment Agency, the Committee of Investment Management and Foreign Economic Cooperation and other relevant agencies.[2]

During the period 1995-2010, Lao People's Democratic Republic (hereafter Lao PDR) made impressive achievements in national electrification whereby electricity access has more than quadrupled. Indeed, the ratio of household electricity use had rapidly increased from 15 per cent in 1995 to 73 per cent in 2010, surpassing expectations and the 70 per cent target. The majority of villages have access to electricity, both on-grid and off-grid. These are outstanding results for a country with a predominantly rural population. Thus the country is on track to achieve its target of 80 per cent national electrification coverage by 2015 and 90 per cent by 2020.[3] This is in contrast with the data reported in *World Energy Outlook 2011*, where it states that the country's electrification rate was at 55 per cent for 2009, which was probably due to a difference in definition of electrification.[4]

In order to reach its 2020 target, the Government pursues an aggressive grid extension programme complemented by off-grid electrification whenever it is cost-effective. In parallel, the Laotian Government, with the support of the World Bank through the expansion of the Power to the Poor Program from EDL is also willing to increase the nationwide connection ratio in areas already covered by the grid, from 80 per cent to 95 per cent of the households.[5] In addition, the Rural Electrification Fund (REF) Secretariat under the Ministry of Energy and Mines (MEM) is working with the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) to promote rural entrepreneurship using an innovative pro-poor public-private site-specific partnership (5Ps). Besides developing local entrepreneurship, 5Ps aim to integrate energy in to broader rural development agenda and reduce stress on the government budget.

At this stage of national electrification, where most of the unconnected population lives in villages and scattered communities in hard-to-reach places, it is expected that as much as 20 per cent of the total population will remain beyond the reach of the mainstream grid for the foreseeable future, especially when the cost of extension has increased.[5] Indeed, over the course of the last seven years, the average cost per grid connection has almost doubled: from about US$450-$550 in 2005 to about US$900 in 2012.[3]

The majority of the rural population, with no access to electricity at present, depends primarily on biomass (fuel wood and charcoal) for domestic energy needs such as cooking and heating.[6]

Hydropower contributes almost all electricity production in Lao PDR (figure 1). The Government has signed memoranda of understanding (MOU) as well as undertaken research studies on more than 70 hydropower studies. Of these, 15 are either operational or under construction. Lao PDR has also signed a MOU to provide 7,000 MW of electricity to Thailand, and another MOU to provide 3,000 MW of electricity to Viet Nam by 2020.

Electricité du Laos had a share of 50.7 per cent of the total installed electricity capacity, the private sector contributes 49.1 per cent and the Provincial Departments of Energy and Mines at 0.16 per cent.[7]

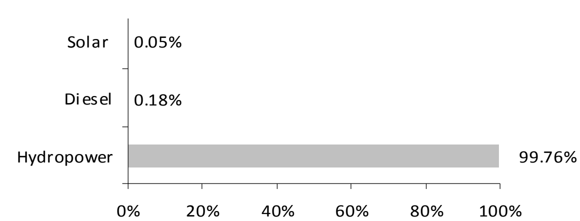

Figure 1 **Electricity generation in Lao People's Democratic Republic**
Source: Laos Ministry of Energy and Mines.[7]
Note: Data from 2008.

Small hydropower sector overview and potential

A total of 10.5 MW small hydropower is in operation, not including pico hydro (figure 2). Some 16.2 MW are under construction and 23.5 MW capacity are at the feasibility stage.

Lao PDR has its own small hydropower classification, where capacities up to 15 MW are considered small hydropower.

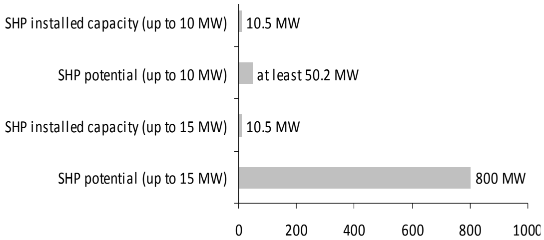

Figure 2 **Small hydropower capacities in the Lao People's Democratic Republic**

Pico hydropower is common in the remote rural areas of the Northern provinces. It is completely market-driven and provides many people in off-grid regions with electricity. An estimated 60,000 low head pico hydropower units provide electricity to 90,000 households (see table).[8]

These low-head turbines are available in rated capacities from 200W up to several kilowatts, but the units producing one kilowatt and less are the most popular in Lao PDR. The low cost (US$50-US$200) makes it affordable for many rural households. Less common are the turgo-type pico hydropower units, requiring less flow but a head of at least several metres.[8] However, pico hydro seems to be not monitored and hence underreported. In 2005, pico hydro was not reported at all in the official energy statistics and information on other technologies such as photovoltaic (PV), solar panels, were also grossly incomplete.[8]

Existing data and estimation of the number of pico hydropower turbines in Lao PDR

Area	*Data*	*Source*		
		Village Off-Grid Promotion and Support Project (VOPS) Survey 2007	*Smits & Bush Own Data*	*Smits and Bush Estimation*
North	No. of surveyed villages	337.0	8	3 200.0
	No. of households	19 535.0	444	240 000.0
	No of pico-hydro turbines	7 051.0	293	47 000.0
	No. of households connected	10 683.0	293	7 000.0
	% of households connected	55.0	66	30.0
	Sharing factor (households/unit)	1.5	..	1.5
South	No. of villages	..	3	2 800.0
	No. of households	..	245	300 000.0
	No. of pico-hydro turbines	..	118	11 000.0
	No of households connected	..	118	17 000.0
	% of households connected	..	48	6.0
	Sharing factor (households/unit)	..	..	1.5

Source: Smits and Bush[8]

A Master Plan Study on Small Hydropower for the Northern part of Lao PDR was conducted by MEM/MIH and Japan International Cooperation Agency (JICA) under the technical assistance modality.[2] Some 24 potential micro/mini hydro sites have been studied, of which 22 sites warranted further reconnaissance. Pre-feasibility studies have been carried out for 11 of these sites, with potential capacities ranging between 30 kW and 8 MW.

The Laos Institute for Renewable Energy (LIRE) together with ETC Energy from The Netherlands conducted a two-year Pico-Hydropower Innovation and Capacity Building Programme. It focused on the sustainable development of pico hydropower use through improving access to reliable pico hydropower services, accessories and information. The programme also focused on the establishment of the first shared pico hydropower system in Lao PDR. Finally, LIRE aimed at raising awareness of the importance of small-scale hydropower for rural livelihoods. Activities included dissemination of pico hydropower technical installation and safety end-user manuals and other documentation in Laotian, training of technical advisors (70 people), the introduction of Electronic Load Controllers (ELC) in the supply chain and support workshops (35 people).

The second component of LIRE's pico-hydropower programme was supported by Bremen Overseas Development Association (BORDA) and the German Embassy in the Lao PDR. It aimed to demonstrate a shared pico hydropower system which provided power to 24 households and four communal buildings of the remote village of Angsang, Huaphan. The system is operated as a community-based service, with village technicians responsible for maintenance and fee collection. Local authorities and LIRE provide guidance and capacity building until independency is achieved. The households are divided into two different tariff sectors, reflecting the different energy needs: a low tariff provides only lighting (30 W limit) and a higher tariff introduced for users who require power for TVs and stereos (100 W). This best practice demonstration site has been a successful model.

The International Finance Corporation (IFC) is contributing alongside MEM to develop village hydro generator sets with stand-alone systems and a mini-grid. Several project proposals including feasibility studies have been proposed by potential developers and it is expected that public private partnerships will be developed under the Rural Electrification Program and support from the REF.[9]

Renewable energy policy

The Laotian Government promotes the development of large hydropower facilities, hoping to export electricity to neighboring countries (in particular Thailand), and thereby achieving significant national income while providing energy security at low tariffs for its population.[10] Additionally it encourages:

- Policies facilitating private sector investments in rural electrification such as the provision of incentives and financing.
- The development of small hydropower systems, bio-fuel, solar, biomass energy at village level to provide electricity and energy to rural and remote communities.

In developing a complementary policy for off-grid rural electrification, the Government initially focused on the introduction of Solar Home Systems (SHS), but more recently it decided to include small hydropower systems.[5] So far, through its off-grid rural electrification policy, the Government has installed around 15,000 SHS in remote areas. The private company Sunlabob Renewable Energy Ltd has introduced an additional 5,000 PV systems.[5] Small hydropower has contributed heavily to rural electrification based on individual investment on pico hydro units in the Northern regions (47,000 turbines).[10]

Legislation on small hydropower

The Draft Renewable Energy Development Strategy of Laos (December 2011) includes a series of proposals and recommendations with regard to the promotion of small hydropower, as well as biofuels, solar, biogas, wind energy and alternative energy sources for transport. Promotion and development of small hydropower in particular addresses units with a capacity below 15 MW.

Barriers to small hydropower development

- Concentration of few actors involved in off-grid electrification.[8] In the short term, any significant innovations to off-grid electrification will emerge from the collaboration of the Laotian Government and World Bank, along with the private sector, since other actors have had only a minor influence in this field.
- Financial challenges. While large hydropower projects attract increased foreign interest and investment, small scale hydropower and pico hydropower receives less attention due to lack of commercial opportunities, making it less attractive to both public and private investors.[10]

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3.4.4 Malaysia

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Key facts

Population	29,179,952[1]
Area	329,961 km^2
Climate	Tropical; annual southwest (April to October) and northeast (October to February) monsoons
Topography	Coastal plains rising to hills and mountains.
Rain pattern	Annual mean rainfall for Peninsular Malaysia is 2,400 mm; Sabah 2,360 mm and Sarawak 3,830 mm.

Electricity sector overview

The Malaysian Government established the Energy Commission on 1 January 2002, under the Energy Commission Act 2001. It assumed all responsibilities of the Department of Electricity and Gas Supply which was dissolved on the same date.

The main utilities are Tenaga National Berhad (TNB), the Sarawak Electricity Supply Company (SESCO) and Sabah Electricity Limited (SESB), each covering the region of Peninsular Malaysia, Sarawak and Sabah respectively and all having the Government as its main shareholder. In all three regions there are also independent power producers (IPPs) supplying some portion of the electricity to the utilities.[2]

The use of distributed power generation technologies such as solar hybrid power generation or micro hydro-electricity to provide access to electricity is greatly viable in Malaysia. These solutions have been applied in approximately 17 per cent of the new connections from 2010 to 2012.[3] The target is to supply five times as many houses with electricity as compared to the 2006-2008 timeframe.

In 2010, the total installed capacity of TNB and IPP in Peninsular Malaysia remains at 7,040 MW and 14,777 MW respectively. Total electricity generation in 2010 was 125,045 GWh, dominated by natural gas and coal (figure 1).

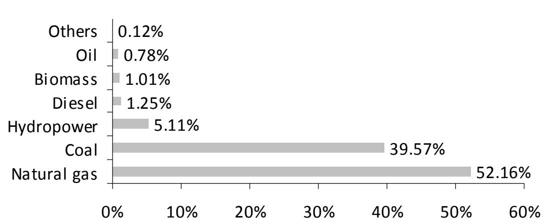

Figure 1 **Electricity generation in Malaysia**
Source: Small Renewable Energy Programme[4]

Small hydropower sector overview and potential

As of 2012, there are 58 mini-scale hydropower stations in Malaysia. TNB Energy Services Sdn Bhd (TNB-ES), a wholly owned subsidiary of Tenaga Nasional Berhad (TNB), has been operating and maintaining 30 mini hydro stations throughout the peninsular with a total installed capacity of approximately 16 MW.[5] Small hydropower has yet to be fully developed. With hilly topography from south to north, east to west and an abundant number of streams flowing to foothills, Malaysia has considerable small hydropower potential.

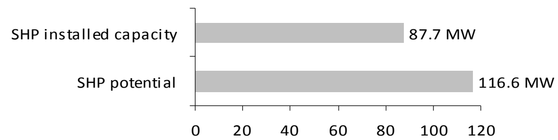

Figure 2 **Small hydropower capacities in Malaysia**
Source: Energy Commission of Malaysia[4], Raman[6]

A total of 149 sites with an estimated micro hydropower potential of 28.9 MW have been identified (figure 2).[6] There are some 150 river systems in Peninsular Malaysia and about 50 river systems in Sabah and Sarawak. It is also predicted that by the year 2020, most rivers and waterways will be fully utilized especially for the generation of electricity.

Access to water and the use, control and diversion of water flows is subject to federal and state regulation. Other regulations apply to any physical alteration of a stream channel or bank that may affect water quality or wildlife habitat.

Renewable energy policy

The Energy Commission, also a government monitoring agency of national renewable energy development, has set a target of 5.5 per cent for electricity from renewable energies. This was made achievable through the establishment of the Sustainable Energy Development Authority, formed as a statutory body under the Sustainable Energy Development Authority Act 726 in 2011.

In 2009, the authority developed the National Renewable Energy Policy and Action Plan aimed at harnessing renewable resources. The document outlines five objectives comprising elements of energy, industry and environment:[7]

1. To increase renewable energy contribution in the national power generation mix.
2. To facilitate the growth of the renewable energy industry.
3. To ensure reasonable renewable energy generation costs.
4. To conserve the environment for future generations.

5. To enhance awareness on the role and importance of renewable energy.

The 8th (2001-2005) and 9th (2006-2010) Malaysia Plans introduced several programmes such as the Small Renewable Energy Programme, the Biogen Full Scale Model demonstration project and the MBIPV programme. Mini-hydro (87.7 MW), biomass (using palm oil empty fruit bunches), biogas (from palm oil mills effluent) and municipal solid waste are among the most popular technologies for renewable energy in Malaysia.[4]

Barriers to small hydropower development

- Bureaucracy issues and problems, institutional and regulatory complexity and inconsistency, i.e. with regards to land acquisition.
- Full small hydropower development is constrained by localized water shortages particularly during drought periods, pollution in more than half of Malaysia's rivers, and climate change effects.
- Cost of capital for small hydropower ishigher than those for conventional power plants.[9] Utilizing locally manufactured components combined with an appropriate operation strategy will alternatively reduce the project costs.[10]
- Access to finance at competitive rates is difficult. Financial institutions are unfamiliar with the small hydropower technology and therefore not as open as towards other technologies.
- Siltation and high sedimentation.
- Public perception that renewable energy, including small hydropower, is still experimental.
- Insufficient renewable energy policies.

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3.4.5 Myanmar

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	54,584,650[1]
Area	676,578 km[2]
Climate	Tropical monsoon; cloudy, rainy, hot, humid summers (southwest monsoon, June to September); less cloudy, scant rainfall, mild temperatures, lower humidity during winter (northeast monsoon, December to April)[1]
Topography	Central lowlands ringed by steep, rugged highlands
Rain pattern	Rainfall up to 5,080 mm in coastal areas and average 1,500 mm in central areas[2]

Electricity sector overview

The annual electrical power consumption has been gradually increasing by year, reaching 4.4 billion KWh in 2011. Electricity is distributed by Ministry of Electric Power No. 1 and No. 2. Electric Power No. 1 is implementing Hydropower Stations Projects to generate electricity and Electric Power No. 2 is responsible for distribution.

The Asian Development Bank (ADB) estimated in 2011 that only 26 per cent of the population had access to grid electricity. The highest electrification rate is 67 per cent in Yangon City, followed by Nay Pyi Taw (50 per cent).[3] The existing grid needs to be upgraded. Rural areas located far away from the grid system urgently need isolated power supply systems. Small hydropower is one of the solutions for isolated power systems.[2]

Myanmar has abundant natural resources for rural electrification, including solar (annual potential is around 52,000 TWh), wind, tidal, biogas and husk.[2] However, only hydropower is being commercially developed with the others in research, development or piloting stage.[3] Hydropower is the main source of electricity generation (figure 1), and gas, the country's greatest source of revenue, is exported.[3]

Water is a key energy resource with hydropower accounting for 75 per cent of the total installed capacity. Myanmar uses only five per cent of its water resources. It is estimated that the hydropower potential of just the four principal rivers is larger than 100 GW, of which only 1,781 MW are currently developed.[4] [5] In 2010, a total of 19 hydropower projects (413.8 MW capacity) were under construction.[2] Large scale hydropower is expected to continue to be developed as a main power source.

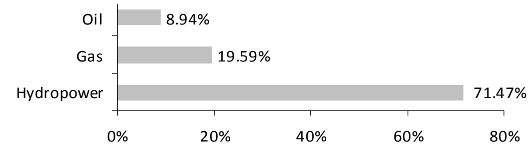

Figure 1 **Electricity generation in Myanmar**
Source: International Energy Agency[6]

Small hydropower sector overview and potential

The country has abundant renewable energy resources and small hydropower potentials. The topography of the country is suited to isolated power supply systems. At present about 3 per cent of the country potential has already been developed and 26 per cent is under implementation.

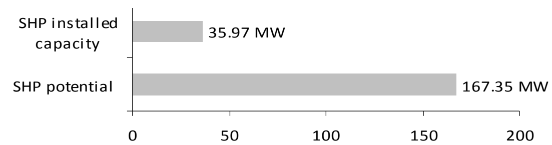

Figure 2 **Small hydropower capacities in Myanmar**

Small hydropower is expected to continue to be developed as a power source for small village electrification. In 2008, up to 33 small hydropower projects with a total of 35.97 MW were in operation (figure 2). Numerous village hydro schemes (capacities less than 50 kW) and turbine installations of 1 kW or less, also supply electricity in hilly regions.[2]

In terms of the small hydropower potential, more than 20 per cent is utilized but still nearly 60 sites with individual capacities between 1 MW and 5 MW remain suitable and could result in around 170 MW of total potential capacity.[2]

There are some local technical capacities related to turbine manufacturing and installation technology. Appropriate renewable energy technologies exist, and the skills to design and build such systems are available. A hydropower turbine and generator factory exists in the Bago division since 2009.[2]

Foreign aid to support small hydropower is strongly recommended as a key factor to promote the development in rural communities. The re-establishment of international banking institutions such as the World Bank and ADB is likely to help bring financial security and facilitate investment for major infrastructure and development indicators.

Renewable energy policy

There is limited information available on Myanmar's renewable energy policy. The country is moving towards a market-based economy to stimulate economic growth and development. As financial growth is a priority, the inclusion of environmental sustainability in policy is expected to form a long-term political vision and agenda.

The Government has voiced interest in promoting renewable energy. Application of renewable energy, energy efficiency and energy conservation measures are being undertaken extendedly. However, natural resource governance remains a challenge, with limited accountability over the revenues from mining, logging and other extractive activities. The country is highly vulnerable to climate change and extreme weather events, as exemplified by the devastating Cyclone Nargis of 2008. A National More Pure Fuel Policy has been drawn.[7]

The Greater Mekong Subregion Economic Cooperation Program Strategic Framework 2012-2022 is also likely to have a significant role in development a national framework to combat environmental issues. The programme has an integrated approach to energy security and environmental performance.

Legislation on small hydropower

There is limited legislation concerning any form of hydropower. Given the rapid developments occurring there is a need to develop a revised framework for hydropower development. During the 5th Mekong Legal Network meeting of legal professional from the six Mekong countries held in 2012 in Chiang Mai, Thailand, the legal challenges, reforms and opportunities in hydropower for lawyers and campaigners working in Myanmar were discussed.[8] This small step is a significant move in the right direction.

Barriers to small hydropower development

- Technical capacity transfer, both with neighbouring countries as well as within the country itself, is needed to develop small hydropower sustainably.[2]
- The economic sanctions have prevented small hydropower development.
- Protestors continue to question the role of hydropower as an export commodity while many people live in darkness. Plans to build several dozen hydropower dams on Myanmar's rivers have been met with fears of damage to livelihoods and food security.[9] Although this is not directly related to small hydropower, it could negatively affect the image of small hydropower.
- Lack of legal framework for the small hydropower sector.[8]

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3.4.6 Philippines

Jose D. Logarta Jr., Philippine Association of Small-scale Hydro Developers, Inc. (Pass-Hydro)

Key facts

Population	103,775,002[1]
Area	300,000 km^2
Climate	Tropical maritime; with northeast monsoon (November to April) and southwest monsoon (May to October)[1]
Topography	Mostly mountains with narrow to extensive coastal lowlands; more than 7,000 islands
Rain pattern	The mean annual rainfall of the Philippines varies from 965 mm to 4,064 mm.[2]

Electricity sector overview

The national electrification rate was 89.7 per cent in 2009.[3] The Philippine power sector continues to undergo the most radical transformation since the end of the Second World War, with the restructuring of the whole industry under the Electric Power Industry Reform Act (EPIRA) of 2001. The reforms include the breakup of what used to be a government monopoly in generation and the privatization of the transmission operations via monopoly franchise. More ambitious steps leading to competition at the retail level are pending at the electricity regulation agency.

As of 2012, the Luzon and Visayas grids are interconnected and central dispatch is undertaken by a system operator. All transactions however, go through a compulsory wholesale pool. The Mindanao grid is isolated and suffers the most transmission constraints and excessive dependence on hydropower.

The electricity production is dominated by thermal sources (figure 1). About 86 per cent of the hydro resource potential can be developed by large hydro at 18 locations across the country. Hydropower is the dominant renewable energy source in the Philippines, accounting for 21 per cent of the 16,359 MWinstalled generation capacity as of 2010. Around 20 per cent of the hydro capacity is privately owned (including all of the small run-of-river plants), or privatized via competitive biddings under EPIRA. The National Irrigation Authority owns a few multi-purpose hydropower units but there are no clear plans afoot to have these privatized.

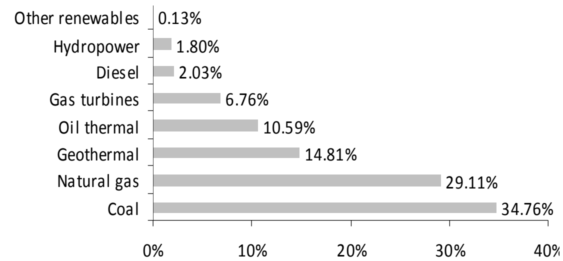

Figure 1 **Electricity generation in the Philippines**
Source: Department of Energy of the Philippines[4]

Small hydropower sector overview and potential

All of the run-of-river small hydropower plants are in private hands. About 888 sites have been identified as having mini-hydropower potential totalling 1,847 MW, the remaining 29 MW being micro hydropower potential (figure 2).

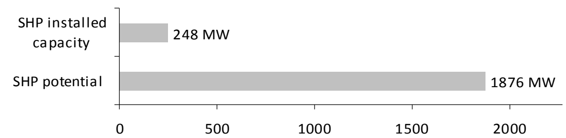

Figure 2 **Small hydropower capacities in the Philippines**

Renewable Energy Policy

Renewables policy is now governed by the Renewable Energy Act of 2008. The most important provisions are the Renewable Portfolio Standards (RPS) that subsumes the more substantive feed-in tariff (FIT). The first set of proposed FIT rates for emerging renewable energy, including small-scale hydro, is under deliberation before the Energy Regulatory Commission (ERC).

Legislation on small hydropower

In 1991, the re-established democratic Congress enacted the mini-hydropower Incentives Act (Republic Act 7156), limiting incentives to run-of-river plants, defined as those utilising the 'kinetic energy of falling or running water', and those with capacity ranges from 101 kW to 10 MW.[5]

The official hydropower development programme of the Philippine Department of Energy foresees a FIT and a RPS as well as mini-hydropower project auctions.[4]

Barriers to small hydropower development

- Political ambivalence and bureaucratic delays in the implementation of the Renewable Energy Act of 2008. Legislators are now calling for 'competitive auctions' to achieve installation targets for the qualified renewable energy technologies, ostensibly to minimize their tariff impacts.
- A more recent development that has alarmed run-of-river small hydropower developers is the

recent policy shift by the National Water Resources Board (NWRB) to drastically reduce the maximum water flow rates from rivers that can be used for electricity generation, rendering projects that have already been awarded service contracts by the Department of Energy unviable.

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4.4.7 Thailand

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	67,091,089[1]
Area	513,120 km[2]
Climate	Tropical, rainy and warm. The southern isthmus is always hot and humid.
Topography	The North is a mountainous region characterized by natural forests, ridges and deep, narrow, alluvial valleys. The Central Plain is a luscious fertile valley. Rolling surface and undulating hills in the Northeast. The South Isthmus is mountainous, with thick virgin forests and rich deposits of minerals and ores.
Rain pattern	Cloudy southwest monsoon (mid-May to September) and a dry, cool northeast monsoon (November to mid-March)

Electricity sector overview

The electrification rate in the country is 99.3 per cent.[2] The Thai power sector has been dominated by three government-owned enterprises since 1970s: the Electricity Generating Authority of Thailand (EGAT) that is responsible for generation and transmission, the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) that are both responsible for distribution and retail services.[3]

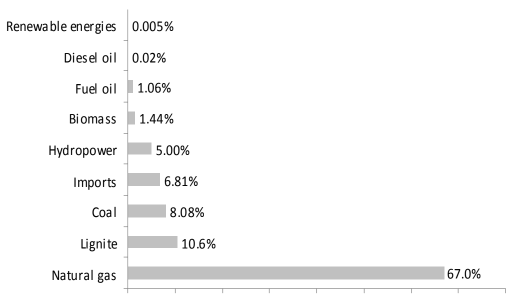

Figure 1 **Electricity generation in Thailand**
Source: Thailand Department of Alternative Energy Development and Efficiency.[5]

The existing structure of the Thai electricity market is dominated by government-controlled oligopolies. EGAT, as the government electricity generator, plays the sole and significant role of supplying electricity to the other vertically linked distributors, such as PEA and MEA. EGAT is presently the largest electricity producer, owning and operating its own power plants countrywide. It also has the sole right to purchase power from other private producers under the government regulation of Enhanced Single Buyer model (ESB).[4] Its capacity to generate electricity accounts for 44 per cent of the total generation.[5] Natural gas is the dominant energy source in the Thai electricity mix (figure 1).

Small hydropower sector overview and potential

Hydropower plants with capacities between 6 MW and 15 MW are classified as small hydropower in Thailand. Capacities between 0.2 MW and 6 MW are classified as mini hydropower. Finally, capacities lower than 0.2 MW are classified as micro hydropower.[6]

In Thailand, the Department of Alternative Energy Development and Efficiency (DEDE) and the PEA are some of the institutions involved with mini and micro-hydropower. Both DEDE and PEA operate mini or micro hydropower plants.

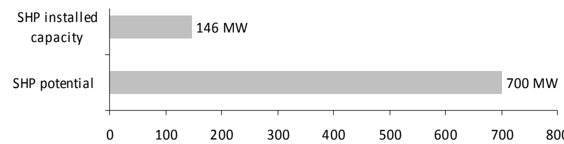

Figure 2 **Small hydropower capacities in Thailand**
Source: Thailand Department of Water Resources[7]

Thailand produced 3,000 GWh of electricity in 2010 from hydropower, of which 53.20 GWh was from small hydropower (considering the 10-MW small hydropower definition).

There are two small plants with a capacity between 6 MW and 15 MW (Thai small hydropower definition), with a total capacity of 15.3 MW and there are at least 23 installed mini hydropower with a total capacity of 128 MW, owned by DEDE.[8] Planned future small hydropower development includes a total of 96 MW to be completed by 2015 and another 43 MW by 2020.[7]

A national small hydropower evaluation was carried out in 2011 and determined a gross theoretical small hydropower potential of 700 MW (figure 2). Information on technical and economically feasibility is not available.[7] According to the DEDE of the Ministry of Energy, the renewable energy potential and targets for small hydropower under the Very Small Power Producers Using Renewable Energy (VSPPs) policy are: 281 MW (2012-2016) and 324 MW (2017-2022).

Under the hydropower section of the Renewable and Alterative Energy Development Plan 2012-2021, the country aims to, among others:[7]

1. Promote community collaboration in order to broaden production and consumption of renewable energy (including hydro).

2. Generate off-grid hydropower at village level for non-electrified households.
3. Support the construction of hydropower plant projects at community level, allowing the local administrative organization or local people to collaborate as project owners. Encourage them to self-manage and maintain the plant.
4. Solve the problems and barriers in micro hydropower projects located in sensitive areas: river basin at the floor 1-B, national park or wild animal preserved zone.
5. Assign the DEDE and EGAT to develop small hydropower of downstream irrigation dams and mini hydropower systems at generation capacity of 200-6,000 kW.
6. Disseminate information and conduct public relations to state the advantages of hydropower projects.
7. Promote research work as a mechanism in the development of an integrated renewable energy industry by conducting research and development of the run-of-river micro hydropower turbine and by studying and developing low-head turbine types.

There are active local manufacturers with experience in small hydropower development in Thailand.

Renewable energy policy

Since energy prices have been rising and have affected the country's economic development the Ministry of Energy has come up with a policy to develop renewable energy and to reduce its import dependency. Under the Alternative Energy Development Plan (AEDP) 2008-2022, Thailand set a target for the renewable energy portfolio at 20.3 per cent of the final energy consumption by 2022.[8] This increased to 25 per cent under the Power Development Plan 2011-2030 and the Renewable and Alterative Energy Development Plan 2012-2021.[6] Targets have been set to promote small hydropower at 0.04 per cent by 2015 and 0.03 per cent by 2020 of energy production.[7]

Legislation on small hydropower

With regards to small hydropower, in 2002, Thailand introduced the supportive VSPPs policy for installations with capacities not greater than 1 MW. VSPPs are private power producers with a generating capacity of less than 10 MW that sell electricity to MEA or PEA. The policy is also applicable for renewable technologies and other non-conventional resources (i.e. waste, agricultural residues, biomass and solar energy), as well as Combined Heat and Power (CHP) and Cogeneration systems.[8]

In September 2006, the policy was altered in order to encompass projects generating 1-10 MW, i.e. Small Power Producers (SPPs).[8]

Barriers to small hydropower development

Some administrative issues have led to small hydropower installations having had to be abandoned when a village wants to connect to PEA supplied electricity.

- There appears to be no mechanism for an electricity buy-back scheme.[9] This could generate much needed local finances and stimulate an economy at the grassroots, where small hydropower could become much more than a clean energy source.
- Expansion of the grid to rural areas with no previous grid access means a competition to off-grid small hydropower plants, because even though grid electricity is more expensive than micro-hydropower – from a national perspective – it is heavily subsidized for rural customers.[9] These kinds of policies undermine small hydropower growth.
- Financial barriers also present a problem as financial institutions, becoming increasingly familiar with renewable energy technology, are still prone to overestimate risk or are unwilling to provide financing on terms that would otherwise allow the development of viable small hydropower opportunities.

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3.4.8 Timor-Leste

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	1,143,667[1]
Area	14,874 km[2]
Climate	Tropical, hot and humid
Topography	Mountainous
Rain pattern	Distinct rainy and dry seasons, affected by the El Niño Southern Oscillation.

Electricity sector overview

The power sector run by Electricidade de Timor-Leste, the national electricity agency, is small and fragmented. The Government states that about one third of the population has access to electricity, generally for six hours per day.[2] In 2007, there was no country-wide transmission system. However, a large number of medium voltage (MV), isolated systems exist distributing power from local diesel generators to consumers. The largest of these systems is located in the capital Dili with a capacity of 19 MW.[3] Twenty-four hour electricity supply exists in Dili and Baucau, however evening outages occur frequently.

The electrification rate is just 18 per cent in the capital´s districts, dropping to a mere 5 per cent in rural areas. This leaves rural Timor-Leste operating on 58 isolated grids (11 on a district level and 47 on the sub-district or village level), all equipped with diesel generators. Some of these generators are sometimes inoperative, due to the lack of maintenance or fuel, or sometimes vandalism. For lighting, the rural population relies mainly on kerosene, plant oils and batteries. Based on the Population Census 2004, and the figures relating to the connectivity to grid-based electricity supply, it was estimated that at least 185,000 households had no access to electricity in 2008, except through the use of batteries.[4]

The rural electrification programme under the National Strategic Development Plan 2011-2030 targets communities in isolated areas that will not be connected to the national grid in the medium term. About 8,000 families in remote areas already have their supply of energy guaranteed through the use of renewable energy resources.

The financial capacity of the sector is affected by the non-payment of power bills, with around only 40 per cent of commercial customers in Dili doing so.[2] This is severely detrimental to the development of the sector and its infrastructure.

Hydro Timor is the coordinating unit for hydropower development in Timor-Leste. It works under the Ministry for Infrastructure, and is supported by the Norwegian Water Resources and Energy Directorate (NVE) through institutional cooperation. In addition to managing the Gariuai Mini Hydropower Project (Baucau - 1.5 GWh/year), its activities include:

- Development of Iralalaru Hydropower Project (Lautem at 28 MW, 189 Gwh/year), scheduled for 2012).
- Hydrological measurement and assessment for potential new hydropower projects in Atsabe Magapu (Ermera), Bobonaro Aiasa (Bobonaro) and Maliana Bulobo (Bobonaro).
- Establishment of a national hydrological network i.e for the measurement of rainfall, river currents and water levels.
- Training of national staff on development, operation and maintenance of small hydropower plants, as well as hydrology and water management.[5]

Small hydropower sector overview and potential

The steep topography of Timor-Leste means that there are few opportunities to utilize artificial reservoirs forcing the development of run-of-river projects.[6]

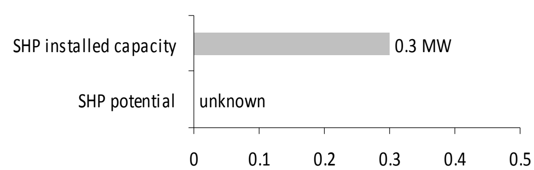

Figure 1 **Small hydropower capacities in Timor-Leste**

The Timor-Leste State Secretary for Energy Policy and the Norwegian Water Resources and Energy Directorate are involved in the development of the Hydropower Master Plan for Timor-Leste for which 23 hydropower projects were studied: 6 large, 16 small and one micro. The Plan is expected to occur sometime in 2012. It is also expected to become an important tool for continued and sustainable development of the hydropower resources in Timor-Leste.[7]

An earlier analysis of potential hydropower sites in Timor-Leste promisingly identified nearly 40 sites that could generate between 1.2 MW and 50 MW. Based on these results, detailed research and analysis including feasibility studies will be conducted on potential mini-hydro sites throughout the country. The majority of mini-hydro projects is reported to have enough water for operation in the wet season only. Yet, construction and operation of these plants is still expected to be economically worthwhile due to savings on the import of fuel. Furthermore construction activity creates jobs and potential crossover benefits for agriculture are expected.[2]

Renewable energy policy

In 2009, the Secretariat of State for Energetic Policy launched a renewable energy programme that covers the following sectors: biogas, solar, biodiesel, hydro and wind. No investments in wind power have been made yet but it is indicated in the plan.[5]

The target is to supply 80 per cent of the population with electricity by 2025. Built upon the 2008–2012 Development Plan of Timor-Leste and parallel to the development of biogas, bio-fuel and the installation of hydropower plants in 2009, the country hopes to meet half of its energy needs from renewables under the National Strategic Development Plan 2011-2030.[4]

The Portuguese company Martifer has identified more than 450 MW of potential renewable energy projects spread across the following technologies: 252 MW hydropower (wire-to-water and regulation), 100 MW hydro pumping, 72 MW wind, 22 MW solar and 6 MW biomass/solid waste.

The Government predicts the establishment of wind and hydropower hybrid systems. In the rainy season hydro will be used, while during the drier period, fuel or biogas generators can be used to guarantee energy sustainability for the community. The community would guarantee the production of energy necessary for their local necessities, and if at all possible, sell the excess for the national electric network.[5]

The Basic Law for Renewable Energies was drafted in 2011 by the Secretariat of State for Energy Policy, who intends to establish a production limit of 2 kW. The energy produced by community electrical power plants will be only for their consumption and the excess sold to the national network. The Government's objective is that community power plants have energy self-sufficiency and can produce a financial income in a way that will help the most remote populations to develop their economy.

To date, most of the renewable energy projects are being implemented by international donors and local and international NGOs, and are tiny compared with the national energetic programme (such as the National Grid or the Tasi Mane Heavy Oil Plant).[8]

Barriers to small hydropower development

- Synergies between government, academia, research institutes and NGOs need to be strengthened in order to secure sustainable development in short and long term. Improved monitoring and evaluation mechanisms would assist the Government to identify lessons and best practices and to scale up and/or replicate successful projects.
- Capacity-building at community level is necessary and should be strengthened, to promote knowledge and experience sharing, as well as skills development, consultation, piloting, learning and effective delegation of authority, support for community rights to manage their land.
- Property rights are unclear.
- Customary laws which deal with marine and natural resources are not defined.
- Concerns stemming from a lack of adequate water infrastructure and vulnerability towards drought due to variability in rainfall, especially during El Niño periods, could result in socio-political tensions and mistrust around small hydropower as it seemingly competes with other water users.[9] [6] Education and public awareness campaigns are important tools in combating this problem.
- Technical difficulties due to the steep and complexity of the terrain.
- High cost of developing renewable technologies in Timor-Leste.
- Installed meters in cities have in many cases been bypassed, leading to a substantial rate of electricity theft, and a low coverage of cost repayment. This kind of behavior does not free up funds that the Government needs to implement small hydropower and renewable energies on a wider scale.

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3.4.9 Viet Nam

Luong Tuan Anh, Center for Hydrology and Water Resources, Vietnam Institute of Meteorology, Hydrology and Environment

Key facts

Population	91,519,289[1]
Area	331,051 km[2]
Climate	Tropical-monsoon with two main seasons: wet and dry
Topography	Low, flat river delta in south and north; central highlands; hilly, mountainous in far north and northwest[1]
Rain pattern	Annual total rainfall is about 1,700-2,000 mm; 70-80 per cent of total rainfall is concentrated in the rainy season.

Electricity sector overview

The majority of the electricity supply in Viet Nam originates from fossil sources and hydropower (figure 1). In 2008, the electric generation capacity in Viet Nam was estimated at 12,357 MW, of which 4,583 MW (37.1 per cent) hydropower plants, 4,835 MW (39.1 per cent) coal, oil, diesel and thermal-gas power stations, 2,939 MW (23.8 per cent) from imports and small hydropower. Viet Nam imports electricity from its neighbour, China, but also exports more electricity to Lao People's Democratic Republic and Cambodia.

Viet Nam has a high potential for hydropower development, with more than 2,360 rivers and streams flowing longer than 10 km. There are 10 principle rivers suitable for construction of hydropower stations with total capacity approximately of 21,000-24,000 MW.[1] Currently, hydropower accounts for a large portion of electric production. The development strategy of the Vietnamese electricity sector in the period of 2006–2015, looking towards 2025, also gives priority to the development of hydropower and encourages investment in other renewable energy forms such as small hydropower, solar and wind power.

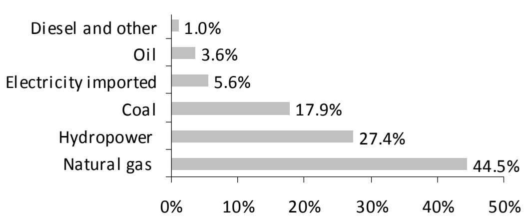

Figure 1 **Electricity generation in Viet Nam**
Source: Viet Nam Department of Energy Economics, Demand Forecast and Demand Side Management[2]

Small hydropower sector overview and potential

In recent years, rapid rate of small hydropower development has been seen in Vietnam. At the end of year 2006, 141 small hydropower plants with an installed capacity 167.1 MW had been constructed and by the end 2009, the number had increased to 156 with a total installed capacity of 621.7 MW (figure 2).

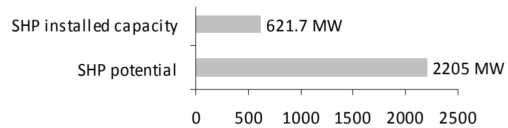

Figure 2 **Small hydropower capacities in Vietnam**
Source: Institute of Energy[3]
Note: Data is based on planned capacity by 2020 and for plants up to 10 MW.

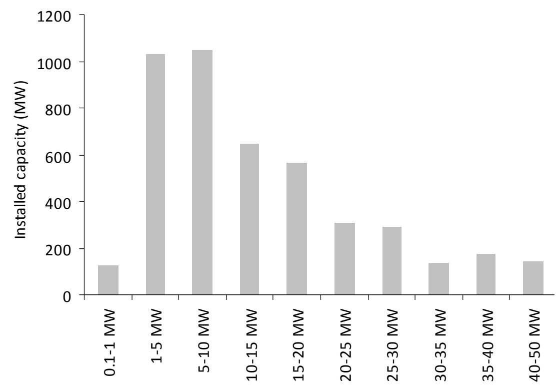

Figure 3 **Small hydropower potential in Viet Nam**
Note: Total of 4,468 MW from 0.1 to less than 50

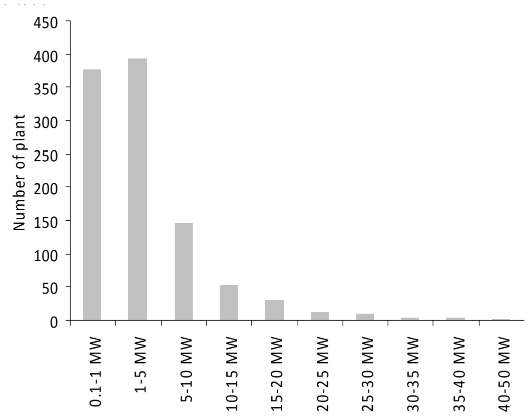

Figure 4 **Development capacity of small hydropower in Viet Nam**
Note: There are about 1,035 potential sites from 0.1 to less than 50 MW.

It is estimated that by 2020, the total capacity of hydropower up to 50 MW shall have reached around 3,000-5,000 MW (figures 3 and 4) and supplied electricity for most households in rural and mountainous areas of Viet Nam. However, according to the estimation of the Institute of Energy, over the long term, the percentage of capacity and power generation of hydropower will reduce significantly in comparison with other energy sources. It is estimated that by 2025, hydropower capacity will hold only 23.1 per cent, whilst solar and wind power will account for 5.6 per cent.

Renewable energy policy

Viet Nam's National Energy Development Strategy up to 2020 (Decision No. 1855/QD-TTg of 27 December 2007) encourages the development of electricity sources using new and renewable energy.

In July 2011, the National Power Development Plan for Period 2011-2020 with Perspective to 2030, prepared by the Institute of Energy under the management of Ministry of Industry and Trade, was approved by the Prime Minister. This Plan, also called Power Development Plan VII, gives priority to the development of renewable energy resources for electricity production, i.e. wind, solar, biomass, etc. The level of 3.5 per cent of total electricity production in 2010 should be increased to 4.5 per cent in 2020 and 6 per cent in 2030. An electrification programme will be promoted in rural, mountainous and island areas so that most rural households will have electricity access by 2020. Priority is given to development of hydropower plants, especially multi-purpose plants such as flood control, water supply and electricity generation. Total capacity of hydropower plants will be increased from 9,200 MW at present to 17,400 MW in 2020. Pumped water storage capacity is anticipated to be about 1,800 MW by 2020 and 5,700 MW by 2030.[4]

As an incentive mechanism for wind power a feed-in tariff (FIT) should be approved soon. In addition, the incentive mechanism also includes the reduction and exemption of income tax, import tax, land use fee, value-added tax, and environment fee.[5]

Legislation on small hydropower

While Viet Nam has no renewable energy feed-in tariff, the Avoided Cost Tariff (ACT) Regulation provides incentives for small-scale renewable energy developers. The avoided cost is defined as the production cost per kWh of the most expensive power generating unit in the national power grid, which would be avoided if the buyer purchases 1 kWh of electricity from a substitute small renewable energy power plant. Eligible project capacity must not exceed 30 MW, and all electricity must be generated from renewable energy, including hydropower.[6]

Barriers to small hydropower development

- Quality of environmental impact assessments and transparency of the related procedure need to be enhanced.
- Requirements for environmental assessments and monitoring during the project implementation are not yet well defined in current legislation.
- Technical improvement of small hydropower local capacity is highly desirable.
- Small hydropower capacity building needs to be strengthened, for example by fostering international exchange of experiences in small hydropower development.

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3.5 Western Asia

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Introduction to the region

Western Asia comprises 18 countries. The region exhibits diverse ecosystems categorized as Mediterranean sub-region (Turkey, Cyprus, Israel), Mashriq sub-region - Mediterranean humid to semi-arid (Syrian Arab Republic, Lebanon, Iraq, Jordan, State of Palestine, Arabian Peninsula (Saudi Arabia, Bahrain, Oman, Kuwait, Yemen, United Arab Emirates, Qatar) and the mountainous Caucasus region (Azerbaijan, Armenia and Georgia).

Most countries receive less than 250 mm of rainfall per year, with Saudi Arabia receiving a minimum of 59 mm. The Caucasus region experiences the highest precipitation with an absolute maximum of 4,100 mm. However there are dry areas as well particularly towards the Northeast and Southern part of Caucasus Mountains. The Arabian Peninsula is characterized as one of the hottest and driest regions in the world, with temperatures often exceeding 50°C. Western Asia has two major rivers, the Euphrates and Tigris, as a whole, the region experiences a very high water stress (water stress index of more than 80 per cent). The United Arab Emirates, Saudi Arabia, Kuwait, Jordan and Bahrain are at extreme risk of water security, showing water stress indices exceeding 100 per cent.[i] The population in Mashriq region depends very much on surface water, whereas those in Arabian Peninsula depend on ground water for water resources finding its foremost usage in agriculture amounting to more than 80 per cent. It is this dire constraint that limits hydropower development in most countries in Western Asia especially Bahrain, Israel, Kuwait, State of Palestine, Oman, Qatar and Saudi Arabia.

Table 1
Overview of countries in Western Asia

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Armenia [ad]	3.26	36.0	100.0	2 983	6 491	1 221	2 400
Azerbaijan	9.23	47.8	..	6 808	18 869	1 805	3 000
Georgia [ae]	4.63	47.0	..	3 400	10 100	2 612	9 300
Iraq	32.30	33.4	86.0	9 000	48 830	2 501	5 020
Jordan [ab]	6.05	21.0	99.9	3 069	14 683	12	61
Lebanon	4.23	12.8	99.9	2 300	13 771	275	622
Turkey [ac]	75.70	30.4	..	51 000	211 208	16 880	60 000
Total	**135.4**	**-**	**-**	**78 560**	**323 952**	**25 306**	**80 403**

Sources:
a. International Journal on Hydropower & Dams[1]
b. ERC Jordan[2]
c. EUAS[3]
d. Sargsyan[4]
e. Birkadze[5]

Oman, Qatar, Saudi Arabia and Yemen rely entirely on oil and natural gas for electricity generation. These are also areas of minimum precipitation and the strategic focus lies within storage of water in large reservoirs/dams for agriculture, flood protection and water security especially Oman and Saudi Arabia. Saudi Arabia, Qatar, Oman, Yemen and Kuwait show no sign of future hydropower development initiatives.

The Syrian Arab Republic employs some hydropower for electricity generation, but has no small hydropower plants. Its electricity generation is primarily based on oil and natural gas, but most of the power plants are functioning below capacity which include both thermal and hydropower plants. The large hydropower potential may have been exhausted in Syrian Arab Republic but further study needs to be conducted in order to identify potential small- and mini-hydropower opportunities.[6]

The United Arab Emirates's electricity demands are met entirely by conventional fossil fuels, mostly natural gas with no hydropower. Water being a scarce resource, there is no long term plan for hydropower utilization. However, interest in deploying renewable energy exists.

Jordan has acute shortages of energy and water, unlike other countries in the region, it has no fossil fuel resources of its own. It is also closely linked to Israel and the State of Palestine in terms of water usage from the Jordan River. Its electricity needs are almost entirely powered by imported fossil fuels. The country struggles with water supplies in general and has an extreme risk rating of water stress with a water stress index exceeding 100 per cent, there is little opportunity and interest for hydropower development in the long term.

Cyprus has an isolated energy system, having no electricity interconnections with other countries due to its island nature. It is almost entirely dependent on imported fossil fuels, natural gas is prominent in electricity generation. It plans to achieve 13 per cent of energy from renewable energy sources by 2020. The renewable energy sources encouraged in the country include wind, solar thermal, photovoltaic and biomass/biogas.

The Caucasus region (Armenia, Azerbaijan and Georgia) is included in the European Union's neighborhood policy. All three countries have similar objectives with respect to diversifying their energy sources and benefiting from their location on energy transit routes.

Turkey's electricity demands are met primarily by combustible fuels which include coal, oil and natural gas; hydropower, geothermal, solar and wind are also used. Besides being an oil producer and an overall energy exporter, Turkey's role as an oil transit country is increasingly important. In September 2010, Turkey integrated its electricity network with the European grid which has significantly stabilized the electricity supply.

Population growth, urbanization, improving living standards and surging development in economic sectors (industry, natural resources and agriculture) affect availability of water and its quality. Variable hydrological regimes in the two most resourceful rivers, Tigris and Euphrates, have resulted in the under-utilization of hydropower plants, with water turbines being shut in many cases. Cross border cooperation in water resources is essential to sustain hydropower and other water end uses. For example, Iraq has no binding agreements with Turkey, Syrian Arab Republic and Iran on water management and sharing. Water projects in Turkey and Syrian Arab Republic have a strong impact on Iraq in terms of water storage and hydropower utilization. Undoubtedly, water being the most vulnerable natural resource in the region, transboundary water management and cooperation is essential to sustainable regional development.

Small hydropower definition

Small hydropower definition in the Western Asia region is not standardized, thus, some countries have its own definition (table 2). Armenia changed its small hydropower plant definition in 2012.[7]

Table 2

Classification of small hydropower in Western Asia

(Megawatts)

Country	*Small (MW)*
Armenia (up to 2011)	< 10
Armenia	< 30
Azerbaijan	0.050 - ≤ 10
Georgia	< 13
Iraq	..
Jordan	..
Lebanon	..
Turkey	..

Sources: See country reports

Regional overview and potential

Eight countries utilize small hydropower in Western Asia, i.e. Armenia, Azerbaijan, Cyprus, Georgia, Iraq, Jordan, Lebanon, Jordan and Turkey (table 1).

Cyprus is not included in this report as there is very limited small hydropower potential, considering its issues with water shortages in the past years. Cyprus's hydropower contribution to the total electricity generation is negligible, with a mere 0.65 MW installed capacity (2 GWh/year) of a single plant. Cyprus Energy Regulatory Authority has accepted 330 kW of small hydropower capacity as contribution under their renewable energy source scheme. Hydropower in Cyprus currently offers limited opportunities which are not commercially profitable.[8] [9]

On the other hand, Turkey has in recent years experienced an increased interest in renewable energy projects (e.g. hydropower and wind power) from the European Investment Bank and project financing in the field of renewable energy, energy efficiency and climate change mitigation projects, collectively amounting to 200 million Euro (about US$260 million).[10] Moreover, Armenia, Georgia, Azerbaijan and Turkey are also members of Inogate Programme as a part of regional energy technical cooperation programme among the European Union countries, Eastern Europe, the Caucasus and Central Asia. The Inogate Programme has supported these four countries in the Western Asia region and continues to do so in energy issues including electricity integration, renewable energy and energy efficiency promotion and development. This could imply greater use of small hydropower plants in the near future.

Lebanon's small hydropower sector however, produces a low output as water resources are scarce and most of it is directed towards irrigation. Conversely, Iraq has access to potential hydropower, however current political instability hinders investment and development. Yet, the Iraqi Government currently has a study on hydropower use underway in addition to a strategy for water and land resources which also takes into consideration of small hydropower.

The total installed capacity is approximately 489 MW in Western Asia (table 3). Leading in small hydropower potential is Turkey, with 6,500 MW, followed by Armenia, Azerbaijan and Georgia. Lebanon, Jordan and Iraq have limited small hydropower potential, while there is almost no potential in Cyprus.

Table 3
Small hydropower up to 10 MW in Western Asia
(Megawatts)

Country	*Potential*	*Installed capacity*
Armenia	430.00	157.70
Azerbaijan	392.00	42.00
Cyprus	0.98	0.65
Georgia	286.00	66.71
Iraq	26.38	6.00
Jordan	58.15	10.00
Lebanon	60.30	30.80
Turkey	6 500.00	175.00
Total	**7 753.81**	**488.86**

Note: Jordan has a technically feasible hydropower potential of 500 GWh/year, but this is not economically viable.[1] Cyprus is not included in this report.

The challenges in the Western Asia region are diverse and varied ecosystems in the Caucasus, Mashriq and Arabian Peninsula revolve mostly around sustainable water access for varied end uses. The Caucasus countries and Turkey boast significant ambitions for small and large hydropower development whereas the primary focus of the rest of Western Asia is on securing the high scarcity natural resource which is constantly depleting, thereby hampering ecosystems, agriculture, as well as economies and infrastructure that depend on water supply.

Development of the water sector in many countries in the region has been primarily focused on water storage facilities and sanitation systems, with little focus on capacity development, accountability and maintenance. Institutional development and sector reforms along with the establishment of cross border water quality management are of concern. Therefore, regional transboundary water cooperation for sharing water appropriately will be an essential requirement to alleviate pressure on renewable and non-renewable water resources and other sources to contribute to an overall social, environmental and economic sustainability.

Note

i. See Maplecroft Water Stress Index 2011

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3.2.1 Armenia

Vahan Sargsyan, Levon Harutyunyan, Scientific Research Institute of Energy, Armenia; Kai Whiting, International Center of Small Hydro Power

Key facts

Population	2,970,495[1]
Area	29,743 km[2]
Climate	Highland continental, hot summers, cold winters.
Topography	Armenian Highland with mountains; little forest land; fast flowing rivers; good soil in Aras River valley. (highest point: Mount Aragats at 4,090 metres)
Rain pattern	Average annual precipitation is around 300 mm.

Electricity overview

The level of electrification in Armenia is 100 per cent. Armenia has only a small number of lignite or brown coal mines, located in the vicinity of Gyumri and Spitak. Oil reserves exist but in a depth that makes it currently uneconomical to extract them.[2] Renewable sources therefore make a sizable contribution to the generation of electricity (figure 1).

Armenia is a net exporter of electricity. In 2011, 358 GWh were imported whilst some 1,225 GWh were exported.[3 4]

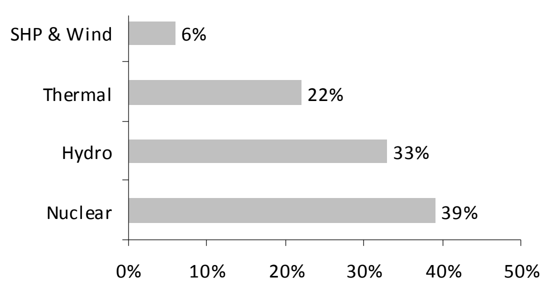

Figure 1 **Electricity generation in Armenia**
Sources: Arka[3], Karapoghosyan[4]
Note: Data from 2011. Thermal power is mostly from natural gas.

Small hydropower sector overview and potential

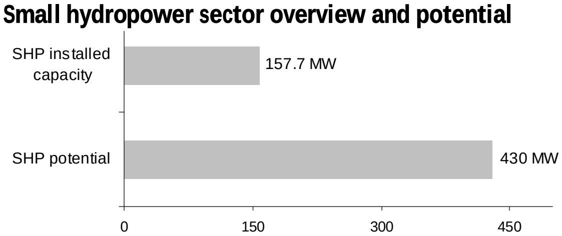

Figure 2 **Small hydropower capacities in Armenia**
Note: This information is for small hydropower up to 10 MW.

The upper capacity limit that defines small hydropower in Armenia has been raised from 10 MW to 30 MW in 2012.[5]

There are three types of small hydropower schemes in Armenia: derivational, water supply on the inclinations of water routes and those located next to dams/reservoirs. As of April 2012, there were about 120 small hydropower plants operating in the country.[3] In 2012, the total small hydropower capacity was 157.7 MW (120 plants) with an annual production of more than 500 GWh/year.[5] It is worth mentioning that all small hydropower plants in Armenia are privately owned. The small hydropower potential is estimated at 430 MW (figure 2).

The history of small hydro development shows that real progress in Armenia took place starting after 2004 when Public Services Regulatory Commission of the Republic of Armenia (PSRC) adopted a clear feed-in-tariff (FIT) for new projects.[6] Several projects were awarded construction licences and were commissioned two or three years after the beginning of construction. A few projects were commissioned even more quickly. The table below shows the annual growth in commissioned projects.

Growth in small hydropower in Armenia, 1999-2010

Year	*Number of units*	*Capacity (MW)*	*Output (GWh)*
Pre-1999	19	29.40	80.0
1999	1	0.75	3.0
2000	2	1.20	2.7
2001	3	1.60	7.4
2002	3	3.50	6.7
2003	3	1.40	5.4
2004	4	12.20	37.8
2005	3	4.00	10.7
2006	11	11.50	30.8
2007	9	10.30	10.3
2008	8	12.60	59.0
2009	12	13.90	58.8
2010	22	28.33	100.1

The results of the small hydropower feasibility studies, including layouts and the concise results of calculations of hydrological and other data, are placed on the official web site of the Ministry of Energy and Natural Resources.[7]

While the small hydropower industry finds numerous barriers to development, it must be recognized that the industry has been successful for the last decade, particularly in the last five years. The small hydropower sector provides more than 5 per cent of the annual electrical needs of Armenia.

A very large boost of support for developers was given in 2005 via the establishment of the Armenia Renewable Resource Energy Efficiency Fund (R2E2).[8] The World Bank and European Bank for Reconstruction and Development provided a US$20 million loan through the Global Environmental Facility and a US$6 million grant. R2E2 has participated in the financing of 27 small hydropower projects, 19 of which are operational and 8 are under active construction. A similar financing mechanism was enabled by KfW. The German Armenian Fund of Renewable Energy (RES-GAF) was established with capital of about €6 million (about US$7.74 million). Unfortunately the industry and the small hydropower projects are too large and specialized for most Armenian banks.

Renewable energy policy

In 2007, a National Program of Energy Saving and Renewable Energy was approved by the Government[9]. It was an unprecedented move resulting in a cross-sectoral assessment of energy saving and renewable energy potential in the Armenian economy as well as recommended actions for optimizing it. Energy related issues are regulated in the Energy Law and renewable energy is covered by the Law on Energy Saving and Renewable Energy.[10] The aim of the latter is to direct and define state policy in a way that strengthens the economy and energy autonomy of the country.[2]

Legislation on small hydropower

The strategy of the energy sector development of the Republic of Armenia was worked out and approved by the Government in 2005. The small hydropower Development Scheme was confirmed by the protocol N3 of the Government of Armenia on 22 January 2009.[11]

In September 2011, the Government made a decision according to which a strategic development programme of the hydropower sector in Armenia was adopted; the programme included small hydropower.

Barriers to small hydropower development

There are many regulatory and legal barriers in Armenia, these include:[5]

- Problems with Power Purchase Agreements (PPA).
- Concurrent term, licensing and water use permits.
- Construction versus operational licence;
- Ownership rights.
- Land classification reform.
- Lacking uniform and effective enforcement of environmental legislation.

In addition there exist technical challenges:

- Small hydropower equipment of low quality. There are technical standards in place but it appears that the standards are often compromised either by negligence or design.
- Low feed-in tariffs.
- High import costs.

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3.5.2 Azerbaijan

Ugranath Chakarvarty, International Center on Small Hydro Power

Key fact

Population	9,493,600[1]
Area	86,660 km[2]
Climate	Dry, semiarid steppe
Topography	Large, flat Kur-Araz Ovaligi (Kura-Araks Lowland, much of it below sea level) with Great Caucasus Mountains to the north, Qarabag Yaylasi (Karabakh Upland) in west; Baku lies on Abseron Yasaqligi (Apsheron Peninsula) that cuts into Caspian Sea.
Rain pattern	Varied, the maximum annual precipitation occurs in Lankaran (1,600-1,800 mm) and the minimum in Absheron (200-350 mm).

Electricity sector overview

Azerbaijan's energy sector follows the management system similar to that of the Soviet period, wherein the enormous task of production, transmission and sale of electricity remained as a state monopoly. The electric power system in Azerbaijan is undoubtedly old and yet powerful in the southern Caucasus region. Azerbaijan is self-sufficient in electricity in terms of installed capacity but remains energy-inefficient. Annual generation is less than expected; the overloaded transmission/distribution system leads to acute peak energy shortages. Azerenerji, a state-owned Joint Stock Company is the major electricity producer and it controls the transmission and distribution network of the country, with a few exceptions. The national electricity network is divided into five regional grids: Baku, Nakhichevan, Sumgait, Ali Bayramly and Ganja, which are currently open to foreign investors.

The total installed capacity in 2011 was 6,808 MW, of which 5,003 MW constituted of fossil fuels and the remaining 1,805 MW of hydropower.[2] It should be noted that different sources report varying electricity capacity and generation data (figure 1). Most of the hydropower is generated from six large hydropower stations constructed during the Soviet time.

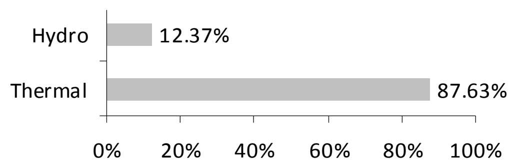

Figure 1 **Electricity generation in Azerbaijan**
Source: ABC.az[3]
Note: Data from 2009.

Small hydropower sector overview and potential

Small hydropower plants are those 'that have a power of 50-10,000 kW, are installed over a regular water flow, and are able to immediately return water to its flow', according to Sub-section C, Section 1 of Article 3 of the Law on Power and Thermal Plants (Order No. 784-IQ).[4]

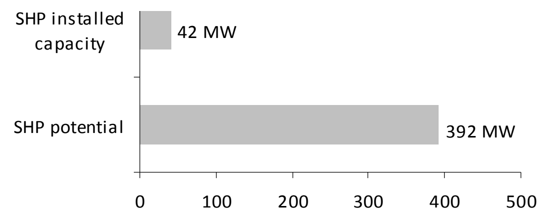

Figure 2 **Small hydropower capacities in Azerbaijan**

The small hydropower share in the country is relatively small, particularly due to Azerbaijan's focus on a centralized large electricity system in the past. Some operational small hydropower plants: Sheki, Mughan, Zeykhur, Gusar, Nyugedi, Chinarly, Balakan, Guba and Zurnabad were offered for privatization under the Presidential Decree in 2001 (table 1). The State Property Committee of Azerbaijan views an average rehabilitation expenditure of AZN 20,000 to AZN 30,000 (US$25,600 to US$38,400); hence it wants to privatize the small hydropower units as soon as possible. As of July 2007, six small hydropower stations remained non-privatized.

In total, 42 MW of small hydropower plants are operational (figure 2). The table below shows selected small hydropower plants.

Installed small hydropower in Azerbaijan

Name	*Location*		*Capacity (MW)*	*Year of commission-ing*
	River	*Region*		
Sheki	Kischay	Sheki	1.6	1929
Mughan	Araz	Mughan	3.8	1962
Zeykhur	Samur	Gusar	9.0	1964
Gusar	Samur	Gusar	1.2	1953
Nyugedi	Gara	Guba	0.8	---
Chinarly	Shamkirchay	Shamkir	0.8	1957
Balakan	Balakanchay	Balakan	0.8	1954
Guba	Kudialchay	Guba	1.2	1936
Zurnabad	Ganja	Khanlar	2.7	1929
Takhta Korpu	Siyazan	Siyazan	2.8	---
Chichekli	Gyandjachai	Khanlar	3.0	---
Total capacity			**27.7**	

Source: United Nations Development Programme[5]
Note: All plants listed are operational. This list may be incomprehensive.

Hydropower resource in Azerbaijan is located alongside rivers such as Kura and its tributaries, Araz, small streams terminating at Caspian Sea and irrigation canals. According to Azerenergi, the country is endowed with a theoretical small hydropower potential of 28,000 GWh, of which 5,000 GWh is the technically feasible potential.

Another boost to the small hydropower sector in Azerbaijan was given when the Asian Development Bank (ADB) and Government of Finland funded and technically assisted in the preparation of the Renewable Energy Development Project (December 2005). It confirmed 21 sites as technically feasible (16 sites are under 10 MW equaling to 40.59 MW), 4 of which were most attractive having a total of 10 MW installed capacity.[6] These four sites have been considered by ADB for financing at about US$25 million, the construction time of the sites remains unconfirmed. However, it was the institutional structure and administrative barriers that were discouraging investment into this sector.

The Ministry of Industry and Energy looks forward to constructing 61 small hydropower units with a total installed capacity of 350 MW until 2020.[2] The Islamic Development Bank has also expressed its interest in hydropower investment of around US$50 million-US$150 million in Azerbaijan.[2]

Renewable energy policy

Renewable energy policy in Azerbaijan is reflected in The State Program on Use of Alternative and Renewable Energy Sources (2005-2013) which focuses on diversifying the sources of primary energy and ensuring energy security, particularly with reference to small hydropower and wind power potential, in order to improve access of energy to rural and remote areas. Azerbaijan's 2020 target includes a 20-per cent share of renewable-generated electricity. The main objectives of the programme include:[7]

- Determination of potential of renewable/alternative energy sources.
- Increase of energy efficiency.
- Creation of new employment opportunities.

The Ministry of Economic Development developed The State Program on Poverty Reduction and Economic Development (SPPRED) in 2003-2005 that recognizes development of renewable energy as a means to fulfill its pursuit of sustainable development.[8]

Legislation on small hydropower

There are no customized laws for renewable energy. The legal framework is built on regulations concerning the energy sector. Small hydropower effectively falls under Law on Utilization of Energy Resources (1996), Law on Electric Energy (1998), Law on Energy (1998) and Law on Electrical Power and Heating Stations (1999). These laws invoke a subsidy for the construction of small hydropower plants having capacity from 50 kW to 10 MW with a guaranteed 'unlimited purchase of energy produced at these (small) plants' (Article 3).[4]

Barriers to small hydropower development

- Lack of environmental priority.
- Legislative gaps and statistical problems.
- Weak institutional coordination.
- Resource curse- too narrow foreign direct investment, crude dependence, lack of operative decision making, clashes of interest.
- Sluggish technological transfer.
- Inadequate relationship with relevant regional and global institutions.

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3.5.3 Georgia

Lara Esser and Kai Whiting, International Center on Small Hydro Power

Key facts

Population	4,570,934[1]
Area	69,700 km[2]
Climate	Very diverse climate. It varies significantly with elevation. Many of the lowland areas of Western Georgia have a Mediterranean climate, relatively warm throughout the year with average temperatures from 5 °C to 12°C. In the north, Georgia is mostly mountainous with the Great Caucasus Mountains and in the south the Lesser Caucasus Mountains. The foothills and mountainous areas experience cool, wet summers and snowy winters. Eastern Georgia has a transitional climate from humid subtropical to continental.[2]
Topography	Mostly mountainous with Great Caucasus Mountains in the north and Lesser Caucasus Mountains in the south; Kolkhet'is Dablobi (Kolkhida Lowland) opens to the Black Sea in the west; Mtkvari River Basin in the east; good soils in river valley flood plains, foothills of Kolkhida Lowland.
Rain pattern	Western Georgia (humid subtropical zone) has annual precipitation ranging from 1,000-4,000 mm, while Eastern Georgia (transitional climate from humid subtropical to continental) has annual precipitation ranging from 400-1,600 mm.[2]

Electricity sector overview

Georgia is steadily liberalizing its electricity market and this has encouraged private acquisition of assets and operations within the sector. The total installed electricity generation capacity is 3,400 MW. Hydropower alone contributes about 2,700 MW. Thermal contributes to 700 MW but it is used only to meet peak load demand. In 2011, large hydropower contributed 55 per cent of the total electricity generation (the two largest plants Enguri and Vardnili Cascade alone accounted for 36 per cent); medium hydropower provided 17 per cent and 3 per cent originated from small hydropower (figure 1). Only 21 per cent comes from thermal power (gas). Some 93 per cent electricity produced is regulated (>13 MW capacity) and 3 per cent is unregulated (<13 MW). A further 4 per cent is imported and 11 per cent exported. Exporting electricity to Turkey and the European Union is restricted, because it contributes to investor risk.[3]

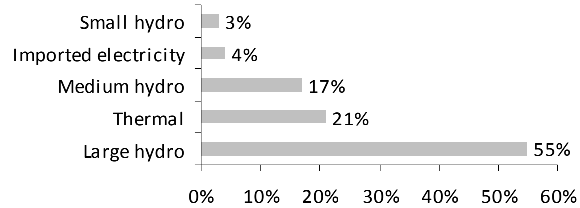

Figure 1 **Electricity generation in Georgia**
Source: Gazadze and Shengelia[3]
Note: Data from 2011.

The generation tariff for hydropower is the lowest in the region at US$0.02/kWh, as compared favourably to the cost of thermal energy (US$0.03/kWh), which is high despite subsidized oil prices.[3]

Small hydropower sector overview and potential

There are 26,000 rivers in the country with a total rivers length of approximately 60,000 km. Around 360 rivers are significant in terms of hydropower production.[2] In 2009, the untapped small hydropower potential was estimated at 5,000 GWh, while by definition, small hydropower (termed as unregulated) plants have capacities of <13 MW.

Of all the hydropower plants in Georgia, 66 per cent or 5,217 MW are seasonal regulation dam/reservoir-type plants, 30 per cent or 2,379 MW are run-of-river type and 4 per cent or 296 MW have capacities lower than 13 MW and are therefore considered small hydropower (figure 2).[3]

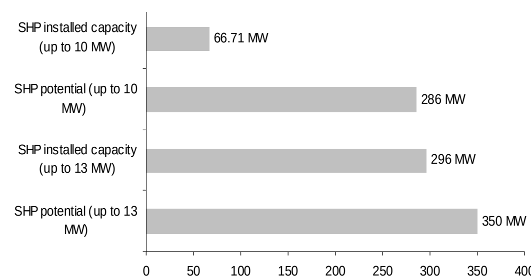

Figure 2 **Small hydropower capacities in Georgia**
Source: Gazadze and Shengelia[3], Birkadze[4] and Ministry of Energy and Natural Resources[5]

An overview of the potential small hydropower sites up for tendering is available on the website of the Ministry of Energy(www.menr.gov.ge).[5] A list of 41 potential sites exists; of which 24 sites are between 1 MW to 10 MW, with a total projected installed capacity of 125.96 MW and are all run-of river type plants. The following table is a list of ongoing investment projects.

Small hydropower investment projects in Georgia

Name	*Company / country*	*Installed capacity (MW)*	*Annual generation (GWh/year)*	*Estimated investment (US$)*	*MOU signing date*	*Start of construction*	*Completion of construction*
Bakhvi HPP	Bakhvi Hydro, Turkey	6.0	35	9 700 000	May 2009	October 2011	August 2012
Aragvi HPP	Energo Aragvi, Georgia	8.0	50	11 000 000	September 2007	February 2012	February 2015
Lukhuni HPP	Rusmetali LLC, Georgia	7.5	46	12 623 762	July 2009	May 2020	December 2024
Kvirila HPP	Zoti Hydro, Chezh Republic – Georgia	5.2	22	11 611 650	May 2009	December 2010	December 2015
Shilda HPP	Georgian Green Energy Development, Georgia	4.8	28	6 000 000	-	October 2011	October 2013
Bakvhi 5 HPP	KGM, Turkey	2.0	11	3 400 000	August 2011	January 2012	July 2013
Gubazeuli 6 HPP	EMCT, Turkey	3.1	20	4 200 000	August 2011	December 2011	December 2013
Kintrishi HPP	- , Georgia	5.0	30	8 000 000	-	-	-
Nabeglavi HPP	Alliance Energy, Georgia	1.9	13	2 800 000	-	-	-

Source: Ministry of Energy and Natural Resources[5]
Note: HPP - hydropower plant

In February 2010, the United Nations Development Programme (UNDP) began seeking bids for consulting services for small hydro development in Georgia. The request for proposals included constructing the 5.4 MW Khadori 2 on the Alazani River. It also included reconstructing the 6.5 MW Ritseula on the Ritseula River, increasing capacity of the Pshavela project to 25 MW (from 450 kW), and reconstructing the 1 MW Achi plant.

Financially, hydropower is in a strong position with the Kreditanstalt für Wiederaufbau Renewable Energy Fund, facilitating renewable energy and particularly hydropower projects by providing capital to Georgian banks so that loans can be extended. In 2012 additional €25 million (about US$32.25 million) were allocated to the Fund.[3]

Renewable energy policy

Georgia has vast resources of almost all types of renewable energy – solar, wind, geothermal, hydro and biomass.[1] The Ministry of Energy is considering the effective use of the country's major energy potential i.e. hydropower resources, and the construction of small, medium and large hydropower stations.

The Georgian Government started to restructure its energy sector in 2004, with the main long term policy objective published as early as 2006 to fully satisfy the country's overall demand for electricity with domestic hydro resources.[6] In 2008, the Government of Georgia approved the Renewable Energy State Program which regulates and supports the construction of new renewable energy projects in the country with a capacity up to 100 MW. It offers long-term purchasing agreements and favourable feed-in tariffs and licence-free electricity generation for power plants up to 10 MW. The Government was tendering for 91 potential new hydropower sites with capacities ranging from 0.6 MW to 99 MW under this programme, with a focus on the development of small- and medium-sized hydropower plants.[2]

Legislation on small hydropower

Small hydropower is defined as small (termed as unregulated) if the installation capacity is <13 MW. The regulation of the hydropower sector offers potential investors many advantages. Newly built hydropower plants remain the exclusive property of investors through a Build-Operate-Own Scheme. Newly constructed small hydropower plants with an installed capacity of <13 MW do not require an operating licence. They do, however, require a construction and environmental permit.[3]

Barriers to small hydropower development

Some of the barriers to small hydropower development in Georgia include:

• Small hydropower plants (especially newly built ones) are not competitive in terms of cost of generation compared to large and medium capacity power.[2] However, investment in small hydropower projects can be made more attractive by grouping them to allow collective procurement, enhancing economies of scale.[3]

• Small hydropower plants have profound seasonality and dependence on river run-off conditions. In the winter time, rivers in Georgia suffer from insufficient water flow, influencing electricity supply.[3]

• Rivers have an unfavourable annual generation profile, with maximum production in summer when power generation exceeds the demand.[1] In general, hydropower production and consequently electricity surpluses can be exported to Georgia's neighbour, Turkey.[3]

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3.5.4 Iraq

Abdul-Ilah Younis Taha, Baghdad University, Iraq

Key facts

Population	31,129,255[1]
Area	435,000 km²
Climate	Mostly desert; mild to cool winters with dry, hot, cloudless summers; northern mountainous regions along Iranian and Turkish borders experience cold winters with occasionally heavy snows that melt in early spring, sometimes causing extensive flooding in central and southern Iraq.
Topography	Mostly broad plains; reedy marshes along Iranian border in south with large flooded areas; mountains along borders with Iran and Turkey.
Rain Pattern	Roughly 90 per cent of the annual rainfall occurs between November and April. The western and southern desert region receives brief heavy rainstorms in the winter of about 100 mm in total. In the rolling upland region, there is basically no precipitation in the summer and some showers in the winter (winter rainfall averages about 380 mm). The alluvial plain of the Tigris and Euphrates delta in the southeast receives most of its precipitation accompanied by thunderstorms in the winter and early spring. The average annual rainfall for this area is only about 100 mm to 170 mm. In the mountains of the north and northeast precipitation occurs mainly in winter and spring, with minimal rainfall in summer. Above 1,500 metres, heavy snowfalls occur in winter, and there is thunderstorm activity in the summer. Annual precipitation for the whole region ranges from 400 mm to 1,000 mm.[2]

Electricity sector overview

Electrification rate in Iraq has dropped from about 98 per cent in the late 1990s to 93 per cent at present. About 15 per cent of the power generated provides continuous supply to essential services. The remaining population gets typically eight hours of national grid electricity each day. It is estimated that 98 per cent of the population has alternative power supplies, either obtained through neighbourhood or private generators. An exception is the autonomous region of Iraqi Kurdistan, where the population has access to electricity 24 hours a day.[3]

Annual power production in Iraq has increased from 29.13 GWh in 2000 to 48.83 GWh in 2010 (with a considerable drop to 25.34 GWh in 2003 as a result of the destruction of power infrastructure). Electricity generation is mainly based on fossil fuels (figure 1).

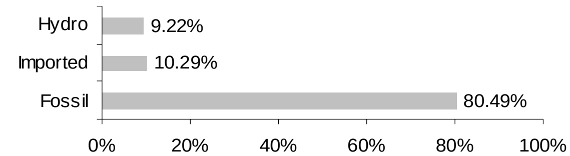

Figure 1 **Electricity generation in Iraq**
Source: Indexmundi[4]
Note: Data from 2010.

Iraq has the third highest oil reserves in the world. Due to the nation's political instability, it still faces energy shortages even though the land is blessed with such essential resources. According to the the country's energy master plan, about 24,400 MW of new capacity will be added between 2012 and 2017, including 13,000 MW of gas-fired capacity, 7,000 MW of thermal power capacity and 400 MW of renewable energy by 2015. A further 4,000 MW will be added by the conversion of simple-cycle power plants to combined-cycle technology.[3]

While hydropower development is part of the long term strategy, the country is currently more interested in developing power plants in a short duration; hence gas- and oil-fired plants are the preferred choice. There is also more focus on developing large dams for irrigation and flood protection. Wind and solar parks are also desired.

Small hydropower sector overview and potential

There is no official definition of small hydropower in the country, but generally, a capacity of up to 80 MW is considered small. The installed capacity of small hydropower projects (according to the country's definition of up to 80 MW) is about 10 per cent of the total hydropower capacity. Currently, there are six small hydropower stations operating in Iraq (table 1). Only one of the listed projects has a capacity below 10 MW (figure 2).

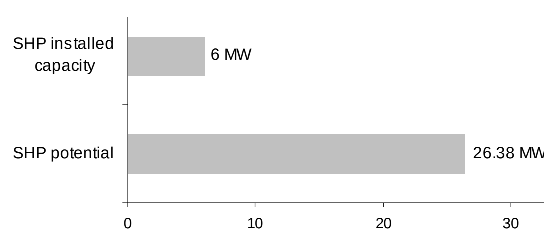

Figure 2 **Small hydropower capacities in Iraq**
Note: Small hydropower definition of up to 10 MW.

It is estimated that the full hydropower potential may be as high as 80,000 GWh annually. In 2006, the Ministry of Water Resources issued a guidance note, Phase I, as part of its Strategy for Water and Land Resources in Iraq.[5] The note is based on the earlier study by the Ministry of Heavy Industry. Examination of the flows used indicates which calculations do not take new developments in upstream riparian countries into considerations, resulting an over-estimation of the hydropower potential. It lists 78 potential hydropower stations, listing for each station, the total potential installed capacity, the rated discharge, the annual energy production, the static head and the unit cost in IQD/kW. It does not explicitly indicate whether the units are small hydropower, but this can be summarized from other listed data.

Table 1
Installed hydropower capacity in Iraq

Project name	*Installed capacity (MW)*	*Ownership*
Dokan Dam	400	Iraqi Government
Darbandikhan Dam	240	Iraqi Government
Mosul Main Dam	750	Iraqi Government
Mosul Dam pump storage plant	200	Iraqi Government
Mosul Regulating Dam	60	Iraqi Government
Haditha Dam	660	Iraqi Government
Samaraa Barrage	80	Iraqi Government
Hemrin Dam	50	Iraqi Government
Adhaim Dam	40	Iraqi Government
Al-Hindiyah Barrage	15	Iraqi Government
Shatt Al-Kuffa Regulator	6	Iraqi Government
Total installed capacity	**2 501**	

Note: Data from 2011.

According to the country's definition of small hydropower below 80 MW, there are 30 potential small hydropower project sites. Applying the small hydropower definition of up to 10 MW, it is estimated that there are at least 12 potential small hydropower sites available with an estimated capacity of 26.38 MW.[6]

Table 2
Small hydropower sites under study in Iraq

Name of Regulator.	*Units*	*Design discharge (m^3/sec)*	*Installed capacity (MW)*
Tarthar Water Divider Regulator	4	171	5.662
Al-Sader Al-Mushtarak Regulator	3	60	1.300
Al-Abbasiya Regulator	2	168	4.683
Al-Btera Regulator	2	118	3.016
Al-Hilla Head Regulator	8	189	2.634
Al-Dagara Regulator	2	31	0.508
Al-Kahla Regulator	2	67	2.394
Al-Kassara Regulator	1	24	0.601
Al-Garraf Head Regulator	4	158	3.650
Qal'at Salih Regulator	2	25	0.416
Al-Khalis Regulator	1	49	0.760
Al-Diwaniya Regulator	3	49	0.755
Total			**26.379**

Source: Ameen[6]

The Ministry of Water Resources is currently undertaking a study entitled 'Strategy for Water and Land Resources of Iraq'. The aim is to develop an integrated strategy for developing and managing water resources throughout Iraq to ensure sustainable management and development of the country's water and land resources. The utilization of the hydropower potential is an integral part of the study.

Renewable energy policy

The Ministry of Electricity has established a Renewable Energy Center. Its main focus at present is to develop solar and wind energy. The Ministry of Heavy Industry commissioned a study on hydropower resources use in Iraq in 1988.[7] The study was undertaken by Technopromexport, an entity that belonged to the Union of Soviet Socialist Republics, and addressed, among other issues, hydropower development and its contribution to the coverage of the load curve in the national power grid. However, there is no renewable energy policy or framework supporting deployment of sustainable renewable energies.

Barriers to small hydropower development

- Times of war and sanctions have left the energy sector, rural agriculture and water infrastructure in a terrible state.
- Constantly evolving plans, frequently cancelled tenders, and risks associated with payments and security continue to hold the power sector back.[3]

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3.5.5 Jordan

Joy Y. Balta, Lebanese American University, Lebanon; Kai Whiting, International Center on Small Hydro Power

Key facts

Population	6,508,887[1]
Area	89,342 km[2]
Climate	Mostly arid desert.
Topography	Mostly desert plateau in east, highland area in west; Great Rift Valley separates East and West Banks of the Jordan River.
Rain Pattern	Rainy season in west (November-April).

Electricity sector overview

The electricity sector in Jordan was established in 1938 by Jordan Electric Company. In order to regulate and modernize the electricity sector, the Jordanian Government in 1967 established the Jordan Electricity Authority. In 1984, the Jordanian Government established the Ministry of Energy and Mineral Resources, after the agreement among Jordan, Turkey, Egypt, Iraq, and the Syrian Arab Republic to interconnect their electric power grids in 1995. The Jordanian Government finally decided to privatize its electricity sector in 1996. As part of the privatization effort in 1999, the Government decided to unbundle the existing state-owned electricity company, National Electric Power Company (NEPCO) into three separate companies: Central Electricity Generation Company (CEGCO), NEPCO and Electric Distribution Company (EDCO) handling electricity generation, transmission, and distribution respectively.

In 2004, the Council of Ministers decided to establish a shareholding company, fully owned by the Government, called Samra Electric Power Generation Company (SEPGCO). A private company owned by American company, AES Corporation, andJapanese company Mitsui & Co. was founded in 2009. It was the first private electricity generating project operating the East Amman power plant/ Al Manakhir. In 2010, Korea Electric Power Corporation and Saudi company Xenel formed a coalition that founded a private company which now runs the Al Qatraneh Electric Power Company.[2 3]

The Ministry of Energy and Mineral Resources supervise the electricity sector, sets policies and strategies, imports energy, and contracts independent power projects (IPPs). The Electricity Regulatory Commission regulates the electricity sector by fixing electricity distribution tariffs, issuing licences and monitoring licensing agreements.

Jordan is considered to have huge reserves of oil shale, which can be utilized commercially by direct incineration to produce electricity. The Jordanian Government has decided to market oil shale, aiming to attract international companies to utilize it. The strategic plan is to rely on oil shale for 14 per cent of the energy mix by 2020.[2]

Total installed electricity generation capacity in 2011 was 3,420 MW according to the annual report of the Electricity Regulatory Commission. Electricity generated in 2011 was around 14,647 GWh, showing a decline rate of 0.9 per cent as compared to 2010.[4] The total hydropower production dropped from 61 GWh in 2010 to 55 GWh in 2011, contributing only a mere 0.34 per cent to the electricity mix (figure 1).[4]

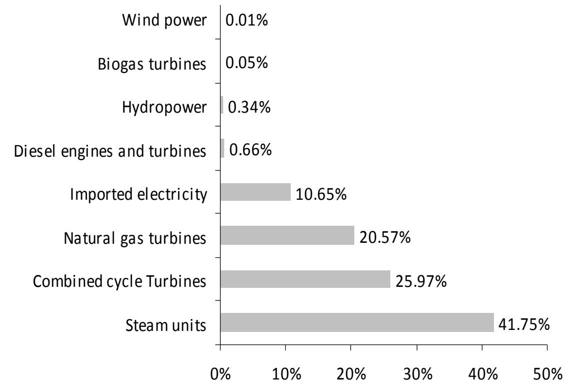

Figure 1 **Electricity generation in Lebanon**
Source: Electricity Regulatory Commission[4]
Note: Data from 2011.

Small hydropower sector overview and potential

In 2004, two small hydropower schemes were operational in Jordan (figure 2).[5] One is located at the Aqaba thermal power station, where its hydropower turbine utilizes the available head of returning cooling seawater, with a capacity of 5 MW. The other is at King Talal dam spanning the river Zarqa, with a rated electricity-generating capacity of about 5 MW. Though the two small hydropower schemes produce only 0.5 per cent of the total national electricity generation, there is a great possibility to generate electricity by developing the elevation difference between the Red Sea and the Dead Sea. A preliminary pre-feasibility study showed that the potential capacity of hydropower station built in this region could be 800 MW.[2 5]

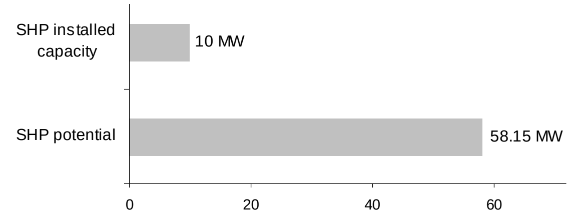

Figure 2 **Small hydropower capacities in Jordan**

Table 1

Small hydropower potential at existing dams in Jordan

Name/Location	*Average annual flow (10^6 m3/yr)*		*Hydropower utilization*		*Estimation hydropower potential (kW)*	*Projected energy generation potential (MWh/yr)*
	In	*Out*	*Yes*	*No*		
Al Wahdah / Irbid	13.0	5.0		X	2 500	15 000
Al Arab / Nothern Shuonah	10.0	11.5		X	5 750	34 500
Sharhabiel / Northern Jordan Valley	5.1	5.8		X	2 900	17 400
King Talal / Jerash	92.2	92.3	X			
Wadi Shuiaib / Southern Shounah	6.1	6.3		X	3 150	18 900
Kafrain / Southern Shounah	11.3	11.3		X	5 650	33 900
Karameh / Southern Shounah	2.1	0.5		X	250	1 500
Tanoor / Jordan Valley	4.1	1.3		X	650	3 900
Waley / Madaba	6.6	8.7		X	4 350	26 100
Mojeb / Karak	3.0	13.0		X	8 000	48 000

Sources: Jabera[6], Jordanian Ministry of Water and Irrigation[7]

Table 2

Small hydropower potential at proposed dams in Jordan

Name / location	*Proposed storage capacity (10^6 m3)*	*Status as of early 2010*	*Hydropower potential (kW)*	*Generation potential (MWh/yr)*
Maa'in / Madaba	1.0	Under study	500	3 000
Lajjun / Karak	1.0	Under study	500	3 000
Dalaghah / Tafila	1.0	Under study	500	3 000
Shuthim / Tafila	1.0	Under study	500	3 000
Kufranjah / Ajlun	9.0	Under study	4 500	27 000
Bin Hammad	5.0	Under study	2 500	15 000
Wahidi / Maa'n	1.8	Under study	900	5 400
Wadi Karak / Karak	2.1	Updating studies	1 050	6 300
Bayer / Eastern desert	4.0	Completed	2 000	12 000
Jafer / Southern desert	0.5	Under construction	250	1 500
Rukban / North eastern desert	2.0	Completed	1 000	6 000
Khanasree / Mafraq	1.0	Under construction	500	3 000
Ghadaf / Central desert	0.5	Completed	250	1 500

Sources: Jabera[6]; Jordanian Ministry of Water and Irrigation[7]

Currently all dams, except one, are being used to store water for the long and dry summer season. Table 1 summarizes the average flows of existing main dams in Jordan and their estimated hydropower generation.[6 7]

Table 2 summarizes the storage capacity for proposed small dams in Jordan and their projected small hydropower potential. Small rivers and streams could be potential locations for small hydropower generation. These sites are located in rural areas.

Small hydropower is a potential energy source in Jordan especially now that the legislation allows for IPPs to operate in the country.[7]

Renewable energy policy

Renewable energy comprises not more than 1 per cent of the total energy resources In Jordan. The Jordanian Government has developed a plan to increase the share of new and renewable energy to the energy mix, reaching 7 per cent by 2015 and 10 per cent by 2020. The two renewable energy sources mainly used in Jordan are wind and bio-energy (biomass). The Annual Report 2011 by the Ministry of Energy and Mineral Resources did not mention any use of hydropower as a source of energy or any potential plan, but recently there has been research into small hydropower in Jordan.

Barriers to small hydropower development

- Limited small hydropower development due to limited availability of surface water resources.
- Lack of local technical small hydropower capacities, contributing to the high cost of these (imported) services and/or goods.[6]
- Absence of targeted incentives for private small hydropower development.
- Difficult access to funding for small hydropower projects.

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3.5.6 Lebanon

Joy Balta, Lebanese American University, Lebanon; Kai Whiting, International Center on Small Hydro Power

Key facts

Population	4,140,289[1]
Area	10,400 km[2]
Climate	Mediterranean; mild to cool, wet winters with hot, dry summers; Lebanon mountains experience heavy winter snows.
Topography	Four main geographical regions running north to south parallel to the Mediterranean - the coastal plain, the Lebanon mountain range, the Bekaa Valley and the Anti-Lebanon range.
Rain Pattern	Average annual rainfall (1965-1999) along the coastal zone ranges between 540 mm and 1,110 mm, whereas the annual average precipitation (rain and snow) over the mountain area ranges between 937 mm and 1,854 mm for the same period.[2]

Electricity sector overview

Lebanon lacks all types of major traditional energy sources, including fossil fuels.[3] Accordingly, 99 per cent of its primary energy needs is met through the main electricity company, Electricité du Liban (EDL) by importing around US$500 million worth of fuel each year to generate the electricity needed.[4] Renewable energy currently provides a minor contribution to the energy balance in Lebanon, its share is less than 5 per cent of primary energy and less than 10 per cent of the electricity production.

Hydropower is the only renewable source used in electricity generation in Lebanon (figure 1), although it has the potential to benefit from other resources, particularly solar and wind.[3] Electricity, thus, is mostly generated from thermal power plants, with a limited contribution from ageing hydropower installations.

The power supply capacity of 2,100 MW is made up of 1,900 MW thermal power and 200 MW hydropower.[5] Hydropower can, however, be as low as 80 MW in a dry year.[6] Imports are currently provided by Egypt and in the past, provided by the Syrian Arab Republic before the outbreak of civil unrest.[7]

The civil war that broke out in 1975 caused vast destruction to the country's infrastructure. The war ceased in 1991, at that point the Lebanese people had adapted to the absence of stable electricity supply and have been using private diesel generators.

Between the 1990s and the end of 2000s, successive governments failed to reform the sector and invest in infrastructure. In 2011, the Government approved a policy paper on the electricity sector prepared by the Minister of Power and Water. It states that the total energy demand in 2009 was 15,000 GWh, EDL supplied 11,522 GWh out of the original demand from different sources.[8 9]

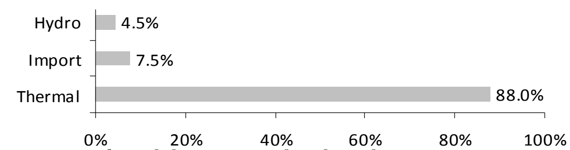

Figure 1 **Electricity generation in Lebanon**

Sources: Habib[8] and Lebanon, Ministry of Energy and Water[9]

Note: Data from 2009. Thermal includes electricity generated by heavy fuel oil-fired steam-turbines and diesel-fired Combined Cycle Gas Turbine power plants

Lebanon is famous for its water resources in an otherwise water deficient region.[10] The Lebanese topography and its relatively short rainy period cause a large volume of water losses without it being put to use. Lebanon receives 8,600 million m^3 of precipitation; however, 50 per cent is lost through evapotranspiration, surface water flows (8 per cent) to neighbouring countries and into underground water (12 per cent), leaving around 2,600 million m^3 surface and groundwater potentially available to the country.[10]

The installed capacity of all hydro plants is 274 MW but the actual generation capacity is 190 MW.[10] Lebanon used to generate 60-70 per cent of its power from hydropower sources prior to the 1960s. In 1974, 41.5 per cent of the total generated electricity was hydropower compared to 4.5 per cent in 2009.[9] A research conducted by Central Administration for Statistics (CAS) reported that 5-12 per cent of electricity production in Lebanon comes from hydropower depending on rainfall and thermal plants productivity.[10]

Small hydropower sector overview and potential

There are nine small hydropower plants producing electricity in Lebanon, with a total installed capacity of 30.8 MW (figure 2 and table 1).[10] Future small hydropower sites are mentioned in table 2, with a total additional capacity of 29.5 MW.

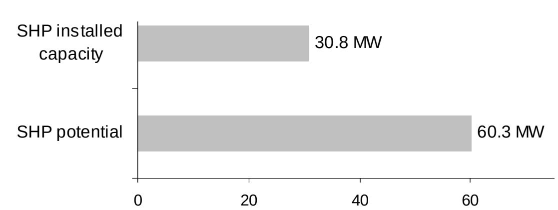

Figure 2 **Small hydropower capacities in Lebanon**

Table 1
Installed small hydropower capacity up to 10 MW in Lebanon

River	*Plant*	*Year*	*Capacity (MW)*	*Storage*	*Annual generation up to 1975 (GWh)*
Kadisha	Blaouza	1961	8.4	Daily	31
	Abu Ali	1933	7.4	Daily	22
	Mar Lichaa	1952	3.1	None	10
	Bcharre	1929	1.6	None	6
Ibrahim	Ibrahim 3	1950	5	None	22
	Bared 2[a]	1962	3.7	None	14
Jaouz	Chekka	1950	5.3	None	17
Kalb	Hraiche[a]	1953	1.9	None	..
Bardouni	Wadi el Arayech[a]	1923	1.1	None	..

Source: Green Line Association[10]
Note: a. Power plants are either partially or fully out of service.

Table 2
Planned small hydropower plants up to 10 MW in Lebanon

River	*SHP Plant*	*Capacity (MW)*
Litani	Bisri	6.0
Safa	Rchmaya	4.5
Assi	Yammouneh[a]	10.0
Bared	Ksaim	5.0
Abou Ali	Bchenine	4.0
Total		**29.5**

Source: Green Line Association[10]
Note: a. Construction about to start

Renewable energy policy

Currently, only hydropower is being used to produce clean energy in Lebanon. From 2010, a policy paper contains plans to introduce wind power through the private sector. The estimated production within three years is 60 MW to 100 MW with an estimated cost of US$115-US$195 million. The goal of the Ministry of Energy and Water (MEW) has set a target to achieve a 12-per cent production of renewable energy by 2020.[9 11 12]

The policy paper recommends the start of a pre-feasibility study on photovoltaic farms in Lebanon, which is now underway. These studies helped the MEW to launch a tender for building photovoltaic farms in Lebanon by February 2013. The MEW plans to advocate the use of solar water heaters by establishing an innovative financing scheme in collaboration with the banking sector. The policy paper encourages both the public and the private sectors to adopt incineration technologies to produce electricity from waste. This sector requires three to four years to be implemented and would produce 15 MW to 20 MW with an estimated budget of US$30-US$50 million.[13 14]

Barriers to small hydropower development

With regard to uses of the water resource, there is a need to evaluate several factors including energy needs, irrigation and domestic water demand. The average rainfall in the 1996-2000 period is between 9 per cent and 14 per cent lower than the average. More water is diverted for irrigation purposes and therefore not available for other uses. This has resulted in a significant decrease in hydropower generation.[10]

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3.5.7 Turkey[i]

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Key facts

Population	79,749,461[1]
Area	783,562 km^2.[1]
Climate	Temperate; hot, dry summers with mild, wet winters; harsher in interior.
Topography	High central plateau (Anatolia); narrow coastal plain; several mountain ranges.
Rain pattern	Annual average precipitation: 643 mm, unevenly distributed. It varies from less than 250 mm in the inland areas of central Anatolia to more than 3,000 mm in the northeastern Black Sea coastal region. Autumn marks the start of the rainy season, which continues until late spring on the western and south-eastern coasts. The Black Sea coast receives rain throughout the year.

Electricity sector overview

Turkey's electrification rate in 2002 was 95 per cent.[2] Its electricity consumption in 2010 was 180.21 TWh. Between 2015 and 2020, electricity demand is predicted to go up to 410 TWh and 571 TWh, respectively.[2 3]

The Turkish Electricity Market Law no. 4628 was published in March 2001 and has led to the establishment of the Electricity Market Regulatory Authority. Thus, the private sector has been able to obtain a licence granted from this authority to own, build and operate power plants.

Hydropower development in Turkey has been carried out for about a century for different purposes, namely electricity generation, land irrigation, water supply for domestic and industrial utilization and flood control in the surrounding area. Hydropower accounts for more than 26 per cent of electricity generation (figure 1).

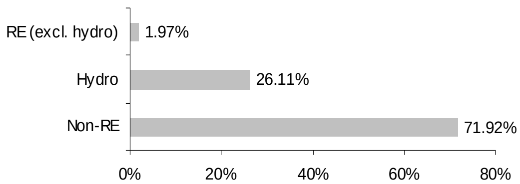

Figure 1 **Electricity generation in Turkey**
Source: Indexmundi[5]
Note: Data from 2011.

In view of the considerable variation in seasonal, annual and regional runoff, it is absolutely necessary for the major rivers in Turkey to have water storage facilities and to allow the use of the water when it is necessary. Consequently, priority has always been given to the construction of water-storage facilities. Significant progress has taken place in the construction of dams throughout the 55 years that have elapsed since the establishment of the State Hydraulic Works.[4]

Small hydropower sector overview and potential

Development of small hydropower began in 1902 in Turkey. Since then, private entrepreneurs and some government organizations and municipalities in rural areas have installed many decentralized small hydropower plants.

Turkey has a mountainous landscape with an average elevation of 1,132 metres. This topography favours the formation of high gradient mountain streams with suitable locations for small hydropower development.[6] The low costs of investment offer attractive opportunities for either domestic or foreign entrepreneurs interested in small hydropower plants.

Since 1990, the amount of small hydropower plants and their capacity have increased more than doubled. The bulk of all small hydropower plants (85 per cent) have been constructed in the last two decades. Around 20 per cent of generating capacity is in private hands. According to their gross head, the percentage of small hydropower plants is as follows: 5 per cent have medium head (5 to 15m) and 95 per cent high head (more than 15m).[7]

By the end of 2002, the total number of small hydropower stations in operation throughout the country was 59 with a total installed capacity 175.5 MW (figure 2), covering less than 2 per cent of the total hydropower potential (13,700MW) in Turkey.[8 9 10 11 12]

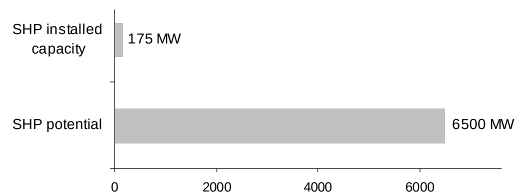

Figure 2 **Small hydropower capacities in Turkey**

In addition to the large hydropower projects with installed capacities greater than 10 MW, it is estimated that there still is considerable small hydropower potential in Turkey.[12] This estimation is provided in table 1.

Among the 25 hydrological basins in Turkey, the Eastern Black Sea Basin has great advantages in terms of small hydropower potential as the annual average precipitation is the highest in the country (2,329 mm in Rize Province). Furthermore, the basin covers sharp valleys and there are a lot of steep streams with considerable discharges and heads.[13 14]

Small hydropower potential in Turkey

Potential	*Generation (GWh/year)*	*Generation (Percentage)*	*Capacity (MW)*
Gross theoretical	50 000	100	16 500
Technical feasible	30 000	60	10 000
Economically feasible	20 000	40	6 500
Economically feasible potential that has been developed	664	3.3	175
Remaining economically feasible potential	19 336	96.7	6 325
Remaining economically feasible potential taking into account environmental constraints (e.g. rivers exempted from damming)	~19 300	96.7	6 325

Source: Balat[7]

With regard to local small hydropower capacities, there are local consulting and engineering companies which provide multi-disciplinary engineering services, locally and internationally. Increasing demand for power-generating turbines and other equipment will benefit the industrial sector and reduce import demand.

Renewable energy policy

With the publishing of Renewable Energy Law No. 5346 in May 2005, the Turkish Government has assured to buy electricity from legal entities with a feed-in tariff of 5.5 euro cents/kWh for 10 years. Besides, 85 per cent discount is applied for forest and land acquisition to build small hydropower plants. Furthermore, law No. 5784 published in July 2008 was expected to attract entrepreneurs to invest in mini- and micro-hydropower plants. After the emergence of this law, the status of legal entity is no longer a pre-requisite for applying a licence to generate electricity from renewable energy, if the plant capacity does not exceed 500 kW. Also, the Government guarantees the purchase of the excess electricity.[6]

Legislation on small hydropower

In Turkey, Environmental Impact Assessment (EIA) reports were not required for hydropower plants with installed capacity below 50 MW before 17 July 2008. However, a regulation on the same date stated that hydropower plants having an installed capacity between 0.5 MW and 25 MW are required to undertake an EIA.[6]

Barriers to small hydropower development

Renewable Energy Law No. 5346 applies to small hydropower or hydropower production facilities having a reservoir area less than 15 km^2 and makes no limitation regarding installed capacity. This makes the interest of private sector move towards large hydropower system for the potentially higher profits.[6]

Note

i. Based upon Dursun, B. and Gokcol, C. (2011). The role of hydropower and contribution of small hydropower plants for sustainable development in Turkey. Renewable Energy, 36, 1227-1235.

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4 Europe
4.1 Eastern Europe
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Introduction to the region
There are 10 countries in Eastern Europe and all of them use small hydropower (table 1). The dominant climate in the region is continental and temperate. Eastern Europe is generally a drier part of Europe. Due to the Russian Federation's geographical size and wide range of climatic conditions it cannot be summarized in the same way as the other countries.

Table 1
Overview of countries in Eastern Europe

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Belarus[c]	9.64	26	..	8 445	32 950	15	45
Bulgaria[a]	7.03	30	..	11 500	44 831	1 434	5 057
Czech Republic[a]	10.18	26	..	20 072	87 560	1 056	2 138
Hungary[a]	9.96	32	..	10 108	35 984	54	222
Republic of Moldova[a]	3.66	..	..	2 076	3 412	64	318
Poland[a]	38.42	39	..	37 367	163 153	900	2 331
Romania[ad]	21.85	43	..	20 630	60 385	6 423	19 523
Russian Federation[abe]	141.75	27	..	218 145	1 0190 400	46 873	166 483
Slovakia[af]	5.48	45	..	8 320	28 135	2 399	3 683
Ukraine[c]	44.85	..	..	54 600	172 900	4 711	13 152
Total	**292.82**	**-**	**-**	**391 263**	**10 819 710**	**63 929**	**212 952**

Sources:
a. International Journal on Hydropower and Dams[1]
b. Ministry of Energy of Russian Federation[2]
c. Energy Regulators Regional Association[3]
d. Romania, Autorităţii Naţionale de Reglementare în domeniul Energiei[4]
e. Ministry of Energy of the Russian Federation[5]
f. Slovenska elektrizacna prenosova sustava[6]

The Czech Republic, Hungary, Poland and Slovakia are the Visegrad Four countries.[i] They closely cooperate on a regional level in the energy sector. Six of the countries are members of the European Union (EU) namely Bulgaria, Czech Republic, Hungary, Poland, Romania and Slovakia. To help EU countries to achieve their renewable energy targets by 2020, including the integration of large volume of wind to the European electricity transmission system, new infrastructure is crucial. Based on the EU Third Energy Package and the conclusions of the European Council in February 2011, an internal harmonized electricity market should be completed by 2014. Austria, Czech Republic, Germany, Hungary, Poland, Slovakia and Slovenia are part of the Central Eastern Europe regional initiative led by the Austrian regulatory authority E-Control. The aim of these regional initiatives is a cross-border continuous intraday trading system across Europe[7]. As a first step, this was successfully implemented in September 2012 among Czech Republic, Slovakia and Hungary.[8]

Traditional thermal energy and nuclear power are still the prevalent electricity sources among the countries as hydropower is not so important, except in the smaller-sized nations. For example, Belarus, which became independent in 1991, is still energy dependent on the Russian Federation while it is also an important transit route for Russian oil and natural gas exports to Eastern Europe. The access to cheap gas from the Russian Federation and the lack of energy diversification policies have prevented Belarus from developing its potential renewable energy resources for electricity generation.[9]

Small hydropower definition
The 10 countries in Eastern Europe use various small hydropower definitions as shown in table 2 below.

Table 2

Classification of small hydropower in Eastern Europe

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*	*Pico (kW)*
Belarus [a]	up to 10		5–100	up to 5
Bulgaria [b]	up to 10			
Czech Rep. [b]	up to 10			
Hungary [b]	up to 5			
Poland [b]	up to 5			
Rep. of Moldova	..			
Romania [b]	up to 10			
Russian Federation [c]	up to 30			
Slovakia [b]	up to 10			
Ukraine	..			

Sources

[a] Belarusian web portal on Renewable Energy.[10] This value may not be official.

[b] European Small Hydropower Association[11]

[c] International Journal on Hydropower and Dams[1]

Regional overview and potential

All 10 countries in the region use small hydropower with a wide range of contributions to their national grids: from 0.1 per cent to 100 per cent. Support mechanisms for small hydropower exist in most countries in the region through tradable green certificates (Poland, Romania), investment support scheme (Slovakia), and feed-in tariffs (Bulgaria, Czech Republic, Hungary, Ukraine[ii]).

While legislative frameworks to support small-scale, alternative or renewable energy exist in Belarus, Republic of Moldova and the Russian Federation, concrete financial support mechanisms for small hydropower remain undefined. Meanwhile the Water Framework Directive is being implemented in all EU member states and its implementation might cause higher residual flow requirements for small hydropower and an increase in their operating costs.

Table 3

Small hydropower up to 10 MW in Eastern Europe

Country	*Potential (MW)*	*Planned (MW)*	*Installed capacity (MW)*	*Generation (GWh/year)*
Belarus	at least 15.0	..	15.0	28
Bulgaria	380.0	117.0	263.0	630
Czech Republic	465.0	43.0	297.0	1 159
Hungary	28.0	14.0	14.0	67
Rep. of Moldova	1.3	1.2	0.1	..
Poland	332.0	57.0	275.0	1 036
Romania	730.0	343.0	387.0	719
Russian Federation [a]	1 300.0	..	1 300.0	..
Slovakia	140.0	60.0	80.0	303
Ukraine [b]	104.0	..	104.0	250
Total	**3 495**	**635.2**	**n2735. 1**	**4 192**

Sources: See country reports

Notes: The total small hydropower potential given for all countries (except the Russian Federation and Ukraine) is based on the estimated installed capacity by 2020.

a. The Russian Federation has a technical feasible potential of 350 000 GWh/year for plants up to 30 MW.[1]

b. Ukraine has planned 2,900 GWh/year.[1]

The total small hydropower installed capacity in the 10 Eastern European countries is approximately 2,735 MW (table 3). The largest country, the Russian Federation, has the highest installed capacity at 1,300 MW. The countries with the least hydropower capacity are Belarus and Republic of Moldova. The small hydropower potential is estimated to be over 3,495 MW (table 3) in the region.

In both the Russian Federation and Belarus the number of installed small hydropower plants used to be much higher, mainly for the purpose of rural electrification of remote areas but as the main electricity grid was developed, many of the plants were shut down due to the lack of economic incentive coupled with a lack of expertise for maintenance.[12]

The Stream Map project[iii] reveals that during the last 10 years new small hydropower potential has been greatly affected by the environmental legislation that falls under areas that are designated, such as EU Natura 2000, the EU Water Framework Directive and others. Environmental mitigation measures will add to the costs of electricity generation, limiting further the economic potential of small hydropower. These environmental limitations are imposed, for example, in Slovakia where only 38 per cent of economic feasible potential is realizable in the current situation.[13]

Note

i. The Visegrad Four, also known as the Visegrad Group or simply V4, reflects the efforts of the Central European countries to work together in a number of fields of common interest within the all-European integration.

ii. The feed-in tariff in Ukraine is usually called green tariff.

iii. The Stream Map project was co-funded by the Intelligent Energy Europe Programme of the European Commission. It aimed to define a clear and consistent roadmap in Europe for the small hydropower sector. The project was completed in 2012.

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4.1.1 Belarus

Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	9,643,566[1]
Area	207,600 km[2]
Climate	Moderate continental climate, with cool humid winters and warm summers[2]
Topography	Generally flat and contains much marshland
Rain pattern	Average annual rainfall of 600 mm to 700 mm. 70 per cent of the rain falls from April to October. Also 75-125 days of snow each year, with falls ranging from 150 mm to 300 mm.[2]

Electricity sector overview

As of 1 January 2012, the total installed electrical capacity of Belarus was 8,445 MW. The State Production Association, Belenergo, carries out the management functions and economic activities of the Belarusian energy system, and owns 7,936.8 MW of it; the remaining capacity is used by industrial (497.7 MW) and owned by independent private producers (figure 1).[3] Belenergo is the sole purchaser of all electricity, including imported electricity mainly from the Russian Federation, Ukraine and Lithuania.[4]

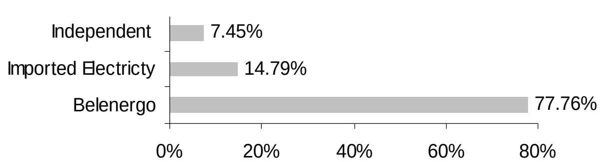

Figure 1 **Electricity generation in Belarus**
Source: Belenergo[3] and Index Mundi[5]

Small hydropower sector overview and potential

In the electricity generation system, there are 35 small hydropower stations with a total installed capacity of 15 MW (figure 2).[4]

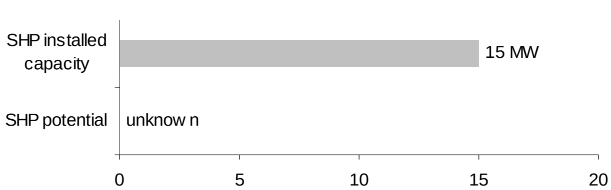

Figure 2 **Small hydropower capacities in Belarus**
Source: Gerasimov[4]

The potential capacity of all the watercourses in Belarus is 850 MW, of which technically available are 520 MW and economically viable 250 MW.[6] Reegle reports that hydropower resources in the country are scare, but there is potential for small hydropower plants in the Northern and Central parts of the country.[7]

In the past, water resources in Belarus were used for water-mills and saw-mills. Over 170 small hydropower plants with a total capacity of 20 MW were constructed from 1950 to 1960 (the largest is in Svisloch, with a capacity of 2.25 MW), but most of them were closed down during the development of a centralized energy system.[8]

Renewable energy policy

The 2004 Local Fuels Programme gave priority to expand the use of wood, peat, and hydropower resources for small-scale energy generation, as well as sustaining oil production. The wide-scale use of other renewable options such as wind, solar, and geothermal energy seem to be less attractive from an economic standpoint because of Belarus's geographical and geological conditions. This Programme set a target of nearly double of the power and heat production from renewable energy resources by 2012.[4]

The National legislation for renewable energy includes the Law (No. 204-3) on Renewable Energy Sources dated 27 December 2010, as well as the resolution of the Ministry of Economy No. 100 of 30 June 2011 'On tariffs on electricity produced from renewable energy sources'.[9] This covers hydro, wind, geothermal, wood and biogas.

The National programme, 'Development of domestic, renewable and nonconventional energy sources for 2011-2015' (No. 586) was approved by the Council of Ministers on 10 May 2011.[9] The state programme for the construction of hydropower plants (2011-2015, approved by the Regulation of the Council of Ministers of the Republic of Belarus of 17 December 2010 N1838) plans to construct and reconstruct 33 hydropower plants with a total capacity of 102.1 MW. The programme aims to improve the country's energy security by replacing fuel and energy imports with renewables and alleviate the environmental impact of the fuel and energy sector.[9]

The Belarusian Ministry of Energy has planned to build cascades of low head hydropower plants with an average capacity of relatively low flooding risks. The Government has approved the plan of 'Energy Security of Belarus' up to 2020. It calls for innovative approaches to ensure energy security and independence.[10]

Barriers to small hydropower development

The main small hydropower potential is in the Northern and Central parts of the country. The landscape of Belarus consists mostly of plains, so only low head power installations are operational.[11] In general, the future prospects in Belarus could see the construction of multiple-use waterworks facilities, such as reservoirs for the regulation of the water flow which are used for the electric power production, water supply, water transport, melioration[i] and water protection.[11]

The development of small-scale power generation by using hydropower calls for enacting policies to facilitate investments in this type of renewable energy. The most critical barriers to small-scale power generation in Belarus include low prices for competing fuels (namely natural gas); unfavourable power pricing rules; incomplete legal framework for independent power producers; and transmission access and interconnection requirements.[4]

Note

i. Similar to amelioration in the context of hydrological land improvements.

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4.1.2 Bulgaria

European Small Hydropower Association, Stream Map

Key facts

Population	7,037,935[1]
Area	110,879 km[2]
Climate	Temperate; cold, damp winters; hot, dry summers
Topography	Mostly mountains with lowlands in north and southeast
Rain pattern	Average annual precipitation is about 630 mm, of which 19 km^3 is runoff across the whole country (27.2%). Higher elevations, which receive the most rainfall in the country, may average over 2,540 mm per year. In the spring, 70% of the total water flow is available and in the summer only 7%.[2]

Electricity sector overview

The gross electric power generation in Bulgaria was 50,700 GWh in 2011.[3] Bulgaria is interconnected with Romania, Greece, Serbia, Macedonia and Albania for both electricity import and/or export.[4] Commercial export of electric power was 21 per cent of gross generation in 2011.[3] Details on electricity generation are given in figure 1.

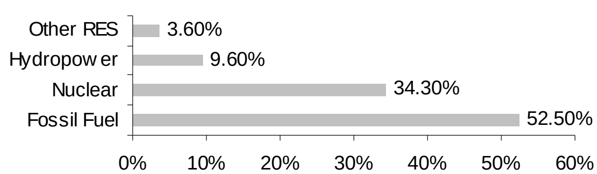

Figure 1 **Electricity generation in Bulgaria**
Source: Energy Regulators' Regional Association[4]

Small hydropower sector overview and potential

The small hydropower growth in Bulgaria has followed a steady upward trend over the past 10 years. In 2010, Bulgaria had 136 small hydropower plants and a total installed capacity of 263 MW (generating 630 GWh) providing 14.31 per cent of the electrical energy produced from renewable energy sources. By 2020, the aim is to have 200 small hydropower plants with a total installed capacity of 380 MW (1,050 GWh) (figure 2).[5]

Most small hydropower plants, according to their generating capacity, are privately owned (84 per cent), but the age of more than half of all small hydropower plants in Bulgaria is over 40–60 years.[6] The last small hydropower potential evaluation took place between 1998 and 2000 when the gross theoretical small hydropower potential was evaluated at 1,527 GWh/year. The technically and economically feasible potential is 755 MW and is able to generate 706 GWh/year. So far about half of the economically feasible potential (44.3 per cent) has been developed.[6]

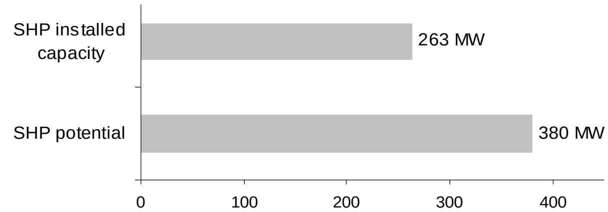

Figure 2 **Small hydropower capacities in Bulgaria**
Source: Stream Map[5]
Note: Potential is based on planned capacity by 2020.

Renewable energy policy

According to the National Renewable Energy Action Plan (NREAP), the country has targeted to meet 16 per cent of energy consumption through renewable sources by 2020.[7] The Energy from Renewable Sources Act (ERSA) is the statutory basis for its feed-in tariff (FIT), it is the main element of the Bulgarian support system. The FIT may not be granted in addition to other incentives. Other support includes subsidies for investment into renewable sources derived from the Operational Programme Development of the Competitiveness of the Bulgarian Economy - the European Regional Development Fund, and loans to participating banks, as part of the Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL).[8]

Legislation on small hydropower

In 2011, the Law on Energy from Renewable Sources came into force with the aim to promote renewable energy development in Bulgaria.[9] This law has been, however, criticized for introducing more restrictions to the renewable energy sector, increasing the development risk and ultimately discouraging investors.[10]

Residual flow regulations are planned and hydropower facilities will have to provide 1,700 Mm^3 water for irrigation and over 850 Mm^3 (cubic megametres) for industrial and potable water. A concession regime is applied for larger water abstractions. Compensation flow (CF) is set as a fraction of the long-term average flow or alternatively minimum mean flow. The losses in small hydropower electricity production resulting from maintaining CF are significant (>10 per cent). The EU Water Framework Directive is in the process of implementation and this may cause higher residual flow for small hydropower and an increase in their operating costs.

Barriers to small hydropower development

Environmental impact assessments are demanded in the small hydropower licensing process and must be carried out for all hydropower projects and for reservoirs with volumes exceeding 106 m^3. The small hydropower manufacturing industry is not well-developed and there is only one domestic turbine manufacturer.

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4.1.3 Czech Republic

European Small Hydropower Association, Stream Map

Key facts

Population	10,177,300[1]
Area	78,867 km[2]
Climate	Temperate; cool summers; cold, cloudy, humid winters
Topography	Bohemia in the west consists of rolling plains, hills, and plateaus surrounded by low mountains; Moravia in the east has very hilly landscape
Rain pattern	Most rain falls during the summer. The average precipitation is 680 mm.[2]

Electricity sector overview

The gross electricity production in the Czech Republic was 87,560 GWh in 2011 with one third of it coming from nuclear sources (figure 1).[3] A 2011's national energy policy draft states that there will be a major increase of nuclear power generation until 2060, to 13.9 GW or up to 18.9 GW in the case of major adoption of electric vehicles, with nuclear producing 60 per cent of the country's power.[4]

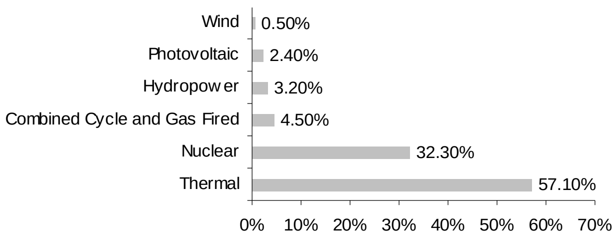

Figure 1 **Electricity generation in Czech Republic**
Source: Energetický regulační úřad[3]

Small hydropower sector overview and potential

The Czech Republic has already developed a major part of its small hydro potential. Nevertheless, systematic growth in installed capacity of 2.5 MW/year was observed in the last 10 years. In 2010, the Czech Republic had 1,452 small hydropower plants and a total installed capacity of 297 MW, generating 1,159 GWh per year (figure 2).[5]

Even faster growth (up to 372 MW in 2020) can be expected in this decade according to its National Renewable Energy Action Plan (NREAP). While this prediction may be considered fairly optimistic, the NREAP electricity generation estimation is rather conservative. By 2020, the aim is to have 1,645 plants with a total installed capacity of 340 MW (1,210 GWh).

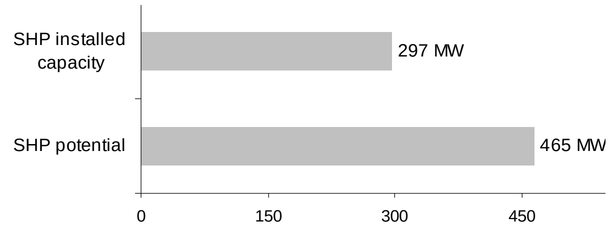

Figure 2 **Small hydropower capacities in Czech Republic**
Source: Stream Map[5]

In 2008, the total economically feasible small hydropower potential was calculated at 465 MW, which means the remaining economically feasible potential was 168 MW, not including the 43 MW planned small hydropower plants.[6]

Renewable energy policy

According to the National Renewable Energy Action Plan (NREAP), the renewable energy target by 2020 is 13.5 per cent of country's energy consumption,.[7]

Legislation on small hydropower

Support mechanisms for small hydropower in the Czech Republic reflect some economic aspects of the small hydro investment process and its significance for the grid.

There is an opt-in guaranteed tariff or green bonus scheme that depends on the time period since commissioning. According to the Act on Promotion of Electricity Production from Renewable Energy Sources, the electricity prices should aid in achieving a 15-year period of recovery of investment. In practice, the guaranteed tariffs range between 7.4 and 12 euro cents/kWh for run-of-river plants and between 5.7 and 15 euro cents/kWh for storage plants (with substantial differences between the peak and off-peak operation); respective values for green bonuses are 3.6 and 8 euro cents/kWh for run-of-river plants and between 2.6 and 9.6 euro cents/kWh for storage plants.[5]

The tariff is announced on an annual basis by the Energy Regulatory Office. Small hydropower plant operators that intend to offer electricity for purchase to the grid should notify the relevant grid operator in advance.

Electricity supply to the grid takes place according to a contract agreed between small hydropower plant operators and local grid operators. The regulatory role of small storage hydropower plants is acknowledged by differentiated energy prices in the grid load-peak and off-peak zones.

When setting the residual flow for small hydropower plants, minimum mean flow and hydro-biological parameters are taken into account. Typically, the residual flow is established to maintain naturally 355 days to 330 days per year.[5]

Investment projects are supported using the means of ECO-ENERGY Programme within the Operational Programme Enterprise and Innovations 2007-2013. Eighteen projects were supported in 2010 with the total amount of support over €11 million (approximately US$14.7 million in 2010) and the mean share of 35 per cent of the investment cost.

Barriers to small hydropower development

One of the main obstacles to small hydropower in Czech Republic is the costs of operation and maintenance, which pushes the price upwards. Renewable energy is considered as a complementary source of energy as the priority is given to solid fuels and nuclear energy. The use of renewable energy sources is ecological therefore its future and financial support depends on the preferences of the political parties in the Government.[8]

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4.1.4 Hungary

European Small Hydropower Association, Stream Map

Key facts

Population	9,958,453[1]
Area	93,028 km^2
Climate	Temperate; cold, cloudy, humid winters; warm summers
Topography	Mostly flat to rolling plains; hills and low mountains on the border with Slovakia
Rain pattern	The total mean annual precipitation is approximately 600 mm.[2]

Electricity sector overview

Hungary had a total installed capacity of 10,108.8 MW and a domestic gross electricity production of 35,984 GWh in 2011. Nuclear energy and natural gas dominate electricity generation (figure 1). Electricity exchange occurs with its neighbours particularly Slovakia, Ukraine and Austria but also Romania, Serbia and Croatia. In 2011, Hungary imported a total of 6,650 GWh electricity.[3]

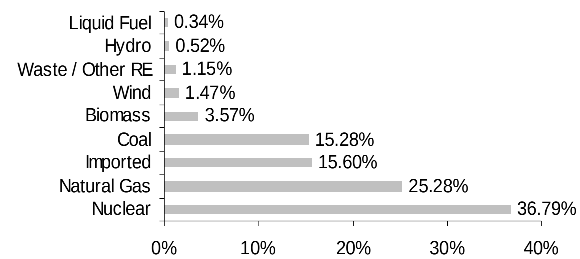

Figure 1 **Electricity generation in Hungary**
Source: Hungarian Energy Office [3]

Small hydropower sector overview and potential

Hungary is one of the less mountainous countries in Eastern Europe. Therefore it has limited hydropower potential and since the 1970s there have been only a few small hydropower developments. In 2010, Hungary had 36 small hydropower plants and a total installed capacity of 14 MW (generating 67 GWh per year). By 2020, the aim is to have 42 plants with a total installed capacity of 28 MW (generating 80 GWh).[4]

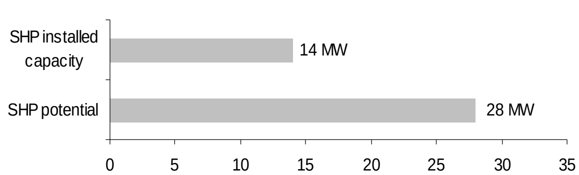

Figure 2 **Small hydropower capacities in Hungary**
Source: Stream Map[4]
Note: Potential is based on planned capacity by 2020.

Hungary's hydro resource potential is located on the Danube basin (66 per cent), the Tisza (10 per cent) and other rivers (24 per cent). It is estimated that only 5-6 per cent of the potential hydro energy can be developed. New hydropower projects consist primarily of small plants, with the possibility of re-using water from existing hydropower plants. Hungary's rivers exhibit a theoretical power of 990 MW, of which 7,446 GWh/year could be generated. On the small streams the theoretical production is 308 GWh/year. In the Renewable Energy Action Plan, Hungary supports smaller size plants (below 10 MW) mainly in the 100-500 kW range.

Renewable energy policy

The approved 2009/28/EC Directive on Renewable Energy sets binding targets on the share of renewable energy in gross final energy consumption. Hungary's renewable energy target is set at 13 per cent by 2020 (according to the EU), but the Hungarian Government is aiming for 14.65 per cent. There is no green certificate system in Hungary, the Government plans to introduce it in the long-term.

Legislation on small hydropower

Hungary has introduced a sustainable (non-central-budget-based) feed-in tariff (FIT) scheme guaranteed until 2020. The system was modified in favour of smaller hydropower plants and those providing remote heating in 2008. Tariffsare to be adjusted yearly in line with the inflation rate. There is a peak and off-peak FIT with the average tariff at around 9 euro cents/kWh x k (k = inflation rate).[4]

Barriers to small hydropower development

Hydropower has long been a much debated topic in Hungary. Plans to construct such facilities on a larger scale have been opposed by the incumbent coalition in the past. The Government still does not consider high-capacity hydropower a real option compared to other sources of energy. It claims that the topographic conditions of Hungary do not allow for favourable and economic utilization of hydropower.[4]

A large part of the country is on flat land, although there are some low hills. Rivers with high water output do not have marked drops in elevation either. In the Government's view, instead of constructing large dams, it is more feasible to establish small-scale hydropower generators (of which there are dozens). Mini hydropower plants with an output of less than 10 MW and turbines installed in river beds could provide energy-efficient solutions for smaller towns and rural areas. According to the Government, the establishment of only such smaller plants is in the national interest.

The development of hydropower plants in protected natural sites are of national importance; based on Annexes 1 and 2 to the Government Decree No 314/2005 (XII. 25), small hydropower development in these areas is conditional depending on outcome of environmental impact assessment and uniform environmental use authorization procedures.

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4.1.5 Republic of Moldova

Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	3,656,843[1]
Area	33,851 km[2]
Climate	Transitional between temperature and continental, with four distinct seasons[3]
Topography	Rolling steppe, gradual slope south to Black Sea[1]
Rain pattern	Total mean annual precipitation over 750 mm.[2]

Electricity sector overview

The electricity market in Republic of Moldova (hereafter Moldova) was formed in the period of 1997-2001 when the energy sector became subject to re-structuring and its main operators came into the market: an electricity transmission and central dispatch-enterprise called Moldtranselectro, several electricity distribution and supply companies, and the National Agency for Energy Regulation (ANRE). Currently, the Ministry of Economy and Commerce regulates the energy sector. The total installed electricity capacity of the Republic was 3,008 MW in 2011. Due to the insufficient capacity as well as the high generation cost, Moldova has to import a large share of its electricity consumption. In addition, because of the inflexibility of the Moldovan power plants (i.e. the limited size of quickly responding spare capacities), the electricity deficit is supplied by Ukraine.[3] ANRE reported that in 2011 domestic production was predominantly derived from fossil fuels (91 per cent) and 9 per cent from hydropower.[4]

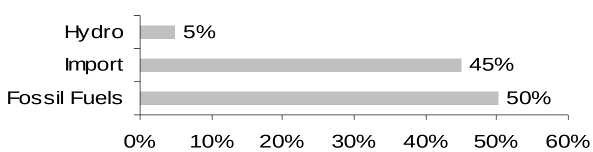

Figure 1 **Electricity generation in the Republic of Moldova**
Source: Energy Regulators' Assocation[4] and Indexmundi[5]

Small hydropower sector overview and potential

There are only two major hydropower plants in Moldova in spite of the large number of rivers. The largest is the Dubasari plant (48 MW) built in 1954 on Dniester, the most important river flowing to Moldova from Ukraine, and the second(16 MW) is located in Costesti on the Prut, it is also the second most important river in the country. Only 100 kW small hydropower is thought to be operating.

Moldova's small hydropower potential is 1,100 GWh/year. The Dniester River basin, the Prut and Danube river basin cover the majority of Moldova's territory, technically these represent the best areas for small hydropower development.[6] Under the Energy Strategy 2020, mini hydro stations with a capacity of 1.2 MW are planned to be built on the Raut river, close to the village of Tribujeni (Orhei district).[7]

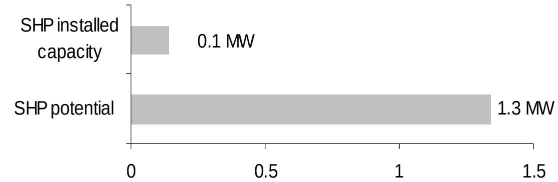

Figure 2 **Small hydropower capacities in the Republic of Moldova**
Source: United Nations Economic Commission for Europe[6]
Note: Potential is based on planned capacity by 2020.

Renewable energy policy

The Energy Strategy until 2020, which was approved in 2007, has objectives, measures and activities to improve the national energy industry, inter alia: improved energy efficiency, use of renewable energies, implementation of tariffs and improvement of energy security.[8] It foresees an increased share of renewable energy sources in the country's energy balance of up to 6 per cent in 2010 and 20 per cent in 2020.[6]

Efficient use of the existing biomass potential could fully supply Moldova's rural population with energy, using cereals, sugar sorghum and oil technical cultures - rape, sunflower, grape seeds from the wine industry.[7]

Barriers to small hydropower development

The main barrier for investments in small hydropower in the country is capital constraints; there are no national or municipal funds for improving energy efficiency or developing renewable energy projects. High interest rates of bank loans further prevent formation of a market for private companies involved in development of energy projects.[9]

So far, implementation of all renewable energy projects has been carried out by State institutions. The lack of public tendering processes has also hindered the formation of a competitive environment for private companies.[9]

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4.1.6 Poland

European Small Hydropower Association, Stream Map

Key facts

Population	38,415,284[i]
Area	312,685 km[2]
Climate	Temperate with cold, cloudy, moderately severe winters with frequent precipitation; mild summers with frequent showers and thundershowers[1]
Topography	Mostly flat plain; mountains along southern border
Rain pattern	Average annual rainfall is 583 mm, in most regions of the country it ranges between 500 mm and 600 mm. In smaller areas in the uplands and the mountains along Poland's southern border annual rainfall may reach as much as 800 mm to 1,500 mm; central Poland receives 450 mm to 550 mm, the coastal zone 500 mm to 600 mm. Two-thirds of annual rainfall occurs in the summer. Snow accounts for two thirds of winter (December to March) precipitation.[2]

Electricity sector overview

The Ministry of Economy is in charge of the power and energy sectors in Poland. The total energy generation of Poland in 2011 was 163,153 GWh from 37,327 MW capacity plants, with the majority derived from fossil fuel energy (figure 1). In 2009, the installed capacity of hydropower was a small part of the whole at 932 MW.[3]

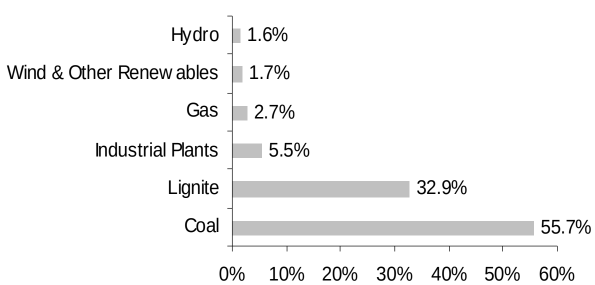

Figure 1 **Electricity generation in Poland**
Source: Urząd Regulacji Energetyki[4]

The Polish National Energy Conservation Agency (KAPE) supports the national sustainable energy policy expressed, for example, in the Constitution of Poland (the part concerning sustainable development); the Energy Law; Principles of Energy Policy by 2020; 2nd National Ecological Policy; Policy of Sustainable Development of Poland; and Development Strategy on Renewable Energy Sector.

Small hydropower sector overview and potential

In 2010 Poland had 722 small hydropower plants and a total installed capacity of 275 MW (generating 1,036 GWh per year). By 2020, the aim is to have 840 plants with a total installed capacity of 332 MW, generating 1,130 GWh (figure 2), while the total economic small hydropower potential with environmental constraints is 1,928 GWh.[5]

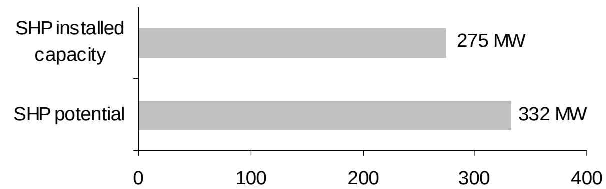

Figure 2 **Small hydropower capacities in Poland**
Source: Stream Map[5]
Note: Potential is based on planned capacity by 2020.

In the past two decades the average annual rise in small hydropower installed capacity was 6 MW. However, much slower growth has been observed since 2005. According to the information by the European Small Hydropower Association, plants with a total capacity of 30 MW are currently under construction or in the phase of advanced construction preparations. Unfortunately, some of them have remained in this state since the 1990s.[5]

It is worth noting that at the end of 2009 there were nine installations with valid electricity production concessions (with total capacity of 5 MW); while seven such concessions issued in 2010. In the coming years, small hydro development in the country will probably see better access to the dams owned by the State and development of technology enabling rational utilization of dams with head below 2 metres. At the beginning of the 1990s, the total hydropower potential was about 200 MW. Since then, small hydropower power plants with total capacity of 120 MW have been put in operation. Only a small fraction has been erected together with new dams. In general, erection of new dams proceeds slowly and encounters numerous obstacles.

In Poland, one of the benefits of small hydropower in developing electric power grid and especially in maintaining the country's electricity parameters in the surrounding areas is somehow rewarded through the reductions of grid connection charges. However, small hydropower plants in Poland are usually treated in the same way as other renewable energy plants with capacities up to 5 MW.

Renewable energy policy

According to Poland's National Renewable Energy Action Plan (NREAP), the renewable energy target by 2020 is 15.5 per cent, [6] The Energy Policy of Poland until 2030 calls for increased generation of electricity from both renewable and co-generation sources, the production mix will gradually diversify, with an increased share of renewable energy (particularly wind and biomass) and the construction of a first-ever nuclear power plant in Poland.[7]

Legislation on small hydropower

Current Polish law provides the following small hydropower related definition for residual flow (RF): 'residual flow is the minimum flow necessary to support biological life in a watercourse'. In practice, the determined residue flow is decided by a methodology set out by the Polish Institute of Meteorology and Water Management (IMGW). The IMGW has published renewable energy values for some Polish watercourses and these data are generally accepted by the water management authorities when assessing the drafts of water use concepts.[5]

A tradable green certificate system exists (6.4 euro cents/kWh on top of 5 euro cents/kWh for 'black' energy). The black energy price is announced annually by the Energy Regulatory Office (URE) based on the free market price from the previous year. URE also annually announces the replacement fee to be paid by energy enterprises having failed to cancel a sufficient number of certificates.

For renewable energy plants with capacity up to 5 MW, 50 per cent of realistic connection costs are covered and no concession charge is imposed on owners with capacity up to 5 MW. Grid impact assessment is required in case of renewable energy plants with capacity over 2 MW connected to the grid with rated voltage exceeding 1 kV.

Barriers to small hydropower development

The discussion on the future of small hydropower in Poland is occasionally affected by the opposition to any development of civil engineering infrastructure of Polish rivers. In 2009, such a discussion resulted in a memorandum demanding a moratorium on the erection of small hydropower plants in Poland; however, while the memorandum was supported by a number of institutions and media, no ban on small hydropower was implemented.[5]

In the past, it was discussed that large heat power plants co-firing biomass with traditional fossil fuels have appeared to be the main beneficiary of the current green certificate system. Changes in the support mechanisms are proposed in the draft of the Renewable Energy Sources Promotion Act, currently under preparation by the Ministry of Economy. New regulations may appear highly unfavourable for large hydro, but are not expected to harm the small hydropower sector.

Only moderate development of the small hydropower sector may be expected if no far going changes in state policy are introduced. New low-head technologies will barely be compensated for deficit in economically attractive sites.[5]

The key recommendations for policymakers in order to overcome the barriers identified include:[5]

- Development of a national programme of harnessing the hydropower potential.
- Continuation of the process of giving access to the state owned dams to the hydropower investors and starting erection of new multitask installations within the framework of partnership between water management authorities and hydropower investors.
- Introducing regulation redirecting the incomes resulting from green certificates in state-owned hydropower plants to support investments within the sector.

Note

i. Census as of 31 March 2011.

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4.1.7 Romania

European Small Hydropower Association, Stream Map

Key facts

Population	21,848,504[1]
Area	238,391 km[2]
Climate	Temperate; cold, cloudy winters with frequent snow and fog; sunny summers with frequent showers and thunderstorms
Topography	Central Transylvanian Basin is separated from the Moldavian Plateau on the east by the Eastern Carpathian Mountains and separated from the Walachian Plain on the south by the Transylvanian Alps
Rain pattern	Total average precipitation is over 750 mm.[2]

Electricity sector overview

The Romanian electricity market was fully liberalized in 2007.[3] The Regulatory Authority for Energy (ANRE) regulates, monitors and controls the operation of the energy sector, electricity and natural gas markets under competition, transparency, efficiency and consumer protection. It implements and monitors measures of national energy efficiency and promotes the renewable energy use of end consumers. Total electricity production in the country was 60,385 GWh in 2011, 1,036 GWh of electricity was imported and 2,942 GWh were exported. Hydropower represents around 27 per cent of electricity generation (figure 1). Due to a major drought that impacted hydropower production, in October 2011, the force majeure clause was activated upon contractual hydro energy obligations.[4]

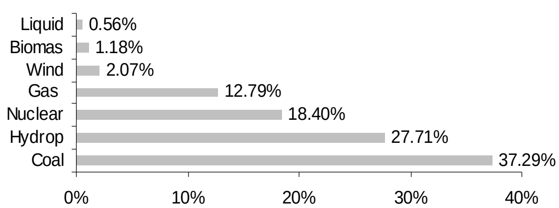

Figure 1 **Electricity generation in Romania**
Source: Autorităţii Naţionale de Reglementare în domeniul Energiei[4]

It should be noted, that nearly 3,000 MW of thermal generation capacity has been decommissioned during the past six years and that further decommissioning is expected due to modernization requirement by the European Union.[5]

Small hydropower sector overview and potential

In 2010, Romania had 274 small hydropower plants and a total installed capacity of 387 MW generating 719 GWh per year (see figure 2). By 2020, the aim is to double the number of plants to nearly 550 plants with a total installed capacity of 730 MW (generating 1,360 GWh).[6]

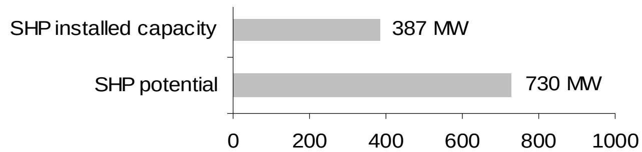

Figure 2 **Small hydropower capacities in Romania**
Source: Stream Map[6]
Note: Potential is based on planned capacity by 2020.

Micro hydropower potential is reported to be distributed throughout Romania in four out of eight regions (i.e. Moldavia, Carpathian Mountains, Transylvania and Sub Carpathians).[3]

Renewable energy policy

The renewable energy target by 2020 is 24 per cent, according to its National Renewable Energy Action Plan (NREAP).[7] A tradable green certificates system exists to promote new renewable energy, particularly hydropower with capacity ≤10 MW, wind energy, biomass, biogas, biofuels, geothermal energy as well as solar energy.[3]

Legislation on small hydropower

The residual flow is imposed by the Ministry of Environment and Forests through its administration the Romanian Waters National Association (ANAR) for each site in the permit of water use. As a common requirement, the reserved flow is imposed to be greater than 10 per cent of the mean flow.[6]

The support scheme is built on mandatory quotas combined with tradable green certificates. For the green electricity produced by small hydropower plants, there are three options to be sold; by bilateral contracts at negotiated prices, on the day-ahead market or to distribution companies at a regulated price which is about €31/MWh with prices in the range of €27-€55 until 2014 and with a minimum guaranteed price of €27 for the period 2015 to 2030.[6]

Small hydropower therefore receives green certificates (GC) according to the following scheme:

- 3 GC/MWh for new plants for 15 years.
- 2 GC/MWh for refurbished plants for 10 years.
- 0.5 GC/MWh for old plants for 3 years.

Barriers to small hydropower development

In Romania, the media is portraying small hydropower as having a negative impact on the environment, leading to low public support and social acceptance for small hydropower development.[6]

The Renewable Energy Framework Directive pushes forward the development of small hydropower. But at the same time, the Water Framework Directive imposes the environmental flow from defining water body statuses and protected areas which could produce a loss in energy at some sites or completely block some small hydropower development. The harmonization of the two Directives remains one of most important goals of the Romanian Government.[6]

For new projects, the developer must have an environmental impact assessment in order to obtain the environmental permit which stipulates all the demands in respect of the environment to be fulfilled by the small hydropower developer.

Stream Map recommends the creation of a 'one-stop shop' for small hydropower investors as well as more cooperation among the Ministry of Environment and Ministry of Economy, Commerce and Business Environment, respectively Romanian Waters National Administration and Hidroelectrica, when issuing new laws, decisions, regulations and for the re-evaluation of the small hydropower potential for all rivers.[6]

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4.1.8 Russian Federation

Pascal Hauser and Lara Esser, International Center on Small Hydro Power

Key facts

Population	141,750,000
Area	17,098,242 km[2]
Climate	Russia is located within four climatic zones: Arctic, sub-Arctic, moderate, and subtropical.[2]
Topography	Broad plain with low hills west of Urals; vast coniferous forest and tundra in Siberia; uplands and mountains along southern border regions[1]
Rain pattern	Annual precipitation decreases from the west to the east, although this trend is complicated by a relief influence. In the European part annual precipitation exceeds 700 mm, reaching 800 mm and more on the highlands. In West Siberia, the amount ranges between 550 mm and 700 mm. To the north, the precipitation decreases to 550 mm to 600 mm on the Baltic Seashore, and to 400 mm to 500 mm on the Kara Seashore. To its south, the precipitation decreases to 500 mm near the Sea of Azov, and to 300 mm on the Low Volga River.[2]

Electricity sector overview

The Ministry of Energy of the Russian Federation (hereafter Russia) reported that the country has about 600 power plants with unit capacities over 5 MW. The total installed capacity of power plants in Russia on 1 January 2012 was 218,145.8 MW, an increase of 4,817.3 MW compared to 2011 through the construction of new energy facilities and upgrading of existing facilities. The installed capacity of the existing fleet of power plants by type of generation is as follows: 68.4 per cent thermal power plants, 20.3 per cent hydropower, and about 11.1 per cent nuclear power. Annual production of electricity in 2011 was 1,019,400 GWh (figure 1).[3 4]

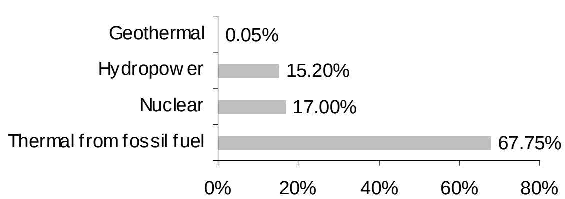

Figure 1 **Electricity generation in Russian Federation**
Sources: Ministry of Energy[3 4 5]
Note: Thermal excludes geothermal.

In 2002, the Russian Government began one of the most ambitious electricity sector reforms to meet substantial electricity sector investment requirements over the next two decades.[6] The main goal was and still remains to be the upgrading of ageing and outdated heating and electricity infrastructure. The restructuring involved the separation and privatization of the generation, transmission and sales companies. The transmission grids were brought under regulatory supervision, although the rest were mostly under state control.

Power generation was divided into seven wholesale generating companies, called OGKs, including RusHydro, 14 territorial generating companies (TGKs - Territorial'naya generiruyushchaya kompaniya), independents and state-owned entities. The OGKs contain power plants and specialize mainly in electric power generation. The TKGs contain predominantly combined heat and power plants, The gradual liberalization of the wholesale electricity market was completed in January 2011 and now allows producers to charge electricity at market prices.[7]

Hydropower plants provide system services (e.g. frequency, power) and are a key element in ensuring the system reliability of the country's Unified Energy System, having more than 90 per cent power reserve adjustment and are able to rapidly increase production to cover peak loads. A programme is being implemented to construct pumped storage plants that are needed for daily regulation of grid systems.

RusHydro has three design institutes and two research institutes, consolidating all of Russia's existing research and design organizations in the hydropower sector. It is developing many renewable energy projects to utilize tidal energy, geothermal energy and small hydropower.[8]

Small hydropower sector overview and potential

Russia's first hydropower plant was built in Altai on River Berezovka in 1882. The four-turbine plant had a capacity of 180 kW, generating electricity for the bilge pumps at a mine. The development of small hydropower in Russia occurred in two different stages: from 1919 to 1945, about 950 small hydropower plants were built, with an average capacity of 35 kW and a total installed capacity of 32 MW, serving one or several collective farms. From 1945 to 1969, hundreds of larger, state-owned hydropower plants were built, operating in local power systems, with capacities ranging from 1 kW to 10 MW.[9] Technically feasible potential for hydro plants of up to 30 MW has been assessed and determined to be 350,000 GWh/year.

As more and more rural residents got connected to the main electricity grid, construction of small hydropower plants stopped and many were shut down, mainly because they could not compete with the low electricity prices, due to, among other reasons, poor design and the lack of skilled workers. In 2010, Russia had only about 300 small hydropower plants left, with a capacity of 1,300 MW, although the rising electricity prices make their construction and operation more and more attractive.[9] About the same amount of small hydropower is realistically developable in the medium term, exact figures are not available at the moment (figure 2).

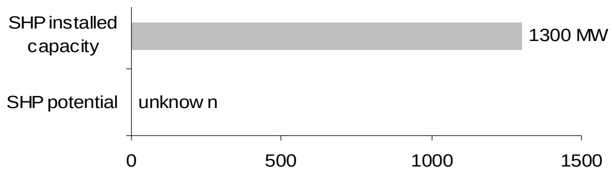

Figure 2 **Small hydropower capacities in Russian Federation**
Source: Enov[9]

Russia accounts for about nine per cent of the world's water resources so the availability of hydropower resources in Russia ranked second highest in the world, surpassing the United States, Brazil and Canada. To date, the total theoretical hydropower potential is 2,900,000 GWh of annual electricity, but the country now only utilizes 20 per cent of this potential. One of the barriers to the developing hydropower is the remote locations of potential sites and distance from the main electricity consumers, which are concentrated in central and eastern Siberia and the Far East.[5]

Renewable energy policy

The Russian Government has published a decree called 'On the Main Trends of National Energy Policy aimed at Increasing the Energy Efficiency of Electric Power Generation through the Use of Renewable Energy Sources during the Period up to 2020'. Renewable energy sources include small hydropower, wind, tidal, geothermal and thermal power using biomass with an aggregate installation of 25 GW until 2020.[10] The aim is to increase the share in electricity generation from renewable energy from 1-4.5 per cent in 2020 with 80 per cent of electricity stemming from small hydropower. Including large hydro (above 25 MW) the target is 19 – 20 per cent.[11] For this purpose, a Small Hydropower Association was created with the approval of the Ministry of Energy, uniting different institutions and aiming for the involvement of Russian and foreign investors as well as specialists.[9]

Barriers to small hydropower development

The main obstacle to small hydropower development in Russia is the lack of long-term financing for construction projects, partly due to the long payback time, but also because of the long process of land allocation and the difficulty in obtaining approvals.[9] In addition, Russia remains dependent on its traditional and still relatively cheap energy sources (oil and gas) and incentives schemes such as subsidies are scarce.[12]

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4.1.9 Slovakia

European Small Hydropower Association, Stream Map; Jana Imrichova, United Nations Industrial Development Organization

Key facts

Population	5,483,088
Area	49,036 km²
Climate	Temperate; cool summers; cold, cloudy, humid winters
Topography	Rugged mountains in the central and northern part and lowlands in the south
Rain pattern	The total average precipitation is about 740 mm.[2]

Electricity sector overview

In 2011, Slovakia produced 28,135 GWh and imported 727 GWh more electricity than it exported (from neighbouring countries).[3] The energy mix of Slovakia is very heterogeneous with the majority covered by two nuclear plants, followed by gas and fossil fuels and finally renewable sources (figure 1).

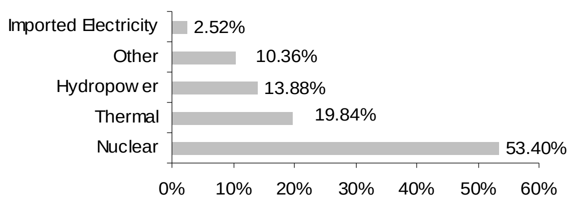

Figure 1 **Electricity generation in Slovakia**
Source: Slovenskej elektrizačnej prenosovej sústavy[3]

At the national level, Slovenské Elektrárne is the biggest electricity provider with coverage of 82 per cent of the country's generation market. It is the main supplier of electricity for the three biggest regional distribution companies in Slovakia (ZSE, Západoslovenská energetika, SSE, Stredoslovenská energetika and VSE, Východoslovenská energetika) and also supplies electricity to large businesses.[4] Due to the closure of some nuclear reactors, the country has gone from being net exporter to net importer of electricity.

Small hydropower sector overview and potential

In 2010, Slovakia had 279 small hydropower plants and a total installed capacity of 80 MW, generating 303 GWh per year (figure 2). By 2020, the aim is to have 380 plants with a total installed capacity of 140 MW generating 443 GWh. Among the existing hydropower plants, an installed small hydro capacity of 32 MW is privately owned. Sixty MW is planned over next 10 years. Most small hydropower planned is located on rivers Hron and Vah.[5]

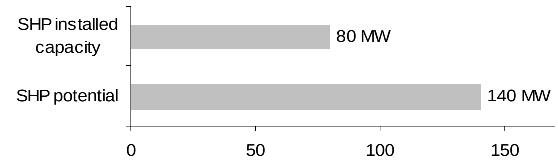

Figure 2 **Small hydropower capacities in Slovakia**
Source: Stream Map[5]
Note: Potential is based on planned capacity by 2020.

Up to the end of the last ruling Government, there had not been sufficient support from the State for small hydropower as 50 per cent of the renewable energy sources support was directed to solar power plants, causing an unprecedented boom (480 MW in photovoltaic plants) and a significant rise in electricity prices. This widely criticized policy was abandoned by the new Government and better times for small hydro are expected.[5]

The following relevant strategic documents have been issued since 2007:[5]

- The strategy for Higher Use of Renewable Energy Sources in the Slovak Republic, Ministry of Economy of the Slovak Republic, dated 4 April 2007.
- The Strategy of Energy Security of the Slovak Republic (Resolution No. 732/2008).
- Act of 19 June 2009 on the Promotion of Renewable Energy Sources and High-efficiency Cogeneration and on amendments to certain acts, Coll. Acts of Law, 309/2009.
- National Action Plan on Renewable Energy Sources of the Slovak Republic, (Resolution No. 677/2010).
- The Concept of Utilizing the Hydropower Potential of Water Courses of the Slovak Republic until 2030.
- Resolution No. 178/2011 of the Slovak Republic. The significance of this last document is to be emphasized as it represents a detailed inventory of all existing and planned plants with their main parameters and assessment of environmental constraints included.

The Government is committed to achieve the 2020 target using the hydropower sector as a significant component of the renewable energy mix. This commitment can be clearly seen in the hydropower development master plan – a highly competent and comprehensive document developed by the Research Institute of Water Management which was recently adopted by the Slovak Government as a National Policy Strategic Act (Resolution No. 178/2011). It can be seen from this and other official documents that the plans for further large hydro development on the Danube and Váh rivers are consequently supported and small hydro is ever more welcome.[5]

Renewable energy policy

Slovakia has encouraged renewable projects by offering tax incentives and keeping current feed-in tariffs relatively low. The renewable energy target of Slovakia by 2020 is 14 per cent of energy consumption, according to its National Renewable Energy Action Plan (NREAP).[6] The electricity from renewable sources is promoted through a feed-in tariff, based on the Renewable Energy Sources Act No. 309/2009 (Act on the Support of Renewable Energy Sources). In December 2010, the Slovak Parliament adopted an Amendment to the Renewable Energy Sources Promotion Act. Effective of 1 February 2011, only solar rooftop facilities or solar facilities on the exterior wall of buildings with capacity not exceeding 100 kW are promoted in the form of additional payment on a feed-in tariff after the Amendment to the Act.[7]

Legislation on small hydropower

Small hydropower plant owners enjoy additional payment for electricity supplied within the period of 15 years from putting the facility into operation or from the year of reconstruction or upgrade of a technological part of the facility. The energy price resulting from additional payment is calculated as a percentage of the base price announced by the Regulatory Office of Network Industries (URSO). The typical value of the base price is 6-11 euro cents/kWh depending on plant capacity. URSO establishes the price individually for each facility based on the submitted proposal, taking into account various factors, including time passed since the re-commissioning and investment assistance have been granted. The support is granted in full value in for power plants with capacity up to 10 MW. In case of higher capacities, the additional payment is granted for electricity production from the 10 MW.

Barriers to small hydropower development

The small hydropower sector in this country is relatively weak compared to large hydro. There is also no representation of the small hydropower sector in Slovakia although some efforts to establish a national association have been reported by the Hydropower Association of the Czech Republic.[5]

Small hydropower projects with capacity over 5 MW; dams with leveling height of over 3 metres as well as reservoirs of sufficiently high volume capacity or free surface area may be subject to an EIA or ascertaining procedure. In case of erecting a small hydropower plant without changes in the civil engineering structures, water authority consent is sufficient. If the installed capacity exceeding 1 MW, a declaration of project compatibility with the long term energy policy concept is required.[5]

In the past few years, there has been stronger opposition against further development of cascades at some rivers.[5]

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4.1.10 Ukraine

Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	44,854,065[1]
Area	603,550 km[2]
Climate	Temperate continental; Mediterranean only on the southern Crimean coast; precipitation disproportionately distributed, highest in west and north, lesser in east and southeast; winters vary from cool along the Black Sea to cold farther inland; summers are warm across the greater part of the country, hot in the south.[1]
Topography	Most of Ukraine consists of fertile plains (steppes) and plateaus, mountains being found only in the west (the Carpathians), and in the Crimean Peninsula in the extreme south.[1]
Rain pattern	Rainfall is unevenly distributed, with more precipitation in the north and west due to the influence of the Carpathian Mountains. Regular snowfalls between October and April.

Electricity sector overview

In 2011, the total electricity production in Ukraine was 193,899 GWh with a total installed capacity of 53,490 MW. Ukraine exported electricity to Russia, Belarus, Moldova, Hungary, Slovakia and Romania, increasing its electricity exports to 6,430 GWh.[2] The bulk of electricity generation is based on fossil fuel and nuclear power plants (figure 1). The Ministry of Fuel and Energy manages the energy sector. UkrhydroEnergo is the main generating utility managing hydro plants.

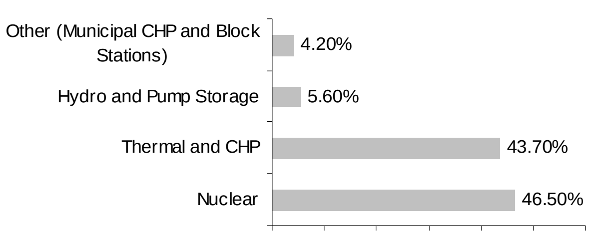

Figure 1 **Electricity generation in Ukraine**
Source: Ministry of Energy and Coal Industry of Ukraine[3]

Small hydropower sector overview and potential

Ukraine has a total of over 4,700 MW hydropower capacity, the majority being large hydro stations, eight of them on the Dnipro River with a total capacity of 3,907 MW and one on the Dnister River with 700 MW.[4] Ukraine's economically feasible hydro-energetic potential is 16,300 GWh, the big rivers' potential now being almost fully developed.

Around 64 small hydropower plants (capacity less than 10 MW) were operating in 2011, with a total capacity of more than 104 MW, generating around 250 GWh/year (figure 2).[5] There are also about 100 small hydropower stations that are not operational but could be restored.[4] The potential of small rivers in Zakarpatska, Lvivska and Chernivetska Oblasts is barely used, over 10 Ukrainian as well as foreign companies have expressed the desire to build small hydropower plants in Ukraine.[5] [6] Small hydropower potential is estimated at 2,900 GWh/year. Plans are there to develop small hydropower on Tissa river in the Carpathian mountains.

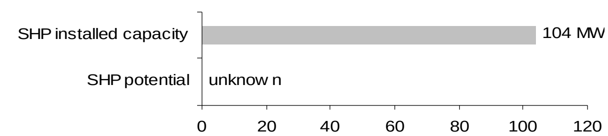

Figure 2 **Small hydropower capacities in Ukraine**
Source: Interfax[5]

Ukraine has a major hydropower resource in its nearly 63,000 small rivers; they totalled up to 28 per cent of the country's total hydropower potential. Developing mini hydropower would encourage the decentralization of the country's energy system and resolve the problem of providing power in hard-to-reach rural areas. For instance, in western Ukraine, micro-, mini- and small-hydropower plants could become the main source of power supply. Main direction for further hydro development will be the rehabilitation of existing hydro plants.

Renewable energy policy

The Ukrainian Government has launched various programmes to develop the use of renewable energies, for example the Energy Strategy presented in 2006, has included an improvement of the security of energy supply and a reduction in energy consumption.[7] This was updated in mid-2011 and again in 2012, where the role of nuclear power was emphasized with 5,000 MW to 7,000 MW of new nuclear proposed by 2030.[8] A law on a green tariff was adopted in 2008. It applies to electricity produced from renewable energy sources, including small hydropower but excluding blast furnace gas, coke oven gas.[4]

Barriers to small hydropower development

Small hydropower needs little capital input and provides both cheap and ecologically clean energy. However, it is not being developed in Ukraine at the moment because the Government is not offering any support.[9]

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4.2 Northern Europe

European Small Hydropower Association, Stream Map

Introduction to the region

There are 18 countries or territories located in Northern Europe and small hydropower is used in 10 of these countries (see table 1). Eight of these countries are European Union (EU) Member States, Iceland and Norway are not members. Within this region, there are further eight islands / territories that do not use small hydropower, namely Åland Islands, Channel Islands, Faeroe Islands, Guernsey, Isle of Man, Jersey, Sark, Svalbard and Jan Mayen Islands.

Table 1

Overview of countries in Northern Europe

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Denmark[ac]	5.54	13	100	12 339	38 790	9.3	21
Estonia[ac]	1.27	31	99	2 258	12 960	8.2	30
Finland[a]	5.26	15	100	16 372	83 090	3 100.0	12 764
Iceland[a]	0.31	7	100	2 579	17 059	1 883.0	12 283
Ireland[d]	4.72	38	100	9 130	27 258	249.0	725
Latvia[abc]	2.19	32	..	2 470	3 569	1 500.0	3 520
Lithuania[a]	3.53	33	..	3 811	12 270	129.0	400
Norway[ae]	4.88	21	100	31 438	124 360	29 973.0	117 900
Sweden[a]	9.10	15	100	35 701	129 400	16 200.0	65 300
UK[ac]	63.05	20	100	90 208	346 000	1 649.0	5 694
Total	**99.85**	**-**	**-**	**206 306**	**794 756**	**54 700.5**	**218 637**

Sources:

a. International Journal on Hydropower and Dams[1]

b. Central Statistical Bureau of Latvia[2 3]

c. World Bank[4]

d. Indexmundi[5]

e. Norwegian Water Resources and Energy Directorate[6]

Note: UK - United Kingdom. Estonia's electrification rate is from the year 2000.

The climate in Northern Europe is impacted by the Gulf Stream and in those areas it is mostly temperate due to the maritime influence. In the Nordic States the climate is characterized by more Arctic influences with cold and snowy conditions in the northern areas of Finland, Sweden, Norway and particularly Iceland. This area is defined by the surrounding volcanic islands, mountainous environments and a diverse range of vegetation.

The national power systems of Denmark, Sweden, Norway and Finland are already interconnected and there are also interconnectors linking these countries with Germany, Poland, Estonia, Russia and the Netherlands. Additionally, the United Kingdom of Great Britain and Northern Ireland (hereafter the United Kingdom) has interconnectors with France and the Netherlands. Within the country, Northern Ireland is interconnected with Scotland over the Moyle interconnector. Since 2012, the East-West interconnector now links the electricity grids of Ireland and the United Kingdom.[7]

Small hydropower definition

The 10 countries in Northern Europe apply various small hydropower definitions as shown in table 2.

Table 2

Classification of small hydropower in Northern Europe

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*	*Pico (kW)*
Denmark [a]	..			
Estonia [a]	up to 1			
Finland [a]	1-10	0.1-1.0	10-100	up to 10
Iceland [b]	0.3-1.0	0.1-0.3	up to 100	
Ireland [a]	up to 10			
Latvia [a]	up to 2			
Lithuania [a]	up to 10			
Norway [a]	1-10	0.1-1.0	up to 100	
Sweden [a]	up to 1.5			
United Kingdom [a]	up to 5			
ESHA and EC [c]	1-10	0.1-1.0	5-100	up to 5

Sources:

a. European Small Hydropower Association[9]

b. Mannvit[10]

c. European Commission[11]

Notes: ESHA – European Small Hydropower Association, EC – European Commission

Regional overview and potential

All 10 countries of the region use small hydropower with a wide range of contribution to their national grids. Both Norway and Sweden experience the highest small hydropower capacities in Northern Europe and both are heavily dependent on (large) hydropower as a source of energy. Their small hydropower contribution is small. Despite this, Sweden has no plans to further develop the number of small hydropower plants; instead, Sweden is aiming to upgrade its current plants. Conversely Norway's motivation to further develop small hydropower is suppressed by drawbacks in procuring grid connections and obtaining licences for the various stages of implementation.

Finland has over achieved its 2020 renewable targets and has a mature small hydropower sector. Recently, financial support for new plants has been withdrawn, leading to a significant decline in the development of new plants.

Denmark's self-sufficient energy approach by the use of renewable technology is commendable. Due to the mature nature of the renewable energy sector of the country, the hydropower potential has been fully developed with further development suppressed by lack of developable sites. In Estonia, strong dependence on thermal energy and a lack of legal motivation for renewable energy has hindered the interest in small hydropower, but nevertheless Estonia aims to increase its use of small hydropower by 2020.

Lithuania is reliant on electricity imports to supplement its energy demand. So it has a strong incentive to support renewable energy, including the use of small hydropower, in order to attain greater self-sufficiency by 2020. Large hydropower dominates the energy sector of Latvia but at the same time there is public support for the use and future development of small hydropower plants.

The United Kingdom is using small hydropower to help meet its targets set for 2020, but the realization of small hydropower is slowed down by strong public concern for perceived environmental concerns related to hydropower.

Ireland has the opportunity to convert abandoned old mills into small hydropower sites. However many of these sites are in non-favourable locations. Nevertheless, there is a large amount of untapped small hydropower potential and a general acceptance of the technology. Iceland benefits from precipitation favourable for small hydropower and a mature and developed hydropower sector. However, the awareness of small hydropower is at a minimum due to the more significant attention paid to the development of large hydro schemes.

The total installed small hydropower capacity is currently more than 3,643 MW in Northern Europe. Norway and Sweden lead with over 1,000 MW each, in contrast to low lying countries such as Denmark, Estonia and Lithuania that have the lowest hydropower capacities in the order of 10-30 MW each. Finland and the United Kingdom are in the middle with a potential of 200-300 MW each (table 3).

Data on the technically feasible potential of remaining small hydropower capacity was not available for any country except for Norway which has a remaining potential of about 200 GWh/year. The small hydropower potential that could be economically feasible with some plans laid down in each country is estimated to be about 141 MW, with over half of this located in the United Kingdom (table 3).

The European Small Hydropower Association (ESHA) Stream Map[i] reports a need for State administrations to compile the figures on their small hydropower potentials and to keep them up to date, since the National Renewable Energy Action Plans (NREAPs) do not always provide figures on the number of hydropower facilities (large, small or micro), which are intended to be constructed by the Member States in the coming years.[8]

Table 3

Small hydropower up to 10 MW in Northern Europe

Country	*Potential (MW)*	*Planned (MW)*	*Installed capacity (MW)*	*Annual generation (GWh)*
Denmark	9.3	0	9.3	28
Estonia	9.0	1	8.0	30
Finland	305.0	3	302.0	1 314
Iceland	at least 25.0	..	25.0	169
Ireland	60.0	18	42.0	160
Latvia	35.0	9	26.0	69
Lithuania	40.0	11	29.0	93
Norway	at least 1 778.0	..	1 778.0	7 600
Sweden	1 230.0	36	1 194.0	4 571
United Kingdom	350.0	80	230.0	800
Total	**3 841.3**	**158**	**3 643.3**	**14 834**

Sources: See country reports and Stream Map[8]

There are different challenges for the development of small hydropower across the region; for example in

Finland, the recently suspended support for small hydropower plants has resulted in a six-fold reduction of the economically feasible potential from 1,200 to 200 GWh/year).

The Stream Map[i] reveals that during the last 10 years new small hydropower potential has been greatly affected by environmental legislation, especially sites located in designated areas, such as Natura 2000, and the EU Water Framework Directive (WFD) among others. Environmental mitigation measures will add to the cost of electricity generation by small hydropower. Strong environmental requirements are imposed for example in the Baltic States (e.g. in Lithuania) with even higher requirements identified in the United Kingdom. Clear recommendations are needed for Denmark, Finland and Sweden on how to interpret the EU Renewable Energy Directive 2009/28/EC and the WFD Directive that appears to be contradictory.[8]

Note

i. The Stream Map was co-funded by the Intelligent Energy Europe Programme of the European Commission. It aimed to define a clear and consistent roadmap in Europe for the small hydropower sector. It was completed in 2012.

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4.2.1 Denmark

European Small Hydropower Association, Stream Map

Key facts

Population	5,543,453[1]
Area	43,094 km[2]
Climate	Temperate; humid and overcast; mild, windy winters and cool summers[1]
Topography	Low and flat to gently rolling plains[1]
Rain Pattern	The average annual precipitation over land is 712 mm but varies greatly from year to year and from place to place. On average, it rains most in the central parts of Jutland with over 900 mm and least in the Kattegat and Bornholm with some 500 mm.[2]

Electricity sector overview

Denmark was the only energy self-sufficient country in the European Union in 2011 with 40.7 per cent of electricity coming from renewable energy sources (figure 1).[3] [4] Wind is the most important renewable energy source in Denmark. Operation of the second largest hydropower plant (Karlsgårdeværket) has been suspended until 2016 to allow wetlands restoration. Thermal power stations provide heat simultaneously for some district heating networks (i.e 76.3 per cent of district heating is produced by combined heat and power plants).[5]

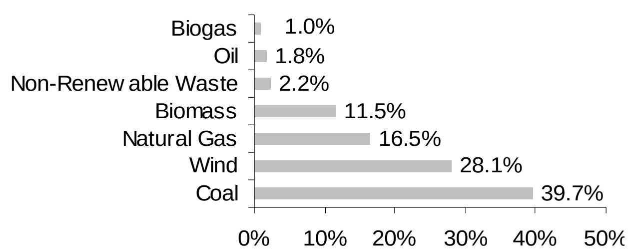

Figure 1 **Electricity generation in Denmark**
Source: Danish Energy Agency[5]

Small hydropower sector overview and potential

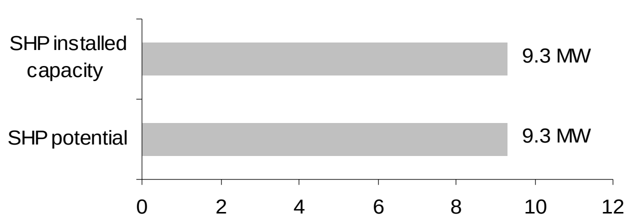

Figure 2 **Small hydropower capacities in Denmark**

In 2010, Denmark had 35 small hydropower plants with a total installed capacity of 9.3 MW (28 GWh/year). Due to environmental constraints, no further hydropower potential is available, the aim is to maintain the number of already installed plants.[6]

Renewable energy policy

The new Danish Energy Agreement for 2020 includes the following targets: more than 35 per cent renewable energy in final energy consumption, 50 per cent of electricity consumption to be supplied by wind power and gross energy consumption reduced by 7.6 per cent in relation to 2010.[4] For 2050, the consumption target is 100 per cent renewable energy in the energy and transport sectors. Electricity production from renewable resources is supported through price premiums and fixed feed-in tariffs. There is a high level of certainty about future support as the support scheme applies to the normal lifetime of the plant.

Legislation on small hydropower

There is support available for hydropower stations of less than 10 MW through the Promotion of Renewable Energy Act (No. 1392 of 27 December 2008).[7] The economic support scheme for small hydropower is the feed-in-tariff of approximately 8 euro cents/kWh. The additional charge for electricity generated by hydropower cannot exceed DKK 1.5 million annually (about US$263,000), from Articles 47 and 48 of the Law on Renewable Energy.[6]

Barriers to small hydropower development

Residual flow requirements are judged individually for each project.[6]

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4.2.2 Estonia

European Small Hydropower Association, Stream Map

Key facts

Population	1,274,709[1]
Area	45,228 km^2
Climate	Maritime; wet, moderate winters, cool summers[1]
Topography	Marshy, lowlands; flat in the north, hilly in the south[1]
Rain pattern	The annual average precipitation varies between 550 mm and 800 mm. As a rule, the coastal zone receives less rainfall than the inland areas. Areas with the highest precipitation are located on the uplands and at a distance of 30–60 km from the western coast.[2]

Electricity sector overview

Electricity production in Estonia is concentrated on oil shale (89.25 per cent in 2011, figure 1).[3] In 2007, only 1.75 per cent of gross consumption of the country was covered by renewable energy.[4] By 2011, it was 10.75 per cent.[3] The electricity market is scheduled to open up in January 2013 and the price will be determined by a market system based on the competition of several electricity sellers.[5] Estonia both imports and exports electricity to Latvia and Lithuania, but only imports electricity from Finland.[6]

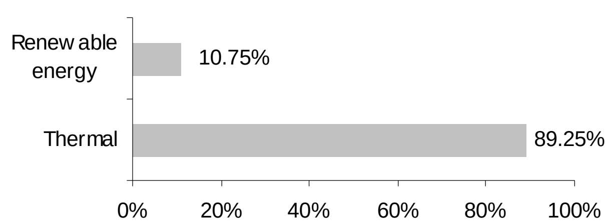

Figure 1 **Electricity generation in Estonia**
Source: Statistics Estonia[3]

Small hydropower sector overview and potential

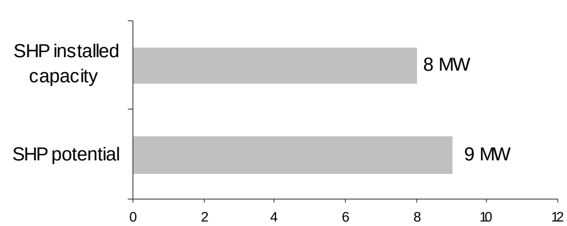

Figure 2 **Small hydropower capacities in Estonia**

In 2010, Estonia had 47 small hydropower plants and a total installed capacity of 8 MW (generating 30 GWh per year). A marginal role is designated for small hydropower within the energy supply. By 2020, the aim is to have 55 plants with a total installed capacity of 9 MW (generating 33 GWh).[7]

Renewable energy policy

According to the National Renewable Energy Action Plan (NREAP), Estonia's target for 2020 is a 25-per cent share of energy from renewable energy sources in gross final energy consumption.[8] In Estonia, access of renewable energy systems to the grid is a subject of general legislation on electricity and so far it has not been legally encouraged. On the other hand, system operators are entitled to connect their systems to the grid according to non-discriminatory criteria and the grid operator is obliged to upgrade the network if it is necessary to connect a plant to the grid. The costs of such an upgrade are borne by the operator of the system in question.[7]

Legislation on small hydropower

A support scheme exists as a feed-in tariff (FIT) or a fixed premium (in addition to the electricity price) that the utility is legally obligated to pay. The FIT is €73.39/MWh and the fixed premium is €53.61/MWh of electricity sold to the grid. These rates are valid for 12 years from commissioning a plant.[7]

Barriers to small hydropower development

Residual flow values are fixed in the water use licensing procedure and are set on the 95 per cent fraction of the flow duration curve. In addition, fishways are often requested.[7] The EU Water Framework Directive has had some impact on small hydropower. A list of watercourses (112 rivers or their reaches) with dams that are preventing the migration of fish has been introduced which will adversely affect small hydropower potential. With regard to environmental impact mitigation measures, the conventional measures are fish passage construction for migrating fish watercourses. In general, public support and social acceptance of small hydropower can be described as positive.[7]

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4.2.3 Finland

European Small Hydropower Association, Stream Map

Key facts

Population	5,262,930
Area	338,145 km^2
Climate	Cold temperate; potentially subarctic but comparatively mild because of moderating influence of the North Atlantic Current, Baltic Sea, and more than 60 000 lakes.[1] The snow cover is usually thickest in mid March, in Lapland often as late as early April.[2]
Topography	Mostly low, flat to rolling plains interspersed with lakes and low hills[1]
Rain pattern	In 2011, annual rainfall was 500–800 mm depending on the region[3]

Electricity sector overview

The domestic electricity production in Finland was 77,200 GWh in 2010, the imported electricity from its neighbours was 10,500 GWh (almost 12 per cent). Its electricity mix is dominated by combined heat and power and nuclear power (figure 1). Finland exceeded its 2020 renewable energy target of 28 per cent in 2009.[4]

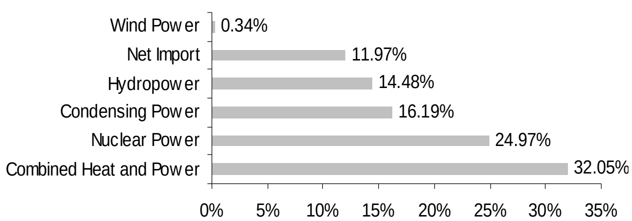

Figure 1 **Electricity generation in Finland**
Source: Statistics Finland[5]
Note: Condensing power includes condensing power plants, shares of condensing electricity of combined heat and power production plants, and peak gas turbines and similar separate electricity production plants.

The deregulation of the electricity market has taken place in stages. The reform and deregulation of the Finnish electricity market started in 1995 with the entry into force of the new Electricity Market Act (386/1995). In late 1998, small-scale consumers were freed from the requirement to use hourly-metering equipment. Since then, all electricity users are free to acquire their electricity from the supplier of their choice.[6]

Small hydropower sector overview and potential

In 2010, Finland had 152 small hydropower plants divided into 73 plants with 1-10 MW and 79 plants with less than 1 MW. The total installed capacity was 302 MW (generating 1,314 GWh per year) (figure 2). In addition to these plants, there are approximately 40-50 plants with a capacity of less than 50 kW (micro-hydro), operated without connection to the national grid.

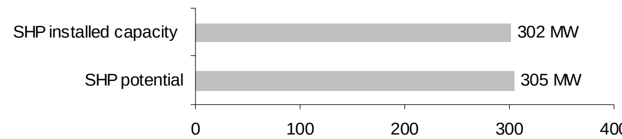

Figure 2 **Small hydropower capacities in Finland**

By 2020, the aim is to have 160 plants with a total installed capacity of 305 MW (generating 1,330 GWh). However, the small hydropower sector has lately been facing a difficult growth environment, where the economic support has been withdrawn. Considering this change in support, the estimate of extra small hydropower potential has recently decreased by up to 90 per cent, from 1,200 GWh in 2005 to around 210 GWh in 2010.

Refurbishment plans are being made mainly to upgrade larger plants of the sector in the range of 1 MW to 10 MW. This work was supported by the decision made in 2010 to raise the upper limit for the energy investment support from 1 MW to 10 MW.

Renewable energy policy

A new subsidy scheme, feed-in tariff (FIT) was established in Finland on 31 December 2010 to promote the production of electricity based on wind power, biogas and wood-based fuel. Small hydropower as well as small scale wind power and bio-electricity fall under the fixed energy support part of the Act. In addition to the fixed production support, an improvement of the energy investment grant was foreseen. An Act on production subsidy for electricity produced from renewable energy sources entered partially into force on 1 January 2011 and was ratified by the EU in the second half of March 2011. The FIT support for large wind power and bio-energy has been kept for the time being, but the fixed production support for small hydro (<1 MW) ended in 12 December 2011.

Legislation on small hydropower

Tax incentives exist for small hydropower developers. Support is granted in the range of 15-25 per cent of the planned investment of the application. This makes it interesting to consider new plants or refurbishments. Projects of high/new technologies and promoting Finnish export receive higher support. Significant budget cuts, however, are expected to take place after 1 January 2013. According to the renewable energy sources production support law of 2010, small hydro of 0.1-1 MW capacity received a support of 4.2 €/MWh but this support was withdrawn by an adjustment to the law stepping into force on 1 January 2012.

Most of Finland's small hydro plants are run-of-river plants which have no or relatively small water storage capacity. These installations normally operate on base load and use cumulative flow continuously. Only a very small number are penstock or canal plants. In Finland, the residual flow is in many cases assumed to be the flow required for the fishways. If there is a requirement for a fishway set by the water licence, the right to control of its design and construction is given to the fishery resources authority.

Barriers to small hydropower development

In Finland the residual flow issue varies a lot; it is generally assumed to be the flow required for the fish-way. A minimum bypass flow can be stated in the hydropower permit, but in many (older) permits there is no such requirement. Authorities can try to alter the permit if the conditions have changed significantly but a court may decide against it. Even with the New Water Law entering into force on 1 January 2012, there are no changes expected for permitting or the simplification of administrative procedures whilst major issues with old licences remain not covered by the law.

The EU Renewable Directive 2009/28/EC (by 2020) has not meant any changes for small hydropower in Finland. The EU Water Framework Directive (WFD) is implemented in Finnish Law and is under application. The general situation for small hydropower is very difficult. Some associations question why small hydropower is not given the same support as other renewables such as wind power and biomass.

To overcome the barriers, it is necessary:

- To include small hydropower in the FIT system as defined in the existing Finnish renewable energy sources-production support law of January 1, 2012 and already applied to the other RES sector in Finland.
- To reduce the barriers for developing small hydropower by setting up clear rules and time frames in the licensing process.
- To reduce the barriers for development of small - scale pico- (smaller than 10 kW) and micro-hydropower (10-100 kW), concerning technical requirements of grid connection and allow direct small hydropower energy transmission to nearby users. In spite of the small hydropower problems in Finland, an increasing interest to renovate small sites for private use has been noticed.

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4.2.4 Iceland

Lara Esser, International Center on Small Hydro Power

Key facts

Population	313,183[1]
Area	103,000 km^2
Climate	Temperate; mild, windy winters; damp, cool summers[1]
Topography	Mostly plateau interspersed with mountain peaks, icefields; coast deeply indented by bays and fjords[1]
Rain pattern	The South Coast receives heavy precipitation.[2]

Electricity sector overview

Nearly all of Iceland's electricity comes from renewable sources, such as large hydro and geothermal power (figure 1). The exceptions are islands Grimsey and Flatey, which are not connected to the national grid and continue to use diesel generators. All power stations with the capacity larger than 1 MW are to be connected to the national grid. The owners of smaller stations are also allowed to sell their electricity.[3]

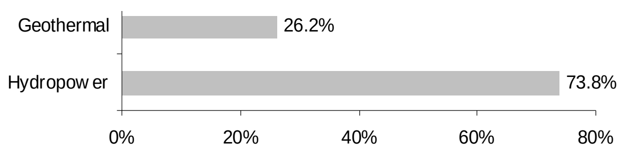

Figure 1 **Electricity generation in Iceland**
Source: National Energy Authority[4]

In 2003, the Electricity Act brought about major changes for Iceland's electricity market, unbundling the market structure into electricity generation, transmission, distribution and supply. Iceland has a competitive market for power generation and supply, while transmission and distribution are subject to concession arrangements and specific regulatory oversight by the National Energy Authority.[5]

Small hydropower sector overview and potential

Iceland's precipitation has an enormous energy potential of up to 220 TWh/year. Much of it is stored in ice caps and groundwater and dissipated by evaporation, groundwater flow and glacier flow. A Master Plan for Hydropower and Geothermal Power was jointly initiated by the Ministry of Industry and the Ministry for the Environment in 1997 and was published in 2011. Details that are available include a hydropower potential in 2010 of 12,592 GWh/year with another 3,326 GWh/year appropriate for development.[6]

There is not much information on installed small hydropower on Iceland, but it is estimated to be at least 25 MW (figure 2). Landsvirkjun, the largest energy company in Iceland, operates two small hydropower plants up to 10 MW: Laxa I (5 MW, generating 3 GWh per year) and Laxa II (9 MW, generating 78 GWh per year).[7] Hverfisfljót (3 MW, generating 24 GWh per year) is a small hydropower plant located in the South East part of Iceland, Múlavirkjun (6 MW, generating 37 GWh per year) is located at the East coast of Iceland and Djúpadalsvirkjun (2 MW, generating 27 GWh per year) is located in Eyjafjörður in North Iceland.[8] Data on small hydropower potential is not available.

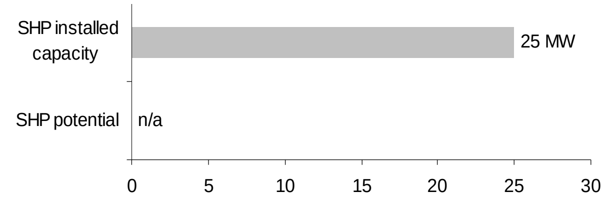

Figure 2 **Small hydropower capacities in Iceland**

Renewable energy policy

As all stationary energy use in Iceland is already from renewable energy, the development of renewable energy projects is not driven by the need to replace non-sustainable energy projects that utilize coal and oil, but to include and enhance sustainability, value creation and efficiency.[9] A state-owned National Energy Fund exists, which grants subsidies for measures that aim to reduce the use of fossil fuels. Among other aims, it supports the development of domestic energy sources instead of fossil fuels (Art. 8 Act No. 87/2003).[10]

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4.2.5 Ireland

Lara Esser, International Center on Small Hydro Power

Key facts

Population	4,722,028
Area	70,273 km^2
Climate	Temperate maritime; mild winters, cool summers; consistently humid[1]
Topography	Mostly level to rolling interior plain surrounded by rugged hills and low mountains; sea cliffs on west coast[1]
Rain Pattern	Annual rainfall in most of the eastern half of the country is between 750 mm and 1,000 mm. In the west it averages between 1,000 mm and 1,250 mm. In many mountainous districts rainfall exceeds 2,000 mm.[2]

Electricity sector overview

Electricity services in Ireland are provided by the Electricity Supply Board (ESB), a state body owned and controlled by the Government. The ESB owns and manages the electricity network and operates 19 major power stations throughout Ireland and a number of smaller stations in 28 sites around the country.[3] The bulk of electricity supply is from fossil fuels (including peat) although wind power is of increasing importance (figure 1).

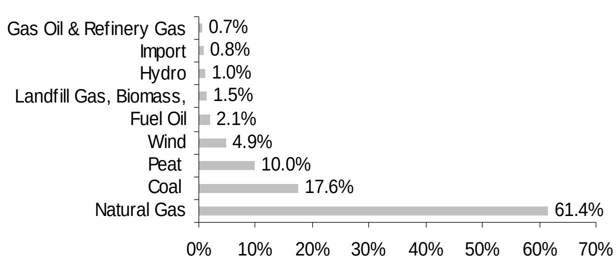

Figure 1 **Electricity generation in Ireland**
Source: Commission of Energy Regulation[4]

In February 2005, the retail electricity market was fully opened to competition.[4] On 1 November 2007, the Single Electricity Market (SEM) went live commencing the trading of wholesale electricity in Ireland and Northern Ireland on an All-Island basis.[5]

Small hydropower sector overview and potential

The existing small hydropower capacity in Ireland is about 42 MW with an estimated generation of 160 GWh per year (figure 2).[6]

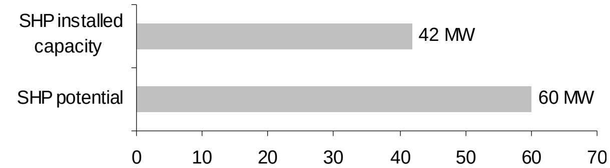

Figure 2 **Small hydropower capacities in Ireland**
Source: Stream Map [6]
Note: Data from 2010. Potential based on planned capacity by 2020.

The Irish Hydropower Association estimates, for example, that up to 600 old mill sites around the country could be developed into hydropower generation sites. A reasonable estimate (assuming that not all of these sites are redeveloped) is 25 MW capacity with a production of up to 130 GWh per year. Additionally, 10 more potential high-head sites (each 500 kW) could be developed.[7]

In 2010, two local authorities commissioned reports to identify the small hydropower potential in their counties. Twenty-seven hydro sites were assessed in County Kilkenny using a calculation tool and producing a map illustrating potential power output. The study identified the hydro resources that can be tapped by local community groups, land owners and local industries. Under the Kilkenny LEADER Partnership Rural Development Strategy 2007-2013, funding is available for the development of renewable energy resources in the county.[8] In 2010, five commercial and five domestic suitable sites were identified for hydropower generation, with a total annual electricity production potential of 1,232 MWh and 116 MWh per year respectively. A further 10 commercial and 100 domestic sites that are financially viable exist in County Clare.[9]

Renewable energy policy

According to the National Renewable Energy Action Plan (NREAP), the renewable energy target of Ireland for 2020 is 16 per cent of gross final energy consumption. Irish Government policy is to encourage the production of energy from renewable resources through the Alternative Energy Requirements Scheme. The Department of Communications, Energy and Natural Resources in its Strategy for Renewable Energy (2012-2020) aims at five strategic goals: increasing on and offshore wind, building a sustainable bioenergy sector, fostering research and development in renewables such as wave and tidal, growing sustainable transport and building out robust and efficient networks.[10]

Legislation on small hydropower

The Renewable Energy Feed-In-Tariff 2 (REFIT2) includes hydropower up to 5 MW, with a rate of 8.3 euro cents per kWh. REFIT 2 is designed to incentivize the addition of 4,000 MW of new renewable electricity capacity to the Irish grid for the period 1 January 2010 to 31 December 2015.[11 12 13 14]

The residual flow depends on the river type and fish requirements. It is decided on individual basis. The Department of Communications Energy and Natural Resources covers residual flow requirements.[11]

Barriers to small hydropower development

While the small hydropower sector is not expected to grow due to lack of suitable undeveloped locations, two small hydropower assessment studies conducted by a local authority show that there is still interest as well as potential for its development especially in the context of rural development.[6 9]

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5.2.6 Latvia

European Small Hydropower Association, Stream Map

Key facts

Population	2,191,580[1]
Area	64,589 km[2]
Climate	Maritime; wet, moderate winters
Topography	Low plain
Rain pattern	The average annual precipitation is 667 mm. The months with most precipitation are July and August, in each of which average rainfall is 78 mm. Least precipitation falls in February and March with monthly average of 33 mm.[2]

Electricity sector overview

The supply of electricity in Latvia is catered mostly by large hydropower and combined heat and power (CHP) plants (based on fossil fuel) with the balance coming from imports (figure 1). The electricity market is dominated by two state-owned companies: Latvenergo and Enefit (affiliation of Estonian state enterprise Eesti Energia).[3] In 2011, AS Latveneg generated 72 per cent of the total electricity supply, purchasing 11 per cent from small electricity energy producers.[4]

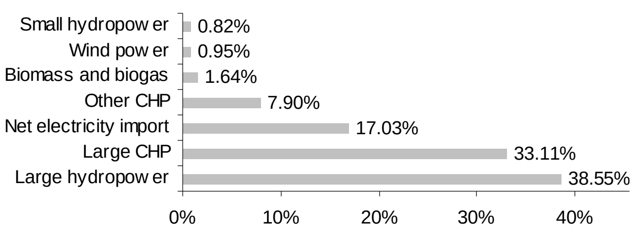

Figure 1 **Electricity generation in Latvia**
Source: Ministry of Economics[4]

In accordance with the European Union requirements, Latvia has been moving towards an open electricity market. In 2007, Latvian electricity sector was opened for unrestricted competition, allowing households and other non-household consumers to choose an alternative supplier of electricity.[5 6]

Small hydropower sector overview and potential

In 2010, Latvia had 142 small hydropower plants and a total installed capacity of 26 MW (generating 69 GWh per year). Only one small hydropower plant exceeds an installed capacity of 1 MW so a marginal role is designated for small hydropower (<10 MW) in the country's energy supply. Some 10 MW additional capacity is planned by 2020. The aim is to have 180 plants with a total installed capacity of 35 MW, generating 85 GWh (figure 2).

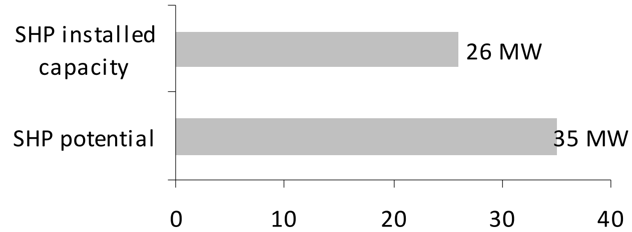

Figure 2 **Small hydropower capacities in Latvia**

Renewable energy policy

Renewable energy represents 30-35 per cent of the country's energy mix and the goal is to reach 40 per cent by 2020.[7] The Regulations on Electricity Generation from Renewable Energy Sources (Cabinet of Ministers Regulation No. 198, initially adopted in July 2007 as Regulation No. 503) prescribes conditions for electricity production using renewable energy sources (wind, small hydro, biomass, biogas, solar) and defines criteria for renewable energy sources electricity. These producers are eligible to sell their electricity within compulsory procurement with fixed purchase prices (feed-in tariff or FIT system), if the installed electrical capacity exceeds 1 MW.

Legislation on small hydropower

Small hydropower plants are not obliged to pay fees for water use. Also, support schemes and tariffs are quite attractive.[3]

With regard to the residual flow regulation, an officially approved compensation flow setting methodology exists. It is set as a mean monthly low flow with a return period of 20 years.[3]

Barriers to small hydropower development

There is clear public support for the technology, however strict environmental legislation is in place. Despite some efforts made by small hydropower promoters, there has not been any simplification of administrative procedures for small hydropower development.

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4.2.7 Lithuania

European Small Hydropower Association, Stream Map

Key facts

Population	3,525,761
Area	65,300 km^2
Climate	Transitional, between maritime and continental; wet, moderate winters and summers
Topography	Lowland, many scattered small lakes, fertile soil
Rain pattern	Mean annual precipitation varies from 550 to 850 mm. The area with the most rainfall is located in the west.[2]

Electricity sector overview

Lithuania's electricity market changed markedly in 2010. As a condition of entry into the European Union, Lithuania agreed in 1999 to close existing units of the Ignalina Nuclear Power Plant due to its lack of containment building and the high risk it had. As a result, Lithuania lost its largest and cheapest producer of electricity, making the country an electricity importer (56 per cent), when it was previously an exporter. Hydropower produces about 10 per cent of electricity needs with thermal plants supplying almost 30 per cent (figure 1).

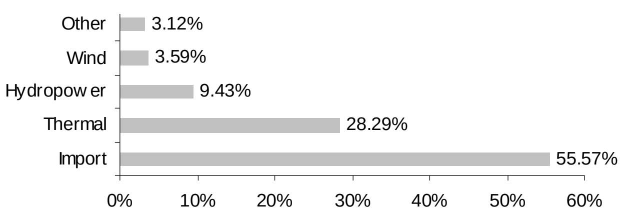

Figure 1 **Electricity generation in Lithuania**
Source: Lithuanian Electricity Association[3]

The EU Third Package directives were implemented, promoting competition in the energy sector by separating production, transmission and distribution. A free electricity market was formed on 1 January 2010.[4]

Small hydropower sector overview and potential

In 2010, Lithuania had 87 small hydropower plants and a total installed capacity of 29 MW (generating 93 GWh per year). By 2020, the aim is to have 110 plants with a total installed capacity of 40 MW (generating 120 GWh) (figure 2).

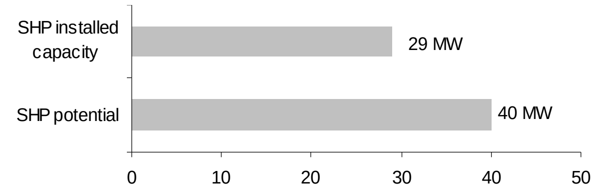

Figure 2 **Small hydropower capacities in Lithuania**

Renewable energy policy

After long debates for more than two years, a law on renewable energy has been introduced in Lithuania. For different power generation technologies, the 2020 targets in terms of installed capacity are proposed. For the hydro sector, it is 141 MW (starting with 129 MW in 2005). This contribution coincides with that given in the National Renewable Energy Action Plan (NREAP) but hydropower proponents wanted to see a bigger figure (up to 250 MW). However, environmental groups prevented this increase.

Legislation on small hydropower

Small hydro is regulated by the Ministry of Economy, Ministry of Environment and the Ministry of Agriculture. Despite the existence of a power granting scheme, there is, up till now, no specific hydropower legislation in Lithuania. There are introductions for simplifications of administrative procedures for renewable energy sources technologies up to 350 kW, however hydropower of any size is excluded from this simplification. An exception is made for hydro technology without dam.

The support system is regulated by a recently promulgated law on renewable energy. A feed-in tariff (FIT) is guaranteed for 12 years commencing from 2011 onwards (current FIT is 5.8 euro cents/kWh). For new plants, a quota obligation system with FIT is in force and auctions will be organized to ensure the least FIT value proposed by a proponent. Very small capacity plants (<30 kW) will have a different FIT.

The licence (permit) for power production is obtained independently regardless of the size of small hydropower plant and each has unlimited validity. Small hydropower developers are responsible for covering the costs of extensions and strengthening the grid although 40 per cent of the cost incurred is subsidized.

Barriers to small hydropower development

The residual flow regulation is set as a mean monthly (30 consecutive days) low flow (return period of 20 years) so the losses in small hydropower electricity production resulting from maintaining residual flow are negligible. For diversion schemes residual flow is 10 per cent of long-term mean flow.

While there is clear public support for small hydropower development in the country, as proven by an inquiry conducted a few years ago evaluating the acceptance of different energy technologies, the country's top officials are reluctant to see further hydropower development. Under the pressure from international and local environmental groups, the officials are suggesting to look for other renewable energy sources technologies rather than in hydro. There was no particular discussion about the role of small hydropower in grid development or its role in energy storage to cover intermittent renewable energy sources.

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4.2.8 Norway

Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	4,885,240
Area	323,802 km^2
Climate	Temperate along coast, modified by North Atlantic Current[1]
Topography	Glaciated; mostly high plateaus and rugged mountains broken by fertile valleys; small, scattered plains; coastline deeply indented by fjords; arctic tundra in north[1]
Rain pattern	Annual average rainfall of 1,400 mm. The largest amounts are found some miles from the western coast. Annual precipitation can range from 300 mm up to more than 4,000 mm, depending on the location.[2]

Electricity sector overview

In 2011, 128,100 GWh of electricity was generated in Norway with more than 95 per cent coming from large hydropower (figure 1).[3]

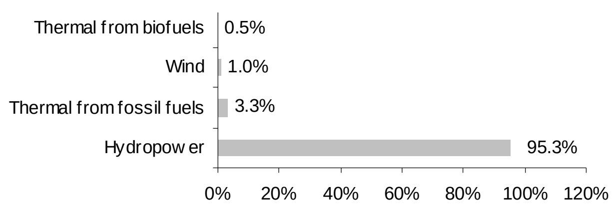

Figure 1 **Electricity generation in Norway**
Source: Norwegian Water Resources and Energy Directorate[4]

Since 1 January 2012, Sweden and Norway have a common electricity certificate market. Over the period until 2020, the two countries aim to increase their production of electricity from renewable energy sources by 26.4 TWh. The joint market will permit trading in both Swedish and Norwegian certificates, and receiving certificates for renewable electricity production in either country.

Small hydropower sector overview and potential

In 2010, 928 small hydropower plants were operational, with a total installed capacity of 1,778 MW, generating around 7,600 GWh per year (mean annual production) (figure 2). The plants have an average age of six to seven years and 35-40 per cent of these plants belong to private owners. There has been high investment in small hydropower development in the last decade, the average age before the year 2000 was 75 to 80 years, some plants were over 100 years old.[5]

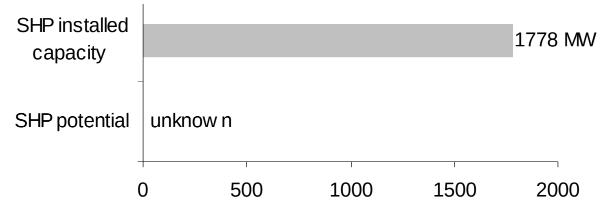

Figure 2 **Small hydropower capacities in Norway**
Source: Norwegian Water Resources and Energy Directorate[5]

The economically feasible small hydropower potential has been evaluated to be 20,000 GWh/year, but there is currently no master plan for small hydropower development in terms of megawatts to be developed.[5] Environmental Impact Assessments are necessary for plants with a mean production above 30-40 GWh/year and these projects need mapping and documentation of biodiversity when applying for a concession.[5]

Renewable energy policy

Norway promotes renewable energy through a quota system, including a certificate trading scheme. In general, all renewable energy generation technologies are eligible for the quota system (Sec. 7 No. 2 Electricity Certificates Act). However, hydropower plants are only eligible if construction started after 1 January 2004 and if their installed capacity does not exceed 1 MW (Sec. 8 Electricity Certificates Act).[3]

Grid operators are obliged to connect renewable energy plants to their grids without discriminating certain (groups of) plant operators. This also applies if a new energy connection requires the development of the grid.[3]

Barriers to small hydropower development

- Grid connection can be an obstacle in some areas, if a certain capacity is not attained.
- There are also several licences to be issued, which can delay the process.[5] In general, the Norwegian Water Resources and Energy Directorate is the overall regulator for small hydropower licensing.
- Licences are provided based on individual assessments without a standardized method. An environmental impact assessment study is required for power plants which generate more than 40 GWh. For small plants from 1 Gwh to 10 GWh, a simplified environmental assessment is required.[6] All new licences are normally given a minimum flow requirement. The legislation allows for changes in practice due to new knowledge and priorities. The common low flow (Qs) is often the starting point to

set a residual flow, and is approximately the 0.956 quantile of the flow duration curve; this is the flow that is exceeded 95.6 per cent of the time.[6]

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4.2.9 Sweden

European Small Hydropower Association, Stream Map

Key facts

Population	9,103,788
Area	450,295 km^2
Climate	Temperate in south, with cold, cloudy winters and cool, partly cloudy summers; subarctic in north
Topography	Mostly flat or gently rolling lowlands; mountains in west
Rain pattern	Precipitation all year, however the rainiest are summer and autumn. In the mountains 1,500 mm to 2,000 mm per year. In the South-west most wet areas have 1,000 mm to 1,200 mm per year. Compared to the measured annual rainfall in general at 500-800mm. Least precipitation on the small islands along the Baltic Sea, and in confined valleys in the mountain regions with around 400 mm per year[2]

Electricity sector overview

Swedish carbon emissions are low compared to other countries, because more than 85 per cent of its electricity comes from wind, nuclear and hydropower (figure 1).

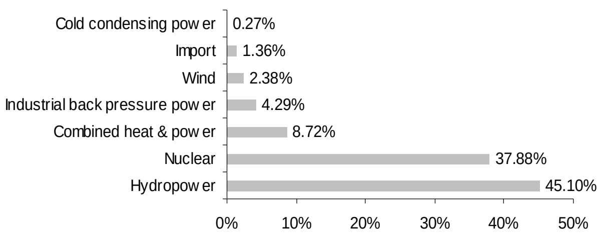

Figure 1 **Electricity generation in Sweden**
Source: Swedish Energy Agency[3]

Since 1 January 2012, Sweden and Norway have a common electricity certificate market. Over the period until 2020, the two countries aim to increase their production of electricity from renewable energy sources by 26.4 TWh. The joint market will permit trading in both Swedish and Norwegian certificates, and receiving certificates for renewable electricity production in either country.

Small hydropower sector overview and potential

In 2010, Sweden had 1,901 small hydropower plants and a total installed capacity of 1,194 MW, generating 4,571 GWh per year (figure 2).

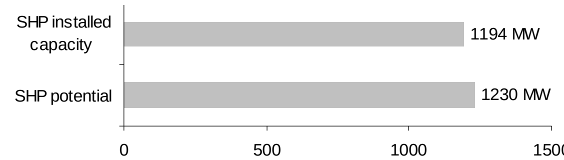

Figure 2 **Small hydropower capacities in Sweden**

Many older small hydropower plants are now phased out of the Swedish support scheme or are undergoing large refurbishment. To be entitled to operate for the next 15 years, it is required that the plants must undergo total refurbishment of all essential parts. As refurbishment is very expensive and not economically viable for smaller small hydropower plants (approximately less than 100 kW), they are facing an uncertain future.

New small hydropower development targets are few. By 2020, the aim is to have 1,960 plants with a total installed capacity of 1,230 MW (generating 5,500 GWh). From 2007 onwards, not many new plants have been built but refurbishment is being made, including upgrading larger small hydropower plants. For smaller small hydropower plants with higher cost per produced kWh, the outcome for investment is more unsecured.

Renewable energy policy

Sweden surpassed its 2020 renewable energy targets in 2009, achieving 50.2 per cent of final energy from renewable energy.[4] A market-based support system for renewable electricity production has been in place in the form of electricity certificates since 2003. The objective of the Swedish electricity certificate system is to increase the production of renewable electricity by 25,000 GWh by year 2020.

Legislation on small hydropower

Renewable and hydropower producers are entitled to certificates from the electricity certificate system under the following conditions:

- At the end of April 2003, small-scale hydropower plants that had a maximum installed capacity of 1,500 kW per production unit (the majority of the small hydropower in this group will be taken out of the system in 2012 if not refurbished to a standard similar to a new plant and have received the Energy Agency's acceptance).
- New plants.
- Resumed operation from plants that had been closed.
- Increased production capacity from existing plants.
- Plants that can no longer operate in an economically viable manner due to decisions by the authorities, or to extensive rebuilding.

A bill submitted by the Government to Parliament in the spring of 2011 proposes tightening up the qualification requirements for hydropower. On top of the incomes from electricity producers (in approved plants) selling power to the market, one certificate unit is allocated for each megawatt-hour of electricity for up to 15 years. The price for certificates is set by the interaction between the supply and demand like any other market and has varied over the years between 1.1 euro cent/kWh (June 2003) and 4.0 euro cents/kWh (August 2008). The certificate system will be in place until the end of 2035.

Environmental impact assessments are required (including consultations, meetings with individuals and organizations), as well as a recommendation by the Environment Court hearing the case. The Environment Court gives out the permit and a review of the permit may then occur after 10 years, assessing the benefits of a measure to be taken compared to its consistency. This often in directly force the water plant owners to give 5-20 per cent of the water flow without compensation.

Barriers to small hydropower development

The EU Renewable Directive 2009/28/EC (by 2020) has not resulted in any changes for small hydropower in Sweden. The EU Water Framework Directive is implemented under the Swedish Law and the effect of the directive in reality will only be known after a Swedish court ruling.

The residual flow is generally not regulated by law. For existing plants a trial may be made, which most of the time leads to demands on residual flow of about 5–20 per cent without any compensation to the owner.

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4.2.10 United Kingdom of Great Britain and Northern Ireland

European Small Hydropower Association, Stream Map

Key facts

Population	63,047,162
Area	243,610 km^2
Climate	Temperate; moderated by prevailing southwest winds over the North Atlantic Current; more than one-half of the days are overcast
Topography	Mostly rugged hills and low mountains; level to rolling plains in east and southeast[1]
Rain pattern	On average more than 1,000 mm, heaviest on the western and northern heights (3,800 mm), lowest along the eastern and south-eastern coasts. Rainfall is distributed fairly evenly throughout the year.[2]

Electricity sector overview

The United Kingdom's total electricity consumption in 2011 was 364,897 GWh (excluding pumped storage), with about two per cent net electricity imports from France (4,700 GWh) and the Netherlands (1,800 GWh).[3] The bulk of electricity is supplied by fossil fuels power plants and nuclear power plants, leaving renewable energy at less than 10 per cent (figure 1).

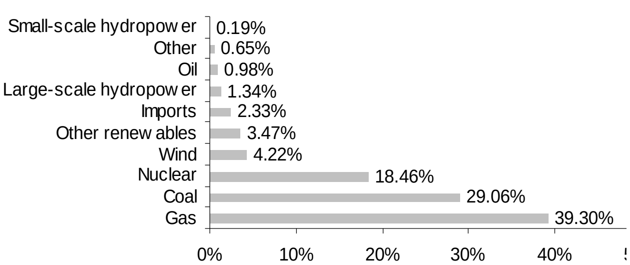

Figure 1 **Electricity generation in the United Kingdom of Great Britain and Northern Ireland**
Source: Department of Energy and Climate Change[3]

Small hydropower sector overview and potential

In 2010, the United Kingdom had 120 small hydropower plants and a total installed capacity of 230 MW, generating 750 GWh per year (figure 2). There has been significantly more development in the last three years due to the financial incentives for renewable energy under the Renewable Obligation Certificates (ROCs) and feed-in tariff (FITs) systems. By 2020, the aim is to have 160 plants with a total installed capacity of 350 MW (generating 1,100 GWh).

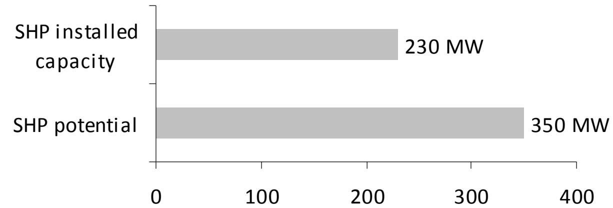

Figure 2 **Small hydropower capacities in the United Kingdom of Great Britain and Northern Ireland**

From the 1960s to year 2000, there had been very little new hydro development in the United Kingdom. Generation from gas, the resulting low electricity process and the monopoly of the three government-owned electricity utilities meant that the relatively expensive initial costs of hydro were non-conducive for producers to tap the remaining potential. In the 1990s, the realization that renewable energy was becoming more essential to offset the use of fossil fuels and the increasing desire for security of energy supplies caused the introduction of the Non-Fossil Fuel Obligation (NFFO). Generators had to provide part of their electricity from renewable sources and higher-than-normal tariff incentives were introduced. This kick-started new hydro schemes but at a very slow pace and NFFO was eventually dropped and considered a fundamentally flawed scheme.

Since 2000, there has been a big increase in the desire for new and refurbished hydropower projects to be built. This was a result of introducing the Renewable Obligation with its associated ROCs (see below). The means by which renewable energy developers benefited via a government-lead initiative based on payment via the nation's electricity bills was seen as fair and resulted in a surge to generate renewable power with wind, being the biggest and quickest technology to benefit and develop. Hydro development also grew and new small hydropower schemes and refurbishment of old plants up to 20 MW capacity saw immediate benefits. In 2010, a FIT was also introduced to incentivize the lower generation area (up to 5 MW) and, in particular, to individuals and communities to promote renewable energy projects.

From 2011, a further 485 MW was needed to be developed to meet the 2020 targets. This would all come from small hydro (up to 10 MW). With the delays in getting actual hydro construction started, owing to the uncertainties surrounding the FIT, this means that approximately 50 MW per year is required. In deliberation with Department of Energy and Climate Change (DECC), the UK hydropower industry has calculated that, with present capabilities, a maximum of 40 MW per year is possible. Discussions continue to see how the present rate of development could be accelerated.

Renewable energy policy

In July 2012, the White Paper on electricity market reform (EMR) was published.[4] The EMR shall ensure security of supply through the provision of a diverse range of energy sources, including renewable, nuclear, carbon capture and storage equipped plants, unabated gas and demand side management. It shall ensure sufficient investment in sustainable low carbon technologies and put the United Kingdom on a path to achieve its 2020 renewable energy targets (15 per cent) as well as its long-term targets to reduce carbon emissions by at least 80 per cent by 2050.[5] [6]

The Renewables Obligation (RO) came into effect in 2002 in England, Wales and Scotland and in 2005 Northern Ireland. It places an obligation on the UK electricity suppliers to source an increasing proportion of electricity they supply to customers from renewable sources. Renewables Obligation Certificates (ROCs) are green certificates issued to operators of accredited renewable generating stations for the renewable electricity they generate. They are available for plants with a capacity over 50 kW except in Northern Ireland. ROCs can be traded and are used by suppliers to demonstrate that they have met their obligation. ROCs are due to be phased-out in 2027, a recent review of the ROC banding system proposed that hydro should, from 2017 onwards, receive only half the ROC value per MWh than it enjoys at present.

Legislation on small hydropower

FITs were introduced to the United Kingdom, with the exception of Northern Ireland, in April 2010. They are available for renewable energy projects up to 5 MW capacity. As a result of the Government spending review from late 2010, the FIT system is being subjected to an early review. In January 2012 the DECC started a consultation about a revised FIT system, the results were recently announced with new tariffs applicable from April 2013.

Although the proposed 2013 tariffs for hydro (per kWh) are reasonable, as shown below, these are subject to whether degression as targets set by DECC are met, which is creating a rush for development and does not encourage sustainable growth of the industry:[7]

- up to 15 kW: 21.65 p/kWh (US$0.334)
- 15-100 kW: 20.10 p/kWh (US$0.310)
- 100- 500 kW: 15.50 p/kWh (US$0.239)
- 500-2,000 kW: 12.48 p/kWh (US$0.193)
- 2,000-5,000 kW: 3.23 p/kWh (US$0.0498)

Barriers to small hydropower development

It is clear from the EU Water Framework Directive (WFD) what the permitting areas are, however little is clear or understood about the Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC and its subsequent amendments). It could be that WFD has a direct impact on whether a hydro scheme is to be developed or not, but the renewable energy sources Directive is theoretically a national target for renewable energy development and have very little impact on individual schemes. The Department for Food and Rural Affairs (DEFRA) administers the WFD in the UK. It is never clear if DEFRA and DECC consider the conflict between the two Directives with regard to hydropower development, or not. DECC is certainly involved in the development of guidance on water abstraction at the working-group level.

Residual flow regulation exists in England and Wales (following the UK Environment Agency's *Good Practice Guidelines to the Hydropower Handbook*, published in August 2009), with values varying from Q95[i] to Q85. In Scotland the default residual flow is Q95, but each project must be reviewed individually. The Scottish Environmental Protection Agency (SEPA) published *Guidance for Applicants on Supporting Information Requirements for Hydropower Applications* in December 2010. In Northern Ireland, the default residual flow value is Q95 but under certain categories of river and river protection, it can be Q80. The Northern Ireland Environment Agency published *Guidance for Run-of-River Hydropower Schemes in Northern Ireland* in July 2011. The Environment Agency's guidance is currently being reviewed to look at various flow options for hydropower and to include more details for high head applications.

The major issue on the development of environmental guidance for hydro and the permitting process is the opposition to hydropower by a very strong angling lobby throughout the United Kingdom.

Major issues which affect hydro developments are:

- Environmental concerns regarding e.g. fish passages.
- In England and Wales, there is a growing requirement for 'splitting' the flow above residual flow values between the hydro scheme and the river. This is being consulted on and reviewed by a working group comprising the Environment Agency and stakeholders (DECC, hydro and angling). Initially, no evidence for flow splitting is apparent.

Despite the issues which adversely affect the progress of hydropower in the UK, there is a general optimistic feeling within the industry. Much of the attention is given to onshore and offshore wind projects which has affected the support for hydropower from the Government. However, the ROC and FIT incentives have caused a real renaissance affecting all aspects and players in the industry.

A combination of economic recession and the introduction of an excessively high FIT for Solar PV threatened funding of the FIT system and a review was called by the Government in late 2010. Hydropower industry suffered the most because banks refused to lend money. Stability has been resumed and some of the uncertainty expelled for the hydropower sector but the overall effect of the review will not be known until developments have gone through the system.

The review of ROC banding suggested halving the payment per MWh for hydropower. The hydropower industry proved that the reason which DECC provided for this was based on incorrect evidence. There is hope that this might be sufficient to return at least to one ROC on completion of DECCs review of the consultation. However, if it does not, then fewer hydropower schemes above 2 MW will be developed, and it may severely threaten its 2020 targets. It also threatens to halve the FIT tariff between 2 MW and 5 MW, which will add to the same conclusion.

Note

i. The flow exceeded for 95 per cent of the time, and used as a marker of low flow.

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4.3 Southern Europe

European Small Hydropower Association, Stream Map

Introduction to the region

Southern Europe comprises 16 territories or countries. Five of these countries do not use small hydropower (i.e. Andorra, Gibraltar, Holy See, Malta and San Marino). Eleven countries use small hydropower, including six European Union (EU) Member States (Croatia[i], Greece, Italy, Portugal, Slovenia, Spain) and two candidate countries i.e. Serbia and Macedonia (table 1). The dominant climate in Southern Europe is continental and temperate, with a maritime climate on the western coasts and a Mediterranean climate in the South.

Table 1

Overview of countries in Southern Europe

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW))*	*Hydropower generation (GWh/year)*
Albania[ab]	3.002	52	..	1 553	7 555	1 461	5 300
Bosnia & Herzegovina[ac]	3.879	..	..	4 300	14 050	2 380	6 200
Croatia[a]	4.48	42	..	3 984	14 670	2 118	7 677
Greece[a]	10.767	39	100	15 397	51 993	3 018	6 004
Italy[a]	61.261	32	100	111 000	288 900	17 800	45 511
The former Yugoslav Republic of Macedonia[a]	2.060	..	..	1 508	6 390	528	2 185
Montenegro[a]	0.645	..	..	867	2 679	658	2 749
Portugal[ad]	10.781	39	100	17 920	54 048	4 988	16 248
Serbia[a]	7.292	48	..	8 355	35 900	2 820	12 471
Slovenia[a]	1.996	50	..	3 046	13 000	846	3 511
Spain[a]	47.042		100	94 966	275 100	18 559	22 888
Total	**153.205**	**-**	**-**	**262 896**	**764 285**	**55 176**	**130 744**

Sources:

a. International Journal on Hydropower and Dams[1]

b. Albanian Energy Regulator[2]

c. State Electricity Regulatory Commission[3]

d. Statistics Portugal[4]

Small hydropower definition

Various small hydropower definitions are applied in Southern Europe (table 2).

Table 2

Classification of small hydropower in Southern Europe

Country	*Small (MW)*	*Mini (MW)*	*Micro (kW)*
Albania	..	..	..
Bosnia & Herzegovina [a]	>5	up to 5	
Croatia [b]	up to 10		
Greece [c]	up to 15		
Italy	1-3	0.1-1.0	up to 100
The former Yugoslav Republic of Macedonia	up to 5		
Montenegro [d]	up to 10		
Portugal [e]	up to 10		
Serbia [f]	up to 10		
Slovenia [g]	up to 10		
Spain [c]	up to 10		

Sources:

a. Foreign Investment Promotion Agency[5]

b. Berakovic[6]

c. ESHA SHERPA[7]

d. European Bank for Reconstruction and Development[8]

e. ESHA Stream Map[9]

f. Serbia Energy[10]

g. Platform Management in the Alps[11]

Regional overview and potential

The Albanian Government strongly promotes the use of renewable energy and is currently in the drafting stage of new renewable energy laws. In addition to the governmental support, the country is also rich in river resources, giving rise to a substantial small hydro potential. Bosnia and Herzegovina do not have an authority responsible for the renewable energy sector. However, hydropower development has been underway with both large- and small- hydropower plants in operation. Awareness of renewable energy in Croatia is at an upward incline, coupled with the Government’s strategic objective to increase the use of renewable energy. At present, the energy supply in Croatia is based on the hydrocarbon reservoirs available within the area. Italy and Spain, followed by Greece, have the highest potential for small hydropower in Southern Europe. Due to amplified legislations and a lack of funding at the present economic downturn, the implementation of small hydropower is experiencing a downward trend. Hydropower is Italy’s second largest source of energy, with legislation and agencies in place to oversee the sector. In fact Italy currently has higher popularity for small rather than large hydropower plants. Macedonia relies on the use of lignite where its diminishing characteristic has provided the Government with an incentive to diversify into renewable energies. Initially, the use of small hydropower was welcomed, however, later there was a shift in favour of larger hydropower plants. Montenegro is aiming to effectively utilize its potential with small hydro plants already in the planning.

Overall Southern Europe has embraced the use of small hydropower, however most of these countries face individual barriers to fully develop their potential resources. The installed small hydropower capacity in Southern Europe is about 5,625 MW. The small hydropower potential is at a minimum of 12,239 MW. The small hydropower potential of Albania and Croatia are not yet known, in most cases the planned capacity was used to determine the potential. Italy has the highest installed capacity, followed by Spain.

Table 3
Small hydropower up to 10 MW in Southern Europe

Country	*Potential (MW)*	*Planned (MW)*	*Installed capacity (MW)*	*Annual generation (GWh)*
Albania[a]	at least 37	..	37	..
Bosnia & Herzegovina	1 000	..	36	134
Croatia[a]	at least 40	..	40	141
Greece	2 000	155	195	735
Italy	7 066	1 165	2 735	10 958
The former Yugloslav Rep. of Macedonia[a]	250	..	45	160
Montenegro[a]	240	231	9	21
Portugal[a]	750	300	450	1 370
Serbia	409	..	50	294
Slovenia[a]	192	75	117	558
Spain[a]	2 185	259	1 926	4 719
Total	**12 239**	**2 185**	**5 625**	**19 090**

Source: See country reports and Stream Map
Note: a. The potential was not available, therefore the known installed capacity or installed and planned capacity was used instead.

The Stream Map was co-funded by the Intelligent Energy Europe Programme of the European Commission. It aimed to define a clear and consistent roadmap in Europe for the small hydropower sector. It was completed in 2012. Stream Map reveals that during the last 10 years, new small hydropower potentials have been reduced through environmental legislation related to designated areas, such as Natura 2000, the EU Water Framework Directive, among others. The mitigation measures required have added to the costs of electricity generation, reducing the economic attractiveness of small hydropower.

Note

i. Croatia joined the European Union on 1 July 2013.

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4.3.1 Albania

Pascal Hauser and Lara Esser, International Center on Small Hydro Power

Key facts

Population	3,002,859[1]
Area	28,748 km[2]
Climate	Mild temperate; cool, cloudy, wet winters; hot, clear, dry summers; interior is cooler and wetter[1]
Topography	Mostly mountains and hills; small plains along coast
Rain pattern	Average annual rainfall is 1,300 mm to 1,400 mm and 80% of this occurs from November to March. The driest area is the southeast part with 600 mm to 700 mm of rainfall annually.2

Electricity sector overview

The *Monitoring Report* on the Energy Strategy 2007-2011 of the Ministry of Economy, Trade and Energy, reported that Albania's electricity sector had difficulties supplying electricity to its consumers in 2011. The country's generating capacity was insufficient to meet demand for electricity, financial losses on non-technical and technical electricity continued to be high, and interconnection lines with neighbouring countries were insufficient to meet demand for electricity import.[3]

Domestic electricity production increased to 4,158 GWh in 2011; 98 per cent of Albania's electricity was produced by the public sector. Electricity imports increased to about 3,170 GWh in 2011.[3] Albania used to be an exporter of electrical power, but has in 1998 became an importer.[4]

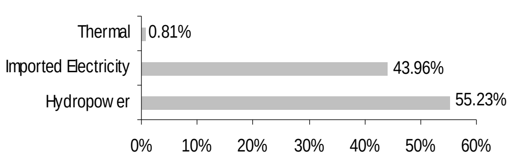

Figure 1 **Electricity generation in Albania**
Source: Ministry of Economy, Trade and Energy and Energy Regulator Regional Association[3 5]

Presently, the Albanian generation system of electricity is mainly based on hydropower from three major rivers in the north of Albania with the rest imported (figure 1).[6] The Albanian Power Corporation (KESH, Korporata Elektroenergjitike Shqiptare - KESH), a fully public-owned corporation, is the sole owner and user of the major hydropower plants. One thermal power plant is in operation since November 2009 (at 97 MW) in the south of Albania, owned by a subsidiary of KESH.[6]

Small hydropower sector overview and potential

Albania is a country rich in rivers, mainly flowing from south-east to north-west and towards the Adriatic coast. The small river flow with big cascades make them an important hydropower source.[7]

The overall hydropower potential in Albania is estimated to be 17 TWh. In 2010, hydropower production was 5,300 GWh. Only 33 per cent of its hydro energy potential has been tapped.

Three rivers are developed in a cascade form: Drin river has three hydropower plants with a total installed capacity of 1,350 MW and constitute 92 per cent of the country's power generation.[8] Mat River has two hydropower plants with a total installed capacity of 49 MW; Bistrica River has a total installed capacity of 27.5 MW.

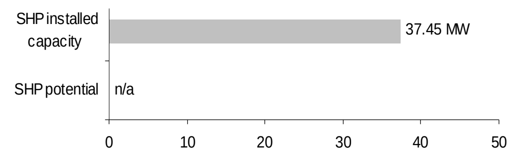

Figure 2 **Small hydropower capacities in Albania**
Source: International Journal on Hydropower and Dams[9]

Seventy small hydropower plants are reported to exist in Albania, with capacities from 20-9,200 kW, but only 38 of them were operational in 2010, the rest is out of function. The average age of small hydropower plants in Albania is 25 years, the initial construction purpose was to supply energy to remote mountain areas.[9]

Out of all small hydropower plants:[7]
• 32 of them operate on concessionary contracts, with an installed capacity of 24.4 MW.
• 16 of them have been privatized, with an installed capacity of 2.047 MW.
• 22 of them are owned by the State, with an installed capacity of 11 MW.

The total small hydropower potential has not been assessed (figure 2).

Renewable energy policy

Albania lacks a national renewable energy policy. The National Energy Strategy promotes minimizing the environmental impact of energy generation, but does not provide guarantees for the uptake of renewable energy. The National Agency of Energy (NAE) prepares and defines the action plans for the implementation of the National Energy Strategy together with the Albanian General Directorates.[4]

The Albanian Government is in the process of preparing a new Power Sector Law and a new Renewable Energy Source Law.[5] The Power Sector Law

No. 9072 (last amended in November 2011) mentions that the Albanian energy regulator, Enti Rregullator I Energjise (ERE) is authorized to grant the status of privileged producer of electric power to either:

- Producers generating electric power using renewable energy sources, whose installed capacity does not exceed 25 MW and in the case of hydropower energy source, it is up to 10 MW; or
- Producers generating electric power through cogeneration schemes whose installed capacity does not exceed 100 MW; or
- Auto-producers for their electric power surplus, provided that they use renewable energy sources and their installed capacity does not exceed 10 MW.[10]

Electricity power producers from non-renewable energy sources, with an installed capacity higher than 50 MW, are obligated to produce and/or supply electricity from renewable energy sources to the power system. The share of electricity from production plants that use renewable energy sources, certified by ERE with Green Certificates and commissioned after the 2 November 2000, should be no less than 3 per cent of their total annual production of the previous year. The quota increased each year by 0.75 per cent during the period of 2010-2012. The above obligation may be fulfilled by buying the same amount of electricity from other producers of renewable energy sources (domestic or imported electricity, if certified as renewable).[10]

For renewable electricity generation connected to the distribution network and producing electricity for tariff customers without Green Certificates, the Council of Ministers in cooperation with the ERE has approved the methodology for calculating the feed-in tariffs for electricity to be sold.[10]

Legislation on small hydropower

In compliance with the Power Sector Law and other secondary legislation, ERE has the authority and responsibility to review prices of electricity sale from existing small power producers (concessionary or private) with installed capacity up to 10 MW and from new producers with installed capacity up to 15 MW. Prices are calculated based on 'the methodology for calculation of unified electricity price for licensees for the production of energy by hydropower plants with installed capacity up to 10 MW' approved by the ERE Board of Commissioners (Decision No. 5, 26 January 2007).[11]

In order to promote further development of the country's hydrological reserve, there is also a methodology for setting the unified electricity price produced by new hydropower plants with installed capacity of up to 15 MW given by concession (Law No. 9663, date 18.12.2006 'On concessions').[11]

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4.3.2 Bosnia and Herzegovina

Pascal Hauser, International Center on Small Hydro Power

Key facts

Population	3,879,296[1]
Area	51,209 km[2]
Climate	Hot summers and cold winters; areas of high elevation have short, cool summers and long, severe winters; mild, rainy winters along coast[1]
Topography	Mountains and valleys. Fast-flowing mountain streams and powerful rivers.
Rain pattern	Annual precipitation 899 mm with more rain in winter[2]

Electricity sector overview

The country is a net electricity exporter, with a total electricity production of 14,050 GWh in 2011. Unfavourable hydrological conditions in 2011 considerably reduced the electricity generated by hydropower plants (4,326 GWh or 46 per cent less than those in 2010), which represent an important part of the electricity generation mix (figure 1).[3]

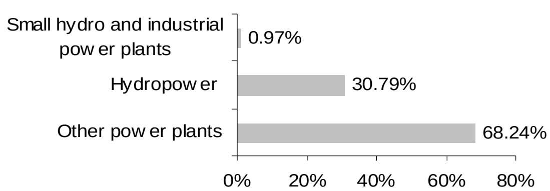

Figure 1 **Electricity generation in Bosnia and Herzegovina**

Source: State Electricity Regulatory Commission[3]

Small hydropower sector overview and potential

The country's gross theoretical hydropower potential is estimated to be 68,800 GWh/year (equivalent to 8,000 MW capacity), the technically feasible potential is 24,000 GWh/year (6,800 MW) and the economically feasible potential is 19,000 GWh/yr (5,600 MW).[4]

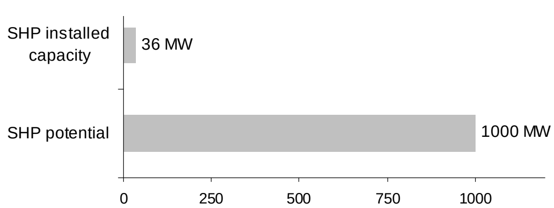

Figure 2 **Small hydropower capacities in Bosnia and Herzegovina**

Source: Economic Commission for Europe[5]

The technical small hydropower potential of Bosnia and Herzegovina is around 1,000 MW, at present there are about 25 small hydropower plants with a total capacity of 36 MW in the country (figure 2).[5] The 2007 Statement on the Security of Supply by the Energy Community of Bosnia and Herzegovina reported that the Government had awarded 100 concessions for the construction of small hydropower plants with a capacity of up to 5 MW (total of 200 MW).[6]

Renewable energy policy

No public institution has yet been assigned to be responsible for renewable energy sources in Bosnia and Herzegovina. The only existing support mechanism is based on two laws that set the minimum electricity purchase price to be paid to producers of renewable energy with an installed capacity of up to 5 MW (Official Gazette FB&H 32/2002 and Official, Gazette RS 71/2003).[7] Power utility companies in Bosnia and Herzegovina are required to buy the electricity produced from renewable energy sources. According to a source in 2009, the price for electricity from small hydro plants was 4.45 euro cents/kWh, which was lower than wind and solar.[5]

Barriers to small hydropower development

A report by the Economic Commission (2009) has reported these in the country: financial barriers such as low energy prices and potential for feed-in tariffs; lack of defined methodology for concession and permit delivery for small hydro projects; and the need for improved administrative procedures for small hydro project development. It is reported that numerous requests for construction of small hydropower plants had been made but progress in actual construction was limited, mainly due to lack of a relevant framework for their implementation and also limited capital availability.[5]

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4.3.3 Croatia

Pascal Hauser and Guillaume Albrieux, International Center on Small Hydro Power

Key facts

Population	4,480,043[1]
Area	56,594 km[2]
Climate	Mediterranean and continental; predominantly continental with hot summers and cold winters; along the coast: mild winters, dry summers
Topography	Geographically diverse; flat plains along Hungarian border, low mountains and highlands near Adriatic coastline and islands
Rain pattern	Annual average precipitation in Croatia is 975 mm, with values ranging from 650 mm in Eastern Slavonia to 3,800 mm in the area of Gorski Kotar.[2]

Electricity sector overview

Croatia's Energy Development Strategy set three basic energy objectives for the period until 2020: security of electricity supply, competitiveness of the energy system, and sustainability of energy development.

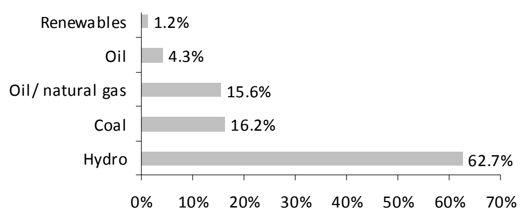

Figure 1 **Electricity generation in Croatia**
Source: Energy Regulator's Regional Association[3]
Note: 4.7 TWh imported.

For the projected electricity consumption of about 28 TWh in 2020, the Strategy envisages construction of 2,700 MW of base-load generating capacity, of which 300 MW is in large hydropower plants and 2,400 MW in thermal power plants.

It also foresees intensive construction of power generating facilities harnessing renewable sources, such as wind parks, small hydropower plants, biomass, biogas, geothermal and solar power plants. The objective is to maintain the share of production from large hydropower and renewable energy sources in total electricity production at present level so that it constitutes 35 per cent by 2020.[4]

The market opened up 100 per cent in July 2008. Power production, transmission, distribution and supply are all legally unbundled. Croatia is a net electricity importer (of 4.7 TWh in 2011).[3]

Small hydropower sector overview and potential

The installed capacity in Croatia is around 1,700 MW for hydropower storage plants and around 380 MW for run-of-river plants, resulting to an electricity production from hydropower sources of 8,309 GWh in 2010.[4] The total installed small hydropower capacity amounts to 39.65 MW (figure 2 and table). The definition for small hydropower plants in Croatia is less than 10 MW of capacity .[5]

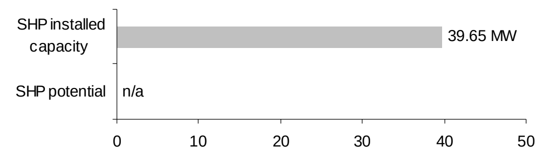

Figure 2 **Small hydropower capacities in Croatia**
Source: Beraković and others[5]

Installed small hydropower capacity in Croatia

Plant name	*Unit Number*	*Total capacity (MW)*	*Operating since*
SHPP Zeleni Vir	2	1.700	1922
SHPP Jaruga	2	7.200	1904
SHPP Ozalj I	2	3.600	1908
SHPP Ozalj II	2	2.200	1952
SHPP Zavrelje	1	2.000	1953
SHPP Krčić	1	0.440	1988
SHPP Čakovec	1	0.340	1982
SHPP Dubrava	2	0.680	1989
HPP Golubić	2	7.500	1981
PHPP Fužine	1	4.600	1957
PHPP Lepenica	1	1.140	1985
SHPP Čabranka Urh	1	0.008	..
SHPP Kupčina Bujan	1	0.045	..
SHPP Cotton industry "Duga Resa"	3	1.100	1937
SHPP Cement plant "10. kolovoz"	2	1.200	1913
SHPP Finvest I	4	1.260	1995
SHPP Finvest II	1	0.030	1997
SHPP Roški slap	2	1.772	1909/1998
SHPP Mataković	2	0.028	2004
HPP Varaždin	1	0.585	1975
HPP Čakovec	1	1.100	1982
HPP Dubrava	1	1.120	1989
Total		**39.648**	

Source: Beraković and others[5]
Note: SHPP – small hydropower plant, HPP – hydropower plant.

The Energy Strategy by the Croatian Ministry of Economy, Labour and Entrepreneurship (2009) set a goal to build at least 100 MW of small hydropower plants by 2020.[6] According to Validzic (2011), about 200 MW of small hydropower plants are in the pipeline.[7] Yet, no potential assessment is available.

Renewable energy policy

Using renewable energy is one of the strategic objectives within the national energy policy. Croatia has a goal to maintain 35 per cent of electricity generation share from renewable energy sources, including large hydropower plants, in its overall electricity consumption until 2020. It will promote a goal of renewable sources, including large hydropower plants, in final energy consumption of 20 per cent.[6]

Legislation on small hydropower

The feed-in tariff system in Croatia is comprehensive, with different tariff structures for plants smaller and larger than 1 MW, including a specific tariff for hydropower.[8] Only hydropower plants up to 10 MW are eligible.[9]

Barriers to small hydropower development

The small hydropower sector development needs high specific investments and faces limitations related to the environmental impact, cultural-historical heritage and landscape protection. In order to achieve the goals determined in the Energy Strategy, Croatia shall motivate the inspection of remaining water courses to determine the exact location and potential for construction, facilitate administrative procedures to obtain the necessary permits to construct small hydropower plants (particularly for small plants under 5 MW), and to harmonize energy legislation and other laws related to water management.[6]

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4.3.4 Greece

European Small Hydropower Association, Stream Map

Key facts

Population	10,767,827[1]
Area	131,957 km[2]
Climate	Temperate; mild, wet winters; hot, dry summers[1]
Topography	Mostly mountains with ranges extending into the sea as peninsulas or chains of islands
Rain pattern	Precipitation ranges from 1,210 mm in the north and the mountains to between 380 mm and 810 mm in the south.[2]

Electricity sector overview

In 2011, the total electricity production of Greece was 51,993 GWh, mainly based on fossil fuels (figure 1) with a total installed capacity of 15,397.5 MW.[3]

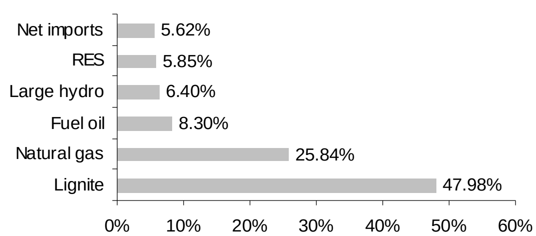

Figure 1 **Electricity generation in Greece**
Source: Regulatory Authority for Energy[3]

The new Energy Law 4001/2011 was adopted in August 2011, transposing the Third Energy Package into national legislation and increasing the authority of the country's regulator Regulatory Authority for Energy (RAE). The responsibilities of the Hellenic Transmission System Operator and the Public Power Corporation have been unbundled and distributed to new subsidiaries.[4]

Small hydropower sector overview and potential

In 2010, Greece had 98 small hydropower plants and a total installed capacity of 196 MW, producing 753 GWh of electricity (figure 2). By 2020, the aim is to have 175 plants with a total installed capacity of 350 MW (1,148 GWh).

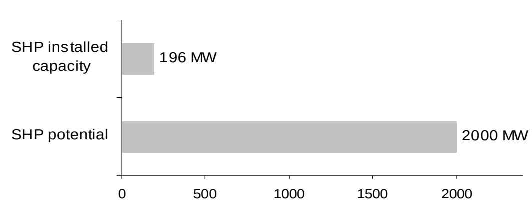

Figure 2 **Small hydropower capacities in Greece**

In the last three years, the trend of putting small hydropower plants into operation has slowed down. The main reasons are difficulties in financing the plants on behalf of the banks, the bureaucratic licensing environment, and the fact that on 31 December 2009, the time limit for Greece to adopt the EU Water Framework Directive expired. This has resulted difficulties in the Greek legal framework in terms of the Water Usage Framework. As a result, less than 10 installation licences have been issued during the last three years, which is a change to the previously very dynamic small hydropower sector up to 2008.

There is a long discussion in Greece about improving the supporting schemes and many new laws, ministerial decisions have been voted for in order to enforce the renewable energy sources development and consequently the small hydropower development. Although there is an obvious trend to unification and simplification of the legal framework, time is still needed for this to be achieved.

Renewable energy policy

The renewable energy target by 2020 is 18 per cent, according to Greece's National Renewable Energy Action Plan (NREAP).[5] The law for the 20-20-20 targets of Greece, passed in 2010 has set a very low target for small hydropower (350 MW) despite its high potential that is estimated at 2,000 MW.

Legislation on small hydropower

The legally binding residual water supply minimum flow that has to be allowed downstream by small hydropower plants must be equal to at least 50 per cent of the daily average water supply for the month of September. During the summer months (June to August), it should constitute 30 per cent of the daily average water supply.

In Greece, the support scheme that is in place for small hydro is a feed-in tariff (FIT). The respective law sets a FIT of €87.7/MWh (about US$117/MWh), up to 20 years, which could be further extended after the renewal of the operation licence. In the case that the small hydropower plant is constructed without any grants from the State, then there is a 20 per cent increase in FIT. Every year, there is a small increase according to a percentage of the yearly inflation and depending on the justified opinion of the Minister of Environment.

A new Ministerial Decision (Ministry of Environment, Energy and Climate Change, EFPE/518/05.04.2011) has been passed. It arbitrarily set limits on the magnitude of a small hydropower plant capacity according to the length of the stream diversion. This decision cancels more than 50 MW small hydropower plants that were already in the queue for receiving licences. In addition, the potential of energy development of small water currents (approximately 500 MW) is cancelled as well.

Barriers to small hydropower development

The transposition and implementation of the EU Water Framework Directive (2000/60/EC) in Greece and the completion of management studies of water districts under this Directive, public consultations for certain Greek areas for the ruling of the Streams were planned in 2011.

Increased awareness of environmental protection has led to a substantial decrease in potential small hydropower sites in mountainous areas where exclusion zones for small hydropower plants have been created.

As any concerned stakeholder can, at any stage of the licensing process, appeal the investment decision to The Council of State, this can often cause delays, risk of an investment being cancelled and potential economic losses for the investor and manufacturers.

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4.3.5 Italy

European Small Hydropower Association, Stream Map

Key facts

Population	61,261,254
Area	301,340 km^2
Climate	Predominantly Mediterranean; Alpine in far north; hot, dry in south
Topography	Mostly rugged and mountainous; some plains, coastal lowland
Rain pattern	Mean annual rainfall varies from about 500 mm on the southeast coast and in Sicily and Sardinia, to over 2,000 mm, in the Alps and on some westerly slopes of the Apennines.[1]

Electricity sector overview

In 2011, more than 86 per cent of electricity consumed in Italy was produced in the country (288,900 GWh) and 13.7 per cent (45,700 GWh) were imported (figure 1).[2]

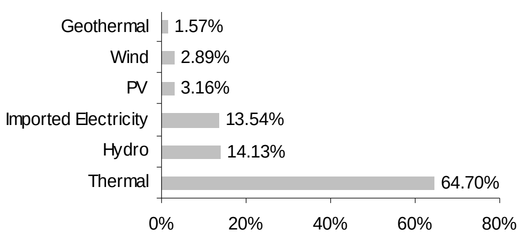

Figure 1 **Electricity generation in Italy**
Source: Terna[2]

The Authority for Electricity and Gas (AEEG) in Italy promotes the development of competition in the power market (Law n. 481/1995). Terna was created in 1999 as a separate company to own, develop and maintain more than 90 per cent of the National Electricity Transmission Network. Meanwhile management of the grid was entrusted to a public operator controlled by the Ministry of Finance called GRTN or Gestore della Rete di Trasmissione Nazionale (Independent System Operator Model). The electricity market was fully liberalized in 2007.[3]

Small hydropower sector overview and potential

In 2010, Italy had 2,427 small hydropower plants with a total installed capacity of 2,735 MW (10,958 GWh) in operation (figure 2). By 2020, the aim is to have 2,250 plants with a total installed capacity of 3,900 MW (12,077 GWh).[4]

Small hydropower plants up to 1 MW, in particular, are growing more than large hydropower plants thanks to the incentive system enforced at present which provides a comprehensive tariff of €220/MWh (about US$293) for the first 15 years. Due to the delay in the transposition and implementation of the EU Water Framework Directive, its effects on the production of small hydropower are not yet clear. The river basin management plans were adopted only at the end of February 2010.

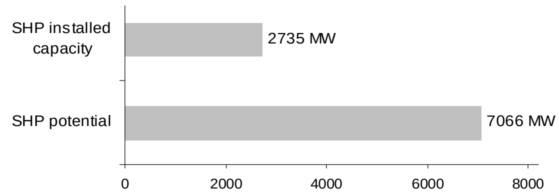

Figure 2 **Small hydropower capacities in Italy**
Source: European Small Hydropower Association[4], Giudici[5]

Renewable energy policy

According to the Italian National Renewable Energy Action Plan (NREAP), its renewable energy target by 2020 is 17 per cent).[6] The Legislative Decree No. 387/2003 (implementation of the Renewable Energy Directive) has introduced 'single permit', a one-stop shop system for all renewable energy sources project developers. The licence for the use of water is not generally integrated in the authorization process.

Legislation on small hydropower

The Italian Environmental Law 152/06 identifies the fields of application of reserved flow and the allocation of competences. The River Basin Authorities have to first identify the general criteria for reserved flow definition (within the specific competence of water balance planning). The Italian regions have the regulatory competence; they introduce the reserved flow regulation in the Water Protection Plans.

There are very different residual flow values, as there is a wide range of methods of calculation suggested by the River Basin Authorities (e.g. based on hydrological and morphological parameters or environmental conditions) and adopted by the Italian regions, so residual flow values can be very different along the same water body, going from one region to another.

Prior to 2013, hydro plants under 1 MW were guaranteed a minimum tariff for their electricity production, while plants 1-10 MW sold their energy at the hourly zonal price. Starting January 2008, a comprehensive feed-in tariff (electricity price plus incentive), which has been set to 22 euro cents/kWh applies to hydropower plants under 1 MW. This can be chosen for 15 years instead of Green Certificates. A new support scheme will come into force in January 2013.

Barriers to small hydropower development

Recommendations by Stream Map are as follows:[4]

- Stabilization of the incentive scheme: the incentive system should be clearly set out and all changes should be scheduled and timed, so that producers can properly plan their investments. In fact, hydropower developers need to know the rules at an early stage: how and under which conditions their projects will be sustained.

- Simplification of administrative procedure: at least for small hydropower plants located on irrigation channels, on water supply systems, integrated in existing dams or wastewater treatment facilities, and for the rehabilitation of old schemes.
- Suitable incentive support for the rehabilitation and upgrading of old plants, to avoid future losses in energy production and, in many cases, to get a chance to improve the schemes' performances also from an environmental point of view.
- Improvement of synergies between small hydropower and smart grids: hydropower has a role in supporting transmission and distribution grids by its capability to regulate frequency and to integrate other discontinuous renewable sources such as solar and wind. Besides large hydropower, small hydropower can also play a role, especially where it is possible to combine it with small basins and integrate it in hybrid systems. More research should be promoted on these aspects and a dedicated regulatory framework should be enforced.

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4.3.6 The former Yugoslav Republic of Macedonia

Pascal Hauser and Guillaume Albrieux, International Center on Small Hydro Power

Key facts

Population	2,060,563
Area	25,713 km^2
Climate	Warm, dry summers and autumns; relatively cold winters with heavy snowfall[1]
Topography	Mountainous territory covered with deep basins and valleys; three large lakes, each divided by a frontier line; country bisected by the Vardar River[1]
Rain pattern	Macedonia has transitional climate from Mediterranean to continental. Average annual precipitation varies from 1,700mm in the western mountainous area to 500 mm in the eastern area.[2]

Electricity sector overview

The former Yugoslav Republic of Macedonia (hereafter Macedonia) produces 70 per cent of its electricity from lignite, but these supplies are diminishing. Forty per cent of its energy production is dependent on imports, including oil and gas. Electric heating in the residential sector is one of the main reasons for the country's high energy consumption, making electricity imports necessary.[4] Hydropower generates around 15 per cent of Macedonia's electricity (figure 1).

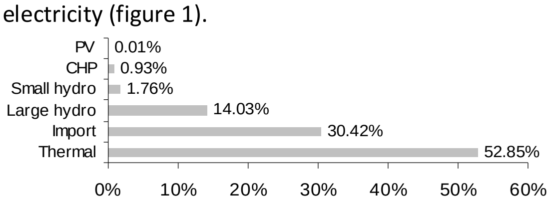

Figure 1 **Electricity generation in the former Yugoslav Republic of Macedonia**
Source: Energy Regulator's Regional Association[3]
Note: PV – photovoltaic, CHP – combined heat and power.

A project 'Capacity building of the Energy Regulatory Commission for Implementation of the New Energy Law' financed by Norwegian Ministry of foreign affairs, officially started on 1 January 2012 and will end on 31 December 2014. The main goal of this project is to ensure the conditions for healthy functioning of competitive, transparent and non-discriminatory energy markets. This project will provide initial support to enforcement of: supply rules in energy sector; rules for allocation of cross-border transmission capacity; rulebook on energy market monitoring, grid codes, market code, price/tariff regulation; and to revise the existing regulation adopted by Energy Regulatory Commission (ERC) of the Macedonia.[3]

Small hydropower sector overview and potential

The *2011 World Atlas and Industry Guide* repored that the country's installed small hydropower capacity as 45 MW, generating 103 GWh/year of electricity.[5] This is slightly different from the small hydropower electricity production of 159 GWh/year reported by the ERC.[3]

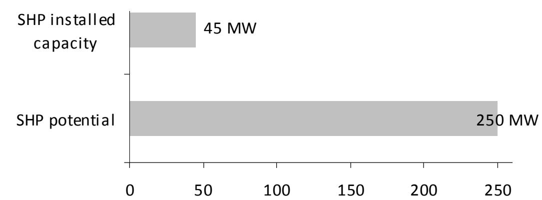

Figure 2 **Small hydropower capacities in the former Yugoslav Republic of Macedonia**
Sources: International Journal on Hydropower and Dams[5], Panovski and Janevska[6]

From 1927 to 1953, around 50 small- and micro-hydropower stations were built, the definition of small being a capacity of up to 5 MW. After that period, only large power plants were constructed, leading to the abandonment of many small hydropower plants.[7] In January 2011, the Ministry of Economy announced a public tender for 44 small hydropower plants with a total installed capacity of 28 MW. The concessions are for power plants to be built on the Vardar, Strumica and Crn Drim rivers. Recently there have been amendments to the law on water permit investments in small hydro schemes across the country.[8]

In 1982, the University in Skopje produced a study that confirmed a potential for construction of 406 small- and mini-hydropower plants with a total installed capacity of about 250 MW. The potential for small- and mini-hydropower (defined by units ranging from 50 kW to 5,000 kW installed capacity) was estimated at 1,088 GWh/year representing 17.5 per cent of the technically available hydropower potential in Macedonia.[4]

Renewable energy policy

Macedonia's renewable energy resources include hydropower, geothermal (greenhouse heating), biomass (heating of households), solar and wind energy.[4] The ERC is the main actor of the Renewable Energy Policy. This is an independent state authority that is responsible for the operation and decision making process within the scope of competencies prescribed by the Energy Law. It encourages wind energy development and prepared the guidelines on the construction of wind power plants in 2008.

Legislation on small hydropower

The feed-in tariffs (FIT) for small hydropower is dependent on the annual generation quantity:

- <1.02 GWh/y - 12 euro cents/kWh
- 1.02 - 2.04 GWh/y - 8 euro cents/kWh
- 2.04 - 4.2 GWh/y - 6 euro cents/kWh
- 4.2 - 8.4 GWh/y - 5 euro cents/kWh
- >8.04 GWh/y - 4.5 euro cents/kWh

The duration of the FIT is 20 years, and it is established by the Energy Commission.[9]

Barriers to small hydropower development

Many barriers are still present in Macedonia; legal and policy barriers, financial, management, information and technology. As a candidate member preparing for accession to the EU, Macedonia has changed some of its legislatives according to the EU Directives. Changes made were on laws on energy, expropriation and land issues which have direct impact on small hydropower plant development. Other changes are envisaged regarding the creation of one-stop-shop for small hydropower plant investors, the introduction of energy labels, rating and certification schemas in order to value renewable energy projects. Technical improvements are also envisaged with the completion of the national cadastre, the enforcement of the national hydrological measurement network and the integration of EU programmes for exploring and developing the small hydropower potential.[10]

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4.3.7 Montenegro

Pascal Hauser and Lara Esser, International Center on Small Hydro Power

Key facts

Population	645,000
Area	13,812 km^2
Climate	Prevalently Mediterranean climate, hot dry summers and autumns and relatively cold winters with heavy snowfalls inland[1]
Topography	Highly indented coastline with narrow coastal plain backed by rugged high limestone mountains and plateaus[1]
Rain Pattern	Annual average rainfall is 2,000 mm, locally up to 5,500 mm, with a maximum of 8,500 mm.[2]

Electricity sector overview

The Kosovo conflict in 1999 severely damaged the infrastructure in Montenegro. The energy generation depends almost entirely on hydropower and lignite resources. Energy efficiency is an issue especially with regard to heating based on electricity.[3 4]

Emergency grants are in place to help rebuild the damaged systems, focusing in the short- and medium-term on the reconstruction of electricity infrastructure. Therefore, renewable energy development will have a lower priority for now, except for the reconstruction of damaged hydropower facilities. There are currently no feed-in tariffs for renewable energy.[3]

In 2011, a total of 2,679 GWh electricity was produced nationally with 1,050 GWh imported. Hydropower dominates the electricity mix (figure 1). The electricity market was opened in 2009 for all sectors except households. It will be opened for households in 2015.[5]

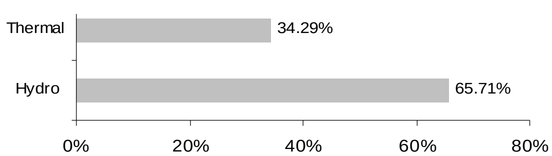

Figure 1 **Electricity generation in Montenegro**
Source: Elektroprivreda Crne Gore[6]

Small hydropower sector overview and potential

So far only about 17 per cent of Montenegro's total hydropower potential has been utilized, mostly in larger power plants. Aware of the situation, the country's Ministry of Economy promotes utilization of hydropower through issuing concessions for hydropower plants.[7] In 2011, 15 companies expressed interest in developing Montenegro's small hydropower potential.[8]

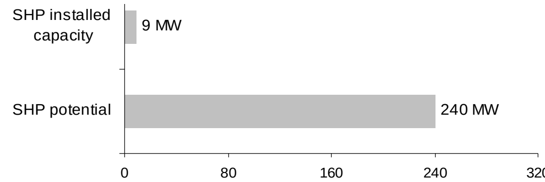

Figure 2 **Small hydropower capacities in Montenegro**

The installed capacity of the seven existing small hydropower plants amounts to 8.92 MW with an average annual production of about 21.4 GWh. The remaining technical hydropower potential of small hydropower plants (excluding the rivers of Tara, Cehotina and Ibar) is estimated at 231 MW and 644 GWh/year, in 70 locations.[9]

Montenegro has a Clean Development Mechanism project that includes the construction of small hydropower plant Otilovici. It uses the excess flow of water from an existing accumulation, in a way that does not change the water regime or the river flow downstream. The construction is scheduled for June 2012 with inauguration in June 2014. The planned electricity production of this is 11.52 GWh.[10]

Renewable energy policy

Montenegro does not have an official renewable target for 2020 and is highly dependent on electricity imports. Fortunately it has significant potential in local renewable energy sources to reduce this dependence[11]. The Energy Development Strategy of Montenegro has a goal to have at least 20 per cent of renewable energy sources in primary energy consumption by 2025, in accordance with the objectives set by the European Commission.[7] The new Energy Act (passed in April 2010) provides incentives for using renewable energy sources and encourages cogeneration.

Legislation on small hydropower

A Small Hydro Development Strategy was adopted in 2006 as part of the energy sector reform.[5]

The Montenegrin Energy Law (Article 32) states that electricity producers operating power plants with an installed capacity of up to 10 MW based on renewable resources, have the right to sell the electricity generated to the distribution network at a price that is calculated with the methodology adopted by the Ministry of Economy.

The Ministry of Economic issued Guidelines for defining the calculation methodology for purchase price for electricity from small hydropower plants (based on the decision 08/1031-1 02.06.2008). The small hydropower production may reach up to 3.5 per cent to cover the annual balance needed for electricity, in accordance with the strategy for development and construction of small hydropower plants in Montenegro.[12]

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4.3.8 Portugal

European Small Hydropower Association, Stream Map

Key facts

Population	10,781,459
Area	92,090 km^2
Climate	Maritime temperate; cool and rainy in north, warmer and drier in south[1]
Topography	Mountainous north of the Tagus River, rolling plains in the south.
Rain Pattern	In the north average rainfall is 1,250 mm to 1,500 mm, with occasional snowfall. In the centre rainy winters with 500 mm to 750 mm average annual rainfall. In the south rainfall does not exceed 500 mm along the coast.

Electricity sector overview

The total national electricity production of Portugal was 54,048 GWh in 2010, with thermal energy dominating the electricity mix (figure 1). Two sub-systems exist, the public electricity system (PES) and the independent electricity system (IES). The PES is obliged to assure the supply of electricity to the continental territory. The Portuguese National Transmission Network is interconnected with the Spanish Electricity Network at nine points. Since 2007, the joint Iberian electricity market was established between the two countries, known as Mercado Ibérico de Electricidade.[3]

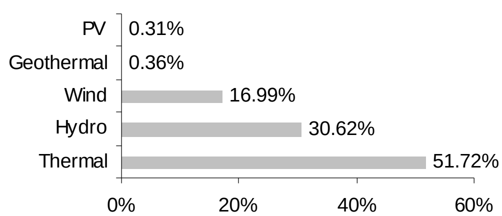

Figure 1 **Electricity generation in Portugal**
Source: Statistics Portugal[2]

Small hydropower sector overview and potential

In 2010, Portugal had 155 small hydropower plants with a total installed capacity of 450 MW generating 1,370 GWh (figure 2). By 2020, the aim is to have 250 plants with a total installed capacity of 750 MW (2,032 GWh).[4]

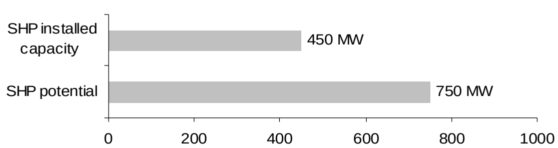

Figure 2 **Small hydropower capacities in Portugal**

Renewable energy policy

Portugal aims for a-60 per cent renewable share for its electricity generation by 2020 in order to satisfy 31 per cent of its final energy consumption by renewable energies.

According to the National Renewable Energy Action Plan (NREAP), small hydropower should contribute 1,511 GWh in 2020, corresponding to a total installed capacity of 750 MW – an increase of around 300 MW. For this purpose, the NREAP projected the definition of a specific plan for small hydropower to develop the existing potential. However, no plan is in place yet and the identified barriers have not been mitigated.

Legislation on small hydropower

There is no regulation published on establishing residual flow. Yet, there are indications that the ecological flow in Portugal should be, on average, 5-10 per cent of the modular flow. Also, this flow should be variable during the year to enable a better adjustment to the differences in the natural hydrological regime and to the spawning seasons. The residual flow would be the sum of the ecological flow with flow necessary for the existing uses as irrigation and water supply.[4]

In Portugal, the support scheme in place for small hydropower is its feed-in tariff (FIT). The Decree-Law 225/2007 indicates an average reference FIT of 7.5-7.7 euro cents/kWh, with a limit to the first 52 GWh/MW or up to 20 years, whichever is reached first. It could be increased to 25 years in exceptional cases. In 2010, a new tariff was defined by the Decree-Law 126/2010 specifying for the public tender launched in that year: 9.5 euro cents/kWh, up to 25 years.[4]

Barriers to small hydropower development

In 2012, the Decree-Law 25/2012 was published, ceasing the award of connections to the grid for all projects of power plants under Special Regime. A month later, the Dispatch 3316/2012 came into power, applying the referred Decree-Law specifically to the small hydropower sector. This meant that not only 'freezing' of all projects, but also invalidating all private initiatives pending on the authorities responsible for the licensing of these power plants., Out of the approximately 700 MW small hydropower potential to be installed and the 250 MW projected potential referred to in the Cabinet Resolution 72/2010 and Decree-Law 126/2010, until now only 150 MW were made available for development. So far only a few projects have actually taken off, while the rest are still undergoing environmental impact studies. Due to these changes in support, uncertainty exists among developers regarding the possibilities of developing new small hydropower plants in Portugal. With respect to public support and social acceptance of small hydropower development, there is no major opposition at the moment to small hydropower.

Further progress can be made in the area of licensing:[4]

- Licensing procedure suitable for small hydro projects can be better coordinated between the national authorities responsible for the process with simplified administrative procedures.
- Instead of launching new tenders, authorities should take advantage of the studies already produced in analysing whether or not to approve submitted licensing applications.
- Establishment of solid criteria to concede licences to develop small hydro, for example, the quality of the projects and the experience of the promoter.
- Establishment of a 'one-stop shop' for potential investors.

Environmental, technical and financial constraints are as follows:

- The analysis and discussion of the imposing minimum ecological flows and compensatory measures for implementing small hydropower involve a joint force between the national authorities and the project developer.

Support mechanisms can be improved as described below:

- Adapting FIT and the concession period to the characteristics of the country (Portugal has a large intra-annual variability in water run-off).
- Introduction of a specific tariff for pump storage on small hydropower plants in Portugal.

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4.3.9 Serbia

Pascal Hauser and Lara Esser, International Center on Small Hydro Power

Key facts

Population	7,292,574
Area	77,474 km^2
Climate	Continental in the north (cold winters and hot, humid summers with well distributed rainfall; continental and Mediterranean climate (relatively cold winters with heavy snowfall and hot, dry summers and autumns) in other parts
Topography	Extremely varied; to the north, rich fertile plains; to the east, limestone ranges and basins; to the southeast, mountains and hills.
Rain pattern	Annual precipitation varies from 550 mm to 650 mm in Vojvodina to 800 mm to 1,200 mm in the mountainous regions. All the lower areas, including the lower Drina basin, have annual precipitation of below 800 mm.[2]

Electricity sector overview

The total electricity production of Serbia in 2010 was 35,900 GWh.[1] Serbia depends on imports of oil and gas for about 40 per cent of its energy. Hydropower accounts for around 30 per cent of its electricity generation, the rest is generated from thermal power plants (figure 1).[3]

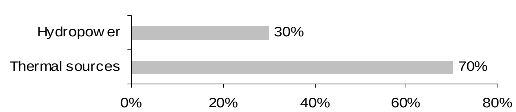

Figure 1 **Electricity generation in Serbia**
Source: Austrian Energy Agency[3]

Serbia's economy is highly energy intensive, in fact its energy per unit of output ration is 2.7 times more than the average of the Organisation for Economic Co-operation and Development (OECD). While energy efficiency is a priority in its energy strategy, Serbia has not yet adopted the planned framework law on rational use of energy.[4]

Serbia adopted the Energy Sector Development Strategy in 2005. An implementation plan followed in 2007 and has most recently been updated in 2010. The development of a new energy strategy for a period of at least 15 years is projected under a new Energy Law that was adopted in 2011. As a member of the Energy Community, Serbia is legally bound to implement large parts of the EU Acquis Communautaire on energy, the new Energy Law represents a substantial step in that direction.[4]

Small hydropower sector overview and potential

Small hydropower, defined as less than 10 MW capacities, has a potential of around 1,800 GWh/year.[3] By using the total energy potential of small hydropower plants, it is possible to meet 4.7 per cent of total power production and around 15 per cent of power production from hydropower plants (see above). The energy potentials of streams for different locations are documented in the Cadastre of Small Hydropower Plants in Serbia, dating from 1987. Construction on places outside the cadastre is also possible with consent of the Ministry of Mining and Energy and other competent ministries and institutions, given the maximum utilization of the potential.

A summary of 38 municipalities with the biggest potential for the construction of small hydropower plants indicates 711 locations with a potential of 409 MW (1,459 GWh/year).[5] Small hydropower installed capacity is close to 50 MW (figure 2).

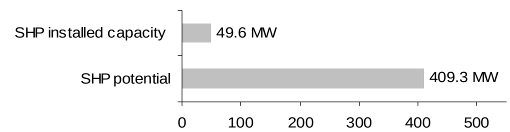

Figure 2 **Small hydropower capacities in Serbia**
Source: Serbia Energy[5], *International Journal on Hydropower and Dams*[6]

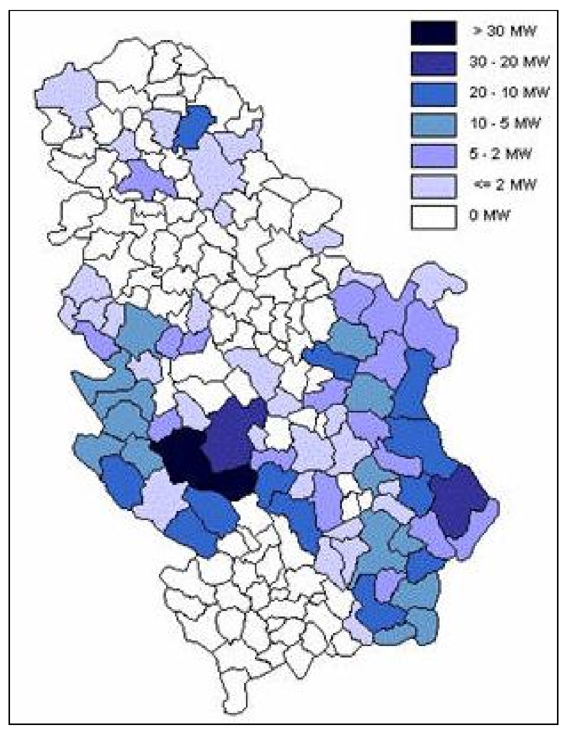

Figure 3 **Map showing the total installed small hydropower capacity**
Source: Renewbl.com[7]

Renewable energy policy

Serbia has a largely untapped and significant potential for renewable energy. Hydropower is the most important potential as compared to other energy sources, at approximately 17,000 GWh, with 10,000 GWh currently in use. Other than hydropower, only biomass has been partly developed as an renewable energy source.[3]

Feed-in tariffs exist, but the administrative procedures for authorization, licensing and network connections are the biggest barrier for the use of renewables.[4]

Serbia took upon itself to increase the share of renewable energy in total energy consumption from 21.2-27 per cent by 2020. Before autumn 2013, key documents regulating the energy sector should already be in place, such as the new Energy Development Strategy of the Republic of Serbia by 2025 with development projections up to 2030.[8]

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4.3.10 Slovenia

European Small Hydropower Association, Stream Map

Key facts

Population	1,996,617
Area	20,273 km^2
Climate	Mediterranean climate on the coast, continental climate with mild to hot summers and cold winters in the plateaus and valleys to the east[1]
Topography	A short coastal strip on the Adriatic, an alpine mountain region adjacent to Italy and Austria, mixed mountains and valleys with numerous rivers to the east
Rain pattern	Total annual amount of precipitations was 1,552 mm (in 2009). The amount of precipitation differs significantly between months. Most meteorological stations recorded maximum amounts in December and minimum amounts in May or September[2]

Electricity sector overview

The electricity market in Slovenia was fully opened on 1 July 2007. Since the electricity market was liberalized, industries and households have been free to choose their supplier of electricity. Distributors are able to set prices. Unbundling is limited to accounts only for the time being. The Energy Act stipulates that transmission, distribution and operation of the relevant networks and supply of electricity to tariff customers are compulsory national commercial public services. Hydropower accounts for 22.60 per cent of the electricity generation (figure 1).

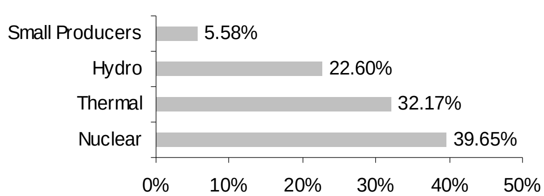

Figure 1 **Electricity generation in Slovenia**
Source: Energy Agency[3]

Small hydropower sector overview and potential

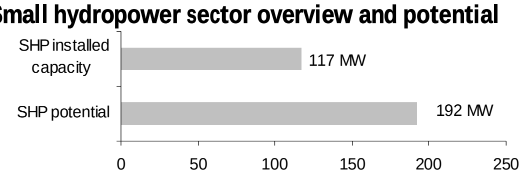

Figure 2 **Small hydropower capacities in Slovenia**
Note: Potential based on planned 2020 capacity.

In 2010, Slovenia had 535 small hydropower plants and a total installed capacity of 117 MW (465 GWh). By 2020, the aim is to have 568 plants with a total installed capacity of 192 MW (758 GWh). The remaining potential cannot be analyzed at this time due to lack of official and reliable data (figure 2).[4]

Renewable energy policy

The Renewable Energy Framework Directive is already fully implemented in the Slovenian energy legislation with the new Energy Act (September 1999), the secondary legislation and the Renewable Energy Sources Action Plan (July 2010). With its binding targets it has a positive impact on the renewable energy sources development.[4]

The EU Water Framework Directive (WFD) is only partially implemented, with the regulation on heavily modified water bodies still missing. In the case of small hydropower, it is understood this is served as a protective legislation, which means that the authorization procedures, especially for the concession, are blocked. The lack of the clear governmental policy and harmonization efforts to bring the two (Renewable Energy Framework Directive and WFD) seemingly opposite interests closer together is the core cause for the slow development of the small hydropower sector.[4]

The Slovenian renewable energy sources target for 2020 is 25 per cent. According to the Renewable Energy Sources Action plan (July 2010):

- The Ministry of the Environment and Spatial Planning will solve the blocked small hydropower concession applications.
- The Ministry of Economy will provide a study of the costs and benefits of existing small hydropower that will serve as a baseline for the sustainable criteria, considering environmental, social and economic effects.

The Action Plan estimated that the country's small hydropower shows a very low increase of installed capacity and annual generation from 2005 to 2020 – 22 per cent and 33 per cent respectively.

Legislation on small hydropower

Residual flow is regulated by Government's Decree (No. 97/2009, 30.11.2009) and calculated using a formula. A feed-in tariff with a premium (Government's Decree (No. 37/2009, 18.5.2009) exists to financially support electricity from renewable energy sources. The methodology for price calculation is based on total annual operational production costs. This includes investment, operational and maintenance costs. The depreciation period is 15 years and the discount rate is 12 per cent.[4]

The small hydropower plants are divided into three categories given their installed capacity: Pi < 50 kW, Pi <1000 kW and Pi <10,000 kW. The guaranteed purchase prices are (in €/MWh):

- €105 (< 50 kW)

- €93 (< 1,000 kW)
- €82 (< 10,000 kW)

In 2009, the premium was determined by the reference market price of €65/MWh, such as:

- €55.9 (< 50 kW)
- €55.9 (< 1,000 kW)
- €58.5 (< 10,000 kW)

The premium already comprised within the guaranteed purchase price. Only small hydropower plants less than 15 years are eligible for the support.

Barriers to small hydropower development

The general atmosphere is quite tense regarding all renewable investments that are potentially causing any environmental impact. While there is public support towards renewable energy sources and lowering greenhouse gas emissions, social acceptance is low among local communities when it comes to some projects.

Complicated administrative procedures, lack of knowledge by landowners and information overload, as well as missing responsibilities from the investments opponents are part of the problem. Further progress can be made in the area of authorization process and financial stability:

- Simplification of the authorization procedure to shorten and accelerate the process. Delegate some of the procedures handling (e.g. for micro hydro under 100 kW) to local authorities, allow one-stop shop service (i.e. authorities should do preliminary work such as identifying potential locations and perform all necessary legal and technical actions), standardize application forms and allow electronic applications and follow-up (and to ensure transparency), standardize grid access.
- Compare positive impacts of small hydropower with environmnetal requirements and find compromise to use the maximum of available energy which is justifyable in view of environmental regulations.
- Harmonize the implementation of the WFD on the Member States level with the Renewable Energy Framework Directive declarations and Action Plans. No blockage due to the missing legislation should be allowed.
- Decrease the investment insecurity by stabilizing the prices within the support system in the long term.
- Increase the banking support and trust among bankers and investors.
- Introduce temporary reliefs on taxes and other duties.

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4.3.11 Spain

European Small Hydropower Association, Stream Map

Key facts

Population	47,042,984
Area	505,370 km^2.[1]
Climate	Temperate; clear, hot summers in interior, more moderate and cloudy along coast; cloudy, cold winters in interior, partly cloudy and cool along coast
Topography	Large, flat to dissected plateau surrounded by rugged hills; Pyrenees Mountains in north
Rain pattern	Average annual precipitation is 650 mm. In 'wet' Spain as a whole this rises to around 1,000 mm, in semi-arid areas 300 mm.

Electricity sector overview

The total net electricity production in Spain was 280 TWh in 2011, of which approximately 6 TWh was exported and 3 TWh was used for pumped hydro. The domestic demand was about 270 TWh.[2] The electricity mix is shown in figure 1.

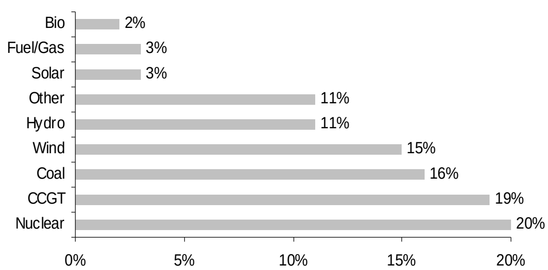

Figure 1 **Electricity generation in Spain**
Source: Red Electrica de Espana[2]

Small hydropower sector overview and potential

In 2010, Spain had 1,047 small hydropower plants and a total installed capacity of 1,926 MW generating 4,719 GWh (figure 2). By 2020, the aim is to have 1,100 plants with a total installed capacity of 2,185 MW (6,280 GWh).[3]

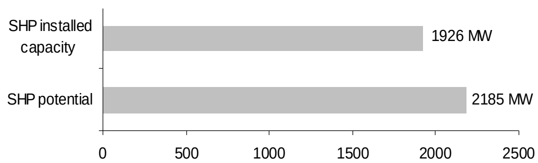

Figure 2 **Small hydropower capacities in Spain**

The average small hydropower growth over the last 10 years had barely reached 2.1 per cent annually, this translates into a capacity increase of 36 MW per year on average. Growth was low due to a series of barriers that have virtually paralyzed the sector. The previous Renewable Energies Plan (PER) 2005-2010 set out for small hydropower sector to achieve a total installed capacity of 2,199 MW by 2010. This was not achieved for plants under 10 MW by 2010.

Renewable energy policy

In 1981, the first Royal Decree was approved, establishing fixed tariffs for small hydropower and thereby, paving the way for the Special Regime for electricity production based on renewable energies introduced in the mid-1990s. Besides, the development of small hydropower laid the ground for the involvement of the banking sector regarding financing renewables in Spain.[i]

Legislation on small hydropower

There is currently no regulation published concerning the residual flow. A recommendation could be made in the sense that this flow should be variable during the year, to enable a better adjustment to the differences of the natural hydrological regime and to the spawning seasons.

There are two different support options (following the current promotion scheme as established through the Royal Decree 661/2007), a feed-in tariff (FIT) and a market premium with a cap and a floor, on the sum of market price and premium.

Plants with a rated power less than 10 MW as well as those with a rated power greater than 10 MW (but less than 50 MW) are considered small-scale hydropower plants. However, on 27 January 2012, the Spanish Council of Ministers approved a Royal Decree-Law 'temporarily' suspending the FIT pre-allocation procedures and removing economic incentives for new power generation capacity involving cogeneration and renewable energy sources (RES-E).

Barriers to small hydropower development

In Spain, it takes an average of six years to obtain the permits for construction and operation, and there are numerous requests for hydropower concessions pending for longer time, some reaching 20 years. This is mainly because of the lack of coordination between the different authorities responsible for the permit procedures.

Furthermore, there is an increasing number of administrative and economic barriers for small hydropower through new preconditions for participating in the electricity market, such as the management of deviations, rules regarding the ride through of voltage dips and new flow measurement systems. In addition, there is an increase of existing taxes, as building permits to introduce the electromechanical elements of the small hydropower plants, as well as new taxes and fees for the existence of reservoirs and later a qualified (real) property tax (IBI), royalties, land value taxes. Likewise, there is a growing difficulty to obtain the necessary construction sites as the land-owners are demanding higher compensations to make them available. It is also important to state the difficulty felt to obtain grid connection for affordable prices and that there have been problems with the expiration of concessions of existing plants with no solution on the horizon.

Another important administrative and economic hurdle is the pre-allocation registration, where all renewable electricity production units must be included before being allowed to join the Special Regime and that has established a vast number of preconditions as described above (cf. power granting schemes).

With the moratorium[ii] in place, especially if it became effective for a longer period and having in mind the long lead times of new small hydropower facilities in Spain, it is more likely that the new national small hydropower target for 2020 (both in the Spanish National Renewable Energy Action Plan in the new PER 2011-2020) of 2,185 MW will not be fulfilled.

In any case, even to fulfill these (very) modest small hydropower targets for 2020, besides maintaining a stable and foreseeable support scheme for small hydropower within the Special Regime, it will be necessary to establish measures such as:

New rules for administrative procedures and concessions:

- Streamlining current procedures for water planning in the river sections where hydropower plants can be implemented under certain conditions, such as residual flows.
- Establish a new unified administrative procedure for water concessions, or modification of the existing ones, applicable for hydropower plants up to 50 MW.
- Promotion of tenders in existing public infrastructures, with new rules for the renovation of concessions and the possibility of modification of concessions already granted.
- Establish the possibility to modify existing water concessions for electricity generation by the responsible authority (i.e. to avoid the process of competing for water concession in cases where the modification does not cause an increase or decrease of the maximum flow nor of the capacity installed greater than 50 per cent of the originally amounts granted and consistent with the River Basin Management Plan in force).

New frameworks/incentives for new types of plants and for rehabilitation, modernization and replacement of facilities:

- Develop a regulatory framework to promote the development of reversible hydropower plants or expand existing ones. Take advantage of existing infrastructure, consistent with current water planning and preserving the environmental.
- Incentivize the rehabilitation, modernization and/or replacement of existing small hydropower.

Promote the rise of the available hydropower potential in the territory of the Hydrographic Confederations[iii] by conducting specific studies to analyze the technical, economic and environmental feasibility of up to 41 state-owned dams to be used as hydropower plants and drafting of the specifications that will serve as a basis for tenders for those classified as viable.[3]

Notes

i. In February 2013, the Spanish Government decided to abolish the remuneration option for Renewable Energy Directive (RES-E) power based on the market price and feed-in premium. It changed the mechanism of indexing RES-E remuneration to the consumer price index and decoupled it from food and fuel price increases.[4]

ii. The Spanish administration passed down the Royal Decree 1/2012 that suspends feed-in tariffs for newly installed generators of renewable power.

iii. The Hydrographic Confederations are public entities in charge of river basins under the Ministry of Environment, Rural and Marine Affairs of Spain; and autonomous bodies under the Department of State for Water and Rural Affairs.

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4.4 Western Europe

European Small Hydropower Association, Stream Map

Introduction to the region

Western Europe includes nine countries, seven of which use small hydropower (excluding Monaco and Liechtenstein). The dominant climate is continental and temperate, with a maritime climate on the coast.

In order for the European countries to achieve their renewable energy targets by 2020, including the integration of large amount of wind power to the European electricity transmission system, new infrastructure is crucial. Based on the European Union Third Energy Package and the conclusions of the European Council in February 2011, an internal harmonized electricity market should be completed by 2014. The regulators of Belgium, France, Germany, Luxemburg and the Netherlands are part of the Central West Electricity (CWE) regional initiative led by the French Regulatory Commission for Energy, while Austria's regulator leads the Central Eastern (CEE) regional initiative.[1] The aim of all European regional initiatives is a continuous intraday trading system across Europe.

Table 1

Overview of countries in Western Europe

Country	Total population (million)	Rural population (%)	National electricity access (%)	Electrical capacity (MW)	Electricity generation (GWh/year)	Hydropower capacity (MW)	Hydropower generation (GWh/year)
Austria[ah]	8.22	32	100	21 400.0	71 075	12 665.00	42 990
Belgium[abgh]	10.44	3	100	15 802.0	91 000	107.00	300
France[ah]	65.95	15	100	123 500.0	550 300	21 300.00	68 000
Germany[ach]	81.15	26	100	172 400.0	612 000	4350.00	19 147
Luxembourg[adh]	0.51	15	100	1 655.3	4 538	39.54	102
Netherlands[aeh]	16.81	17	100	26 600.0	118 138	37.60	109
Switzerland[afh]	8.00	26	100	17 885.0	63 723	12 297.00	37 450
Total	**191.08**	**-**	**-**	**379 242.3**	**1 510 774**	**50 796.14**	**168 098**

Sources:
a. International Journal on Hydropower & Dams[2]
b. Belgian Commission for Electricity and Gas Regulation[3]
c. Bundesnetzagentur[4]
d. Institut Luxembourgeois de Régulation[5]
e. Tennet[6]
f. Swiss Bundesamt fuer Energie[7]
g. European Commission[8]
h. Photius[9]

Small hydropower definition

Among the different countries, various small hydropower definitions are applied (table 2).

Table 2

Classification of small hydropower in Western Europe

Country	Small (MW)	Mini (MW)	Micro (kW)	Pico (kW)
Austria[a]	up to 10			
Austria	2-10	0.6-2.0	5-500	up to 50
Belgium	..			
France[b]	< 12 or < 10	0.5-2.0	up to 500	
Germany[a]	up to 1			
Germany[c]	up to 5			
Luxembourg[d]	1-6	Up to 1		
Netherlands[b]	up to 15			
Switzerland[c]	1-10	0.1-1.0		

Sources:
a. Platform Water Management in the Alps[10]
b. Agence locale des Énergies et du Climat[11]
c. European Small Hydropower Association[12]
d. International Energy Agency and Organization for Economic Co-operation and Development[13]

Regional overview

Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland are the seven countries that use small hydropower. Small hydropower support mechanisms exist in all countries through tradable green certificates (Belgium), investment support or subsidies (the Netherlands, and for Austria from 2010 onwards), and feed-in tariffs (Austria, France, Germany, Luxembourg, Switzerland). The Water Framework Directive is being implemented in all European Union Member States (only Switzerland is not part of the European Union).

The total installed small hydropower capacity (defined as up to 10 MW) is around 6,000 MW in Western Europe. France has the highest installed small hydropower capacity, followed by Germany, Austria and Switzerland.

Table 3

Small hydropower up to 10 MW in Western Europe

Country	*Potential (MW)*	*Planned SHP (MW)*	*Installed capacity (MW)*	*Annual generation (GWh)*
Austria	1 300	191	1 109	4 983
Belgium	92	31	61	191
France	2 615	505	2 110	6 920
Germany	1 830	98	1 732	8 043
Luxembourg	44	10	34	100
Netherlands	at least 3	..	3	8
Switzerland	at least 760	..	760	3 400
Total	**6 644**	**>835**	**5 809**	**23 645**

Sources: See country reports.

Table 3 shows the installed small hydropower capacities, most of the information on small hydropower potential was not available so planned capacity additions was reported instead.

The Stream Map project[i] reveals that during the last 10 years new small hydropower potential in Western Europe has been greatly affected by environmental legislation, especially for sites in designated areas, such as Natura 2000, and sites affected by the Water Framework Directive, among others. Mitigation measures will add to the costs of electricity generation. Germany, the fourth largest country with regard to small hydropower installed capacity within the EU, experiences the biggest reduction of its hydropower resource; only 7 per cent of the economically feasible potential can be realized under current conditions. Slightly larger environmentally compliant potential has been identified in France (some 50 per cent). In Austria the Stream Map project, for example, recommends higher economical support to cover the additional environmental costs.[14]

Note

i. The Stream Map project was co-funded by the Intelligent Energy Europe Programme of the European Commission. It aimed to define a clear and consistent roadmap in Europe for the small hydropower sector. It was completed in 2012.

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4.4.1 Austria

European Small Hydropower Association, Stream Map

Key facts

Population	8,219,743
Area	83,871 km^2
Climate	Temperate, continental. Cloudy, cold winters with frequent rain and some snow in lowlands and snow in mountains; moderate summers with occasional showers[1]
Topography	Mountainous in the west and south (Alps); along the eastern and northern margins mostly flat or gently sloping[1]
Rain pattern	Rainfall ranges from more than 1,020 mm annually in the western mountains to less than 660 mm in the driest region, near Vienna.[2]

Electricity sector overview

The total electricity production in Austria was 71,075 GWh in 2010, with hydropower generating more than 56 per cent (figure 1).[3] Most of the imported electricity comes from Germany and Czech Republic.

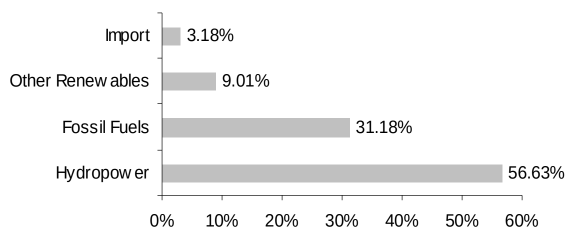

Figure 1 **Electricity generation in Austria**
Source: Ministry for Economy, Family and Youth[3]

Small hydropower sector overview and potential

In 2010, Austria had 2,589 small hydropower plants and a total installed capacity of 1,109 MW (4,983 GWh). By 2020, the aim is to have 2,870 small hydropower plants, with a total installed capacity of 1,300 MW (6,050 GWh) (figure 2).

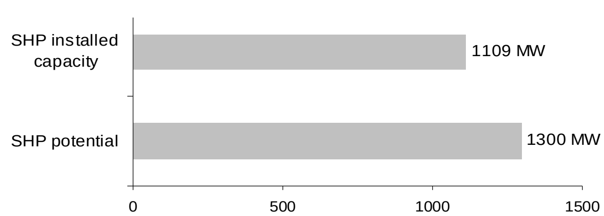

Figure 2 **Small hydropower capacities in Austria**
Note: Potential is based on planned capacity by 2020.

Renewable energy policy

Austria's 2020 renewable energy target, according to its National Renewable Energy Action Plan, is 34.2 per cent.[4] Electricity from renewable sources is supported mainly through a feed-in tariff (FIT), which is set out in the Green Electricity Act (ÖSG or Ökostromgesetz, last amended in 2012) and the regulations related thereto. The construction of small- and medium-sized hydropower plants is subsidized under the Subsidy Directive 2010 on the granting of investment subsidies, as set out in Sec. 12, Sec. 12a and Sec. 13a of the Green Electricity Act (ÖSG), for the construction of combined heat and power (CHP) plants and small- and medium-sized hydropower plants.

Legislation on small hydropower

Since 2010 there is a regulation in force (Qualitätszielverordnung) giving recommendations on residual flow, based on three criteria using formulas. These formulas provide values being suitable to meet the ecological demands. If an owner is willing to carry out a more detailed hydro biological study, proving that less residual flow will provide sufficient ecological quality, the values calculated by the formula may be lowered.

Before 2003 the federal states of Austria had individual tariff regulations. In 2003 a country wide FIT system was implemented. The amount varies between 33 and 62 €/MWh (about US$43 to US$81 per MW) depending on the amount of production and renovation efforts of the owner. The tariff was guaranteed for 13 years.

Starting from 2010 an investment support system has been installed replacing the FIT system:

- <50 kW: 1,500 €/kW (about US$1,950 /kW);
- 50 – 500 kW: 30 per cent of investment (max. 1,500 €/kW (about US$1,950/kW));
- 500 – 2000 kW: 20-30 per cent of investment, (max. €1,000-€1,500/kW (about US$1,300 - US$1,950/kW));
- 2 – 10 MW: 10-20 per cent of investment (max. €400-€1,000/kW (about US$520US$1,300/kW)).

Existing plants running under the FIT system will continue getting the tariff. The new system is only valid for new plants erected and set into operation after 2010.

The leading law in hydropower development is the Water Act regulating everything dealing with water. The Water Framework Directive (WFD) is implemented there. Additional requests are based on the environmental protection law, the forest law and the spatial planning laws. Finally the Green Electricity Act regulates support.

Barriers to small hydropower development

Concerns on the main environmental topics like reserved flow and fish bypassing the requests from the Government are continuously increasing and sometimes the consensus already reached is not stable and reliable.

The development of small hydropower is far behind the targets and there is no indication that the situation will change. There is a large gap between the general political obligation to increase the renewable energy production also coming from small hydropower and the reality of granting procedures which are often delayed.

The support scheme has been changed in 2010 from FIT to investment support. Recently, it has become possible to choose among these two options. Small hydropower operators prefer FIT. The administrative procedures have become more difficult due to additional requests from the Government executing the WFD. The budget dedicated to the support scheme is limited and in some years the requests coming from the owners exceed the money available.

The general opinion of mass media is very critical towards the development of small hydropower. However, the local population does not have a unique position and is predominantly in favour of small hydro. Social acceptance depends on the individual project and the benefits deriving from the project.

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4.4.2 Belgium

European Small Hydropower Association, Stream Map

Key facts

Population	10,438,353
Area	30,528 km^2
Climate	Temperate; mild winters, cool summers; rainy, humid, cloudy
Topography	Flat coastal plains in northwest, central rolling hills, rugged mountains of Ardennes Forest in southeast[1]
Rain pattern	Except for the highlands, rainfall is seldom heavy. Average annual precipitation is between 700 mm and 1,000 mm.[2]

Electricity sector overview

Total installed production capacity of Belgium was 15,802 MW in 2010. Net consumption plus network losses were estimated at 91,000 GWh in 2010. Nuclear energy provides more than half of the country's electricity (figure 1).[3]

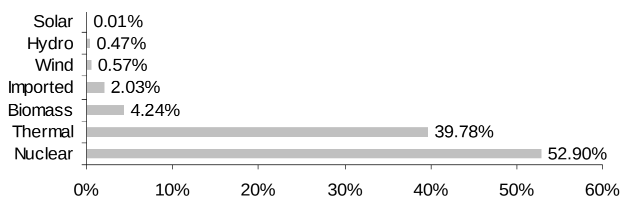

Figure 1 **Electricity generation in Belgium**

Source: London Research International[4], Indexmundi[5]

Small hydropower sector overview and potential

In 2010, Belgium had 92 small hydropower plants and a total installed capacity of 61 MW (191 GWh). By 2020, the aim is to have 134 small hydropower plants, with a total installed capacity of 92 MW (285 GWh).

Considering the limited potential of small hydropower in Belgium (materialized in the National Renewable Energy Action Plan's objectives), there has been very little discussion on the role of small hydropower for energy production, its role in a balanced energy mix, or as a source of socio-economic development. The main remaining potential will be developed on three to four main waterways, under public concessions.

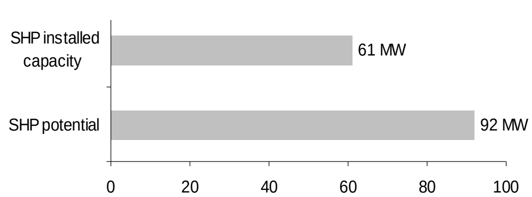

Figure 2 **Small hydropower capacities in Belgium**

Note: Potential is based on planned capacity by 2020.

Renewable energy policy

Belgium is a federal state of three regions: The Flemish region, the Walloon region and the Brussels-Capital region. The evolution of the Belgian energy policy has been shaped by this system, and has led to the transfer of wide competences from the State to the Regions.[6] The 2020 renewable energy target is 13 per cent.[6] Belgium uses a tradable green certificate (TGC) system as its primary support mechanism for the deployment of renewable power technologies. There are four different TGCs (i.e. federal, Flemish, Wallonian and Brussels green certificate) that vary in price and conditions.

In general, renewable energy is a regional matter; only offshore wind power is governed by national regulations. The federal grid operator shall meet public obligations, which include the purchase of green certificates at a minimum price set by law. Electricity suppliers are obliged to present green certificates to prove that a certain proportion (quota) of the electricity supplied to their final consumers in Belgium was generated from renewable sources. This quota may differ according to the region.[6]

Subsidies exist in the Wallonian region which promote the use of biogas and biomass combined heat and power (CHP) plants, solar energy, and hydropower as well as wind power plants.[6]

Legislation on small hydropower

The residual flow generation is decided upon case by case. Small hydropower is supported by the green certificates for the duration of 15 years. The minimum price is 6.5 euro cents/kWh, while the market price in 2010 was 8.5 euro cents/kWh.

Barriers to small hydropower development

The Austrian Government wants to modify the classification of small hydropower installations in the environmental legislation framework, to 'classify' all ranges of installations from class 1 to class 3 (i.e. also the smaller ones <10 kW that were not classified). The positive effect of this project-legislation will hopefully be that permitting will happen within binding delays, and should be linked with clear sectoral conditions. A potentially negative effect is that it will discourage very small operators. The sectoral conditions will be the key element in this new regulation, in which the small hydropower sector should be consulted.

Opposition to small hydropower is concentrated around a few people and organizations, among fishermen, civil servants and academics. Usually the public has little interest in this topic.

The Stream Map Project recommends the elaboration of clear and balanced development conditions ('sectorielles et intégrales'), in close collaboration with main stakeholders, in order to balance the interests of ecosystem and fish protection with the socio-economic interest of small hydropower. A good equilibrium should be found related to the environmental constraints imposed, between the costs that should be supported by the operator, and the costs that are inherent to the region's obligation to fulfill the EU Water Framework Directive.

Linked to the previous issue, the fact that all installations will be submitted to environmental permit is positive since it imposes strict binding delays for decisions. One recommendation is that all other discussions or procedures related to the authorization (AMCE, authorization of modification of the waterway, for example) should be included in the same procedure, with the same binding delays.

Small hydropower equipment could be given a clear development framework, as it is the case for wind energy development ('Cadre de Référence'), on the basis of an exhaustive inventory of the potential, a regional equipment programme, and if necessary a public call for developers.

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4.4.3 France

European Small Hydropower Association, Stream Map

Key facts

Population	65,630,692 [1]
Area	643,801 km[2]
Climate	Three types of climates may be found; oceanic (west), continental (central, east) and Mediterranean (south), except in the mountainous southwest).[2]
Topography	Mostly flat plains or gently rolling hills in north and west; remainder is mountainous, especially Pyrenees in south and Alps in east[1]
Rain pattern	Annual precipitation ranges from 680 mm in the central and southern region to 1,000 mm around Paris / Bordeaux. In the northern coastal and the mountainous areas precipitation can reach more than 1,120 mm.[2]

Electricity sector overview

Electricity generation in France is predominantly based on nuclear energy (figure 1). Renewable energies, especially wind and hydro, account for about 11 per cent of the electricity mix.

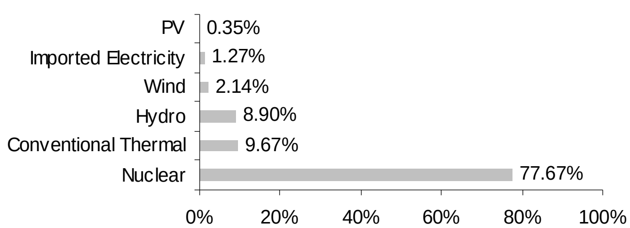

Figure 1 **Electricity generation in France**
Source: Commissariat General au Développement Durable[3]

Small hydropower sector overview and potential

In 2010, France had 1,935 small hydropower plants and a total installed capacity of 2,110 MW (6,920 GWh) (figure 2). By 2020, the aim is to have 2,355 small hydropower plants with a total installed capacity of 2,615 MW (8,730 GWh).

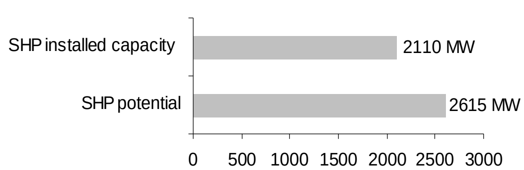

Figure 2 **Small hydropower capacities in France**
Note: Potential is based on planned capacity by 2020.

In 2012, Union Française de l'Électricité (UFE) in association with France Hydro Électricité carried out a map of residual sites for hydro development. A potential of 10.6 TWh was set up. However, the technical feasibility of each site was not analyzed and the option of improving existing hydro plants were not considered, nor energy losses due to the implementation of the EU Water Framework Directive.

Most of the hydro potential can be found in greenfield schemes. Around 500 sites from 300 kW to 50 MW could generate 9.5 TWh. Existing small weirs can be equipped generating 1.1 TWh and be an opportunity to enhance ecological continuity. The Alps, Massif Central and the Pyrenees are the main locations.

For small hydro, the total potential is estimated at about 527 new greenfield sites (1,214 MW and 4,368 GWh) and at equipping 734 of existing small weirs (303 MW and 1,068 GWh). To estimate the feasible potential, the following ratio was applied – cut one third for economic and technical constraints and another third for environmental constraints (revision of classification in course), i.e. 419 power plants, 525 MW and 1,812 GWh by 2020.

A commitment agreement for the development of sustainable hydropower in compliance with aquatic environments restoration was signed in June 2010 to promote hydropower if deemed suitable with environment specifications. A part of the engagement directly concerns the equipment of existing weirs. The methodology and the "suitable conditions" to build a power plant onto existing weirs need to be made more precise.

A guidebook *Towards the Hydroelectric Plant of the 21st Century* for the development of small hydropower plants with regard to the natural environment is available. It defines standards for the conception of a high environmental quality plant. This guide is recognized and disseminated by national administrations.

The French water administration, drafted an inventory of obstacles in rivers and aims to assess the degree to which those obstacles block the movement of species and sediment. A database was created in May 2012, including more than 60,000 obstacles such as dams, locks, weirs, mills no longer in operation.[4] A protocol called Informations sur la continuité écologique (ICE) has been also created to measure the capacity of obstruction of these obstacles.[4] This vast project, bringing together a large number of partners, will identify the installations causing the greatest problems and make it possible to set priorities for corrective action. It will be also a good tool to identify new potential sites for small hydropower.

Renewable energy policy

A regional plan for climate, air and energy (Schéma régional du climat de l'air et de l'énergie, SRCAE), was jointly developed by the State and the regional authorities. In particular, this plan defines, for 2020 and by geographical area, qualitative and quantitative regional targets for the valorization of potential territorial renewable energy, taking into account the national targets. In practice, this means identifying all sources for the production of renewable energies and of energy savings according to socio-economic and environmental criteria, and defining, in association with the local stakeholders (infra-regional authorities, companies, citizens), the level of regional contribution in achieving the targets set by France. These plans represent a strategic planning tool to guide the activities of local and regional authorities. SRCAE are in process. SRCAE, for hydropower potential, are based on producers' data and compatibility with lists of no-go rivers and restoration of river continuity priorities.

Legislation on small hydropower

The maximum duration of permits is 75 years for big concessions. For relicensing, the duration is 20 years if there is no particular investment and around 30 to 40 years if there is much investment. France has a lot of perpetual old permits for former mills subject to new environmental prescriptions.

Residual flow regulation exists, i.e. 10 per cent of inter-annual average flow and for modules over 80 m^3/s, 5 per cent of the module is admissible. While the minimum (10 or 5 per cent) is set by the law, the adapted minimum ecological flow is set case by case through the environmental assessment. The most used method is the micro-habitats method (EVHA), but there are other possible methods adapted when this one does not fit with the type of river. Since 1984, the reserved flow was around 10 per cent of the average annual flow. Since 2006, 10 per cent is the minimum, and local administrations often ask for more (12 to 17 per cent), without any justification on improvement or maintenance of good ecological status. In the extreme periods of low water level, the Préfet, head of the Department (French subdivision) can decide to lower temporarily the residual flow.[5]

A feed-in tariff (FIT) for installed capacity not exceeding 12 MW (art. 10 par. 2 Loi n°2000-108; art. 2 Décret n°2000-1196) has been established. H97 is a contract signed in 1997 for 15 years. This was renewed in October 2012 for another 15 years against a plan of investment.[6] H97 FIT is between €55 and €65/MWh (about between 72 and 85 US$/MWh).

H07 is a 20-year contract for new small hydropower plants or for the plants which are renewed (investment of €1,172/kW (about US$1525 /kW). The H07 FIT is between €60 and €100/MWh (between US$78 and US$130/MWh). The tariff is not interesting for plants over 400 kW of installed capacity (threshold effect).

Barriers to small hydropower development

About 2,000 GWh will be lost by minimum flow rising in 2014 for existing plants and due to removals of a few dams. Through the Law about minimum flow, producers accepted a certain loss of production. The loss of production will be compensated by refurbishment (1,000 GWh) and modernization (1,000 GWh).

The French producers who cannot or do not wish to invest to benefit from a new FIT contract will have to sell their production on the market. This new situation worries the small producers who are not able to value their production on a market that does not take into account specificities of the small hydropower production (i.e. the green value and the decentralized production).

Conflict between river protection and hydro development is rising. The French Government is carrying out a pre-planning mechanism. On one side the Government classifies the rivers in order to determine absolute protected rivers for water bodies of very good status, migratory species or 'biodiversity reservoirs'. At the regional level, areas with renewable potentials are designated.

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4.4.4 Germany

European Small Hydropower Association, Stream Map

Key facts

Population	81,305,856[1]
Area	357,022km[2]
Climate	Temperate and marine; cool, cloudy, wet winters and summers; occasional warm mountain (foehn) wind
Topography	Lowlands in north, uplands in centre, Bavarian Alps in south
Rain pattern	The average annual precipitation is 789 mm. Decrease of rainfall from west to east[2]

Electricity sector overview

Gross power production in Germany was 612 TWh in 2011 with lignite, coal and nuclear dominating the electricity mix (figure 1). In September 2012, the power plant list of the Federal Network Agency included a gross capacity of 172.4 GW (71.22 GW from renewable power sources, 67.5 GW are eligible under the Act on Granting Priority to Renewable Energy Sources (EEG, Erneuerbare-Energien Gesetz).[3]

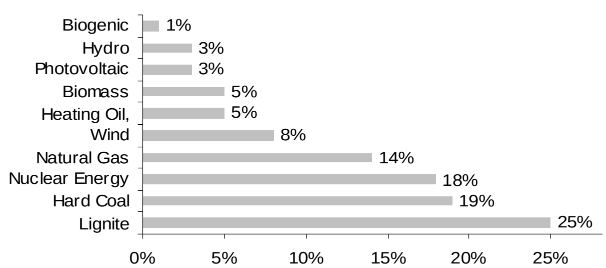

Figure 1 **Electricity generation in Germany**
Source: Federal Ministry of Economy and Technology[4]

Small hydropower sector overview and potential

In 2010, Germany had 7,512 small hydropower plants and a total installed capacity of 1,732 MW (8,043 GWh) (figure 2). By 2020, the aim is to have 7,800 plants with a total installed capacity of 1,830 MW (8,600 GWh).

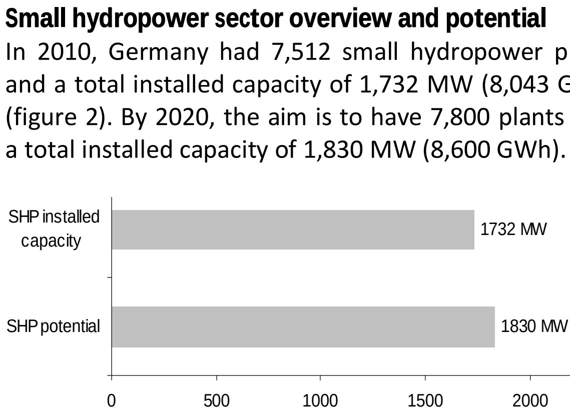

Figure 2 **Small hydropower capacities in Germany**
Note: Potential is based on planned capacity by 2020.

Renewable energy policy

Electricity from renewable sources is supported through a feed-in tariff (FIT). The criteria for eligibility and the tariff levels are set out in the Act on Granting Priority to Renewable Energy Sources (EEG). The EEG also introduced the so-called market premium and the flexibility premium for plant operators who directly sell their electricity from renewable sources. Moreover, low interest loans for investments in new plants are provided for by Kreditanstalt für Wiederaufbau (KfW) Renewable Energy Programme Standard.[5]

A new EEG is on the way with adjusted goals, which will keep the goal of 80 per cent renewable sources in electricity production in 2050. It is, however, already now foreseeable, that the minimum goal of 35 per cent renewable sources in 2020 will be surpassed.[6]

Legislation on small hydropower

Generally the residual flow is regulated to be 30 per cent of mean low water flow. There are no water use fees. Concession fees differ from Federal State to Federal State, e.g. €10,000 (about US$13,000) for 150 kW concession in the state of Hesse. The duration of new concessions is a minimum of 20 years up to a maximum of 30 years.

The duration of FIT is 20 years, while the tariffs are revised every four years. Starting 1 January 2012, the FIT will be increased by about 10 per cent to:

- 12.7 euro cents/kWh < 500 kW
- 8.3 euro cents/kWh < 2 MW
- 6.3 euro cents/kWh < 5 MW
- 5.5 euro cents/kWh < 10 MW
- 5.3 euro cents/kWh < 20 MW

Barriers to small hydropower development

Currently, no further change in support schemes, permitting ease, and simplification of administration procedures are underway. The role of small hydropower (standby energy, storage capacity) in future smart grids is not yet sufficiently recognized and therefore not supported by legislative and administrative activity. Environmental concerns remain, being voiced by various stakeholders (e.g. NGO, fishing clubs, local stakeholders).

The EU Renewable Energy Framework Directive has had no positive impact, while the EU Water Framework Directive (WFD) has had a negative impact on small hydropower development. The WFD directive will be transposed into German law until 2015. The following mitigation measures regarding environmental impacts are currently focused on: upstream/downstream fish ladders, smaller distance between bars of rake cleaners

(15 mm) and river bed management/ naturalization of water flow. There is no support of the EU Renewable Energy Framework Directive so far for new licences or power increase of existing small hydropower plants.

The Stream Map recommends investment support (subsidy) for the reactivation of thousands of small hydropower plants in former flour and saw mills as recognition of the important role of hydropower; and the establishment of standardized guidelines for the administrative handling of the permitting and licensing procedures in Germany.

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4.4.5 Luxembourg

European Small Hydropower Association, Stream Map

Key facts

Population	509,074 [1]
Area	2,586 km[2]
Climate	Modified continental with mild winters, cool summers[1]
Topography	Mostly gently rolling uplands with broad, shallow valleys; uplands to slightly mountainous in the north; steep slope down to Moselle flood plain in the southeast[1]
Rain pattern	Average annual precipitation was 733.2 mm.[2]

Electricity sector overview

Luxembourg is a net electricity importer, which produced 3,713 GWh of electricity in 2011, mainly from thermal power plants (figure 1).

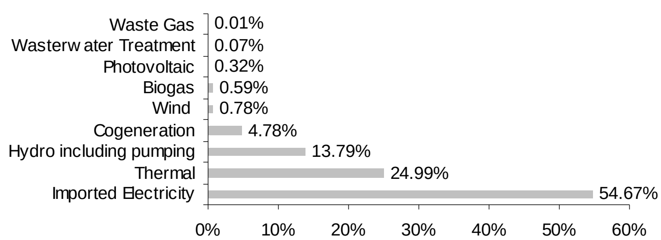

Figure 1 **Electricity generation in Luxembourg**
Source: Institut Luxembourgeois de Régulation[3], Statistics Portal[4]

Small hydropower sector overview and potential

In 2010, Luxembourg had 33 small hydropower plants and a total installed capacity of 34 MW (100 GWh). By 2020, the aim is to have 42 plants with a total installed capacity of 44 MW with a total generation of 124 GWh (figure 2).

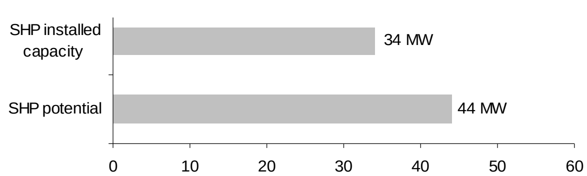

Figure 2 **Small hydropower capacities in Luxembourg**
Note: Potential is based on planned capacity by 2020.

The identified potential for producing more hydropower energy is limited in Luxembourg due to its small country size. However, its current potential lies in:

- One new site on the Sauer river: 5 MW.
- Reactivation of 10 micro power plants.
- Upgrading of Seo's power plants; Seo is the main hydropower generator (95 per cent of the installed capacity).

According to My Energy and Seo, there are no plans currently to create new hydropower plants, neither to reactivate/upgrade old sites. The renewable electricity consumption will be more than four times higher in 2020 than in 2005; the growth should mainly be sourced from photovoltaic, wind and biomass.

Renewable energy policy

Electricity from renewable sources is mainly promoted through a feed-in tariff (FIT) as well as through subsidies.

Legislation on small hydropower

The residual flow is decided on a case by case basis.
There are various support schemes including FIT and investment subsidies available for small hydropower. The FIT, applicable since January 2008, is higher than in the previous system and guaranteed for 15 years with an annual degression rate of 0.25 per cent since 2008.

- Up to 1 MW: €105/MWh (about US$136.6/MWh)
- From 1 MW to 6 MW: €85/MWh (about US$110.6/MWh)

The investment subsidies provide a percentage of the eligible expenses which are the difference between the costs of the investment in hydropower and the costs of investment in a gas-powered station with equivalent power. The percentage of the eligible expenses varies with the size of the company, from 65 per cent to 45 per cent. The investment subsidies applicable since January 2010 are more appropriate.

Barriers to small hydropower development

Lacking concrete information on small hydropower potential is the main barrier for Luxembourg. The Stream Map Project recommends the Energy Agency to develop a programme to reactivate/upgrade the micro power plants which were identified in the 2007 report.

A clear estimate of the practical potential for expanding hydropower production within Luxembourg is needed, therefore a comprehensive study, using a geographic information system (GIS) based computer model, should be carried out.

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4.4.6 The Netherlands

European Small Hydropower Association, Stream Map

Key facts

Population	16,730,632[1]
Area	41,543 km^2
Climate	Temperate; marine; cool summers and mild winters
Topography	Mostly coastal lowland and reclaimed land (polders); some hills in southeast
Rain pattern	Average annual precipitation is 847 mm.[2]

Electricity sector overview

The Netherlands produced a total of 118,138.9 GWh of electricity in 2010, mainly based on gas, and imported electricity at 15,584 GWh (figure 1). The Netherlands is also working with Belgium, Luxembourg, France and Germany on an integrated North-West European electricity market.

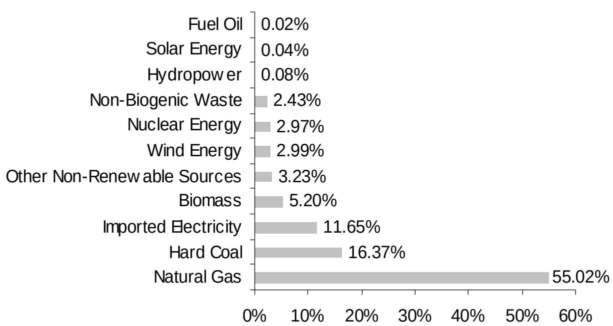

Figure 1 **Electricity generation in the Netherlands**
Source: Statistics Netherlands[3]

Small hydropower sector overview and potential

Small hydropower accounts for a minor part of the hydropower production (less than 8 per cent), only three plants have a capacity between 0.1 and 10 MW; and a few plants have a capacity under 0.1 MW.

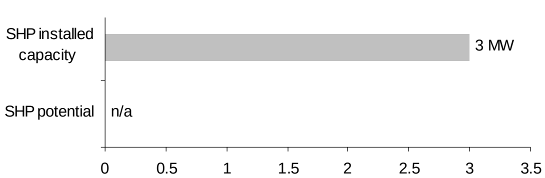

Figure 2 **Small hydropower capacities in the Netherlands**

In 2010, the Netherlands had 17 small hydropower plants and a total installed capacity of 3 MW (8 GWh) (figure 2). By 2020, the aim is to have a total of 25 plants. Many small watermills could still be reactivated. No exact potential estimate is available presently. A report issued by Deltares in April 2010 identified the overall hydro potential from rivers as 100 MW, the small hydropower potential has not been estimated.

Renewable energy policy

The European target for renewable energy in the Netherlands is 14 per cent in 2020. The production of renewable energy will be promoted with the following instruments:[4]

- Sustainable Energy Incentive Scheme Plus (SDE+).
- Obligation for use of biofuels in the transport sector.
- Co-firing with biomass in coal-fired power stations.
- Import of renewable energy.

The growth should mainly be sourced from wind, biomass and photovoltaic; hydropower is expected to account for less than one per cent.

Legislation on small hydropower

Small hydropower is mainly supported by the Stimulering Duurzame Energie (SDE) operating subsidy and the Energy Investment Allowance tax deduction. The SDE+ in 2011 has changed compared to the SDE subsidy that started in 2008. The SDE offers long-term (15 years for hydropower) financial security by covering the unprofitable component of projects. The subsidy is the difference between a basic amount (cost price of the renewable energy) and the energy market price. In 2011, application was open during four different time slots. Each slot had a different limit. The Dutch Government determined a maximum SDE+ budget for 2011. If this maximum is reached in a certain slot, no SDE+ is available for the next slots. This means: first come, first serve, and the projects that tender in the first slot (with lower subsidy) have the best chance to get the subsidy awarded.

For small hydropower plants with a height <5 metres, the SDE provides a maximum of 12.2 euro cents/kWh (minus the energy market price) for 3,800 hours, for small hydropower plants with a height >5 metres: 7.1 euro cents/kWh (minus the energy market price) maximum for 4,800 hours.

The Energy Investment Allowance tax deduction ensures that 44 per cent of the investment costs can be deducted from the taxable profit.

Barriers to small hydropower development

The main limitation results from the low hydrological potential in a flat country. Moreover, it is very difficult to obtain Waterwet (water law) and Natuur-beschermingswet (nature preservation law) permits, due to new fish mortality requirements. While almost all sites are government property; no government policy is in place for allocation of sites to developers, this also creates a barrier.

It is therefore, recommended to carry out a comprehensive study, using a geographic based information system (GIS) based computer model in order to provide a clear estimate of the practical potential for expanding hydropower production, including small hydropower within the Netherlands.

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4.4.7 Switzerland

Martin Bölli, Skat Consulting, Switzerland

Key facts

Population	7,925,517
Area	41,277 km^2
Climate	Temperate, but varies with altitude; cold, cloudy, rainy/snowy winters; cool to warm, cloudy, humid summers with occasional showers[1]
Topography	Mostly mountains (Alps in south, Jura in northwest) with a central plateau of rolling hills, plains, and large lakes
Rain pattern	Along the northern Prealps and Alps, as well as in the South, average annual precipitation is about 2,000 mm, which contrasts with the Valais region (between 500 mm- 600 mm) and the Engadin region (between 600 mm - 700 mm). In the lowlands north of the Alps, the average amount is between 1,000 mm and 1,500 mm. Apart from the Valais region, the amount of rainfall in summer is approximately twice as large as that in winter.[2]

Electricity sector overview

In 2011, the total production of electricity in Switzerland was 63,723 GWh. Swiss electricity production is dominated by hydropower (half of it is produced by storage power plants) and nuclear energy which accounts for 39 per cent (figure 1). Switzerland is a transit country for electricity, in 2011, it imported 79,589 GWh and exported 77,156 GWh.[3]

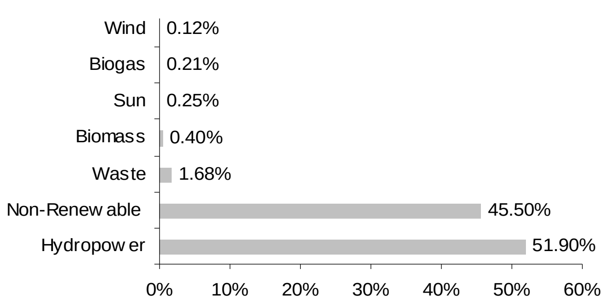

Figure 1 **Electricity generation in Switzerland**
Source: Bundesamt für Energie[3]

Small hydropower sector overview and potential

Currently, over 1,100 small hydropower plants produce about 3.6 TWh each year. About 800 GWh are produced annually in power plants with an output of less than 1 MW (about 950 power plants) and 270 GWh from plants with an output of less than 300 kW (about 750 power plants). Small hydropower plants are owned by utilities, private companies or individuals. The regulation guarantees that the full (renewable energy) production of Independent Power Producers (IPP) has to be absorbed by the national grid. Details about small hydropower plants with a capacity of more than 300 kW can be found in the Swiss Hydropower Statistics.[7] Detailed statistical data of smaller power plants is not available but is based on market observation and a study from the 1980s.

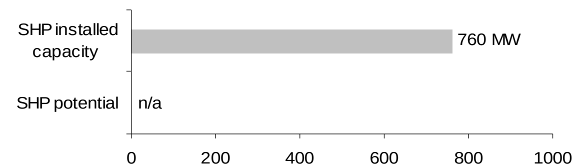

Figure 2 **Small hydropower capacities in Switzerland**
Source: Swiss Federal Office of Energy[6]

Most of the large hydropower potential has been developed. Today, the potential of small hydropower is even higher than the remaining one for large hydropower stations.[7] The remaining small hydropower potential is estimated to be 4.3 TWh/year, divided into:

- Rehabilitation und upgrading of existing power plants: about additional 2.4 TWh/year
- New constructions, taking into consideration sustainability aspects: additional 1.9 TWh/year

Around 100 years ago, nearly 7,000 mills, waterwheels or small turbines were in operation, some of which generated electricity while others were intended for mechanical uses. Due to insufficient viability and competition with lower production costs of large power plants the majority of these facilities were subsequently closed down. But since the 1990s, small hydropower plants have come back into favour again thanks to its Federal Government's action programmes aimed at promoting renewable energy.

The main objective of the small hydropower programme by the Swiss Federal Office of Energy is to cost-effectively develop the existing expansion potential of small-scale plants with an output up to 1 MW by directly and indirectly promoting corresponding projects.

Renewable energy policy

On 31 January 2001, Energy Minister Moritz Leuenberger launched the Swiss Energy programme on the basis of the Energy Act and CO_2 Act, referring to it as 'a platform for an intelligent energy policy'. The main strength of this programme aimed at promoting energy efficiency and the use of renewable energy lies in close co-operation between the Federal Government, the cantons and municipalities, and numerous partners from trade and industry, environmental and consumer organizations, and public and private agencies. It has already made a positive impact, significantly improving energy efficiency and increasing the proportion of renewable energy, while becoming a major driving force behind innovation in Switzerland's economy.[4]

The term 'renewable energy' refers both to conventional hydropower and to other 'new' forms of renewable energy. The proportion of the latter to Switzerland's overall energy consumption is still very modest today, but thanks to technological progress, increasing economic competitiveness and the positive image of renewable energy, its growth prospects are excellent, both in the near future and over the long term. The introduction in 2008 of remuneration at cost for input into the grid will give electricity from renewable energy sources a considerable boost.

On 23 March 2007, the Parliament revised the Swiss Federal Energy Act at the same time as it adopted the Swiss Federal Electricity Supply Act. The revised Energy Act stipulates that the production of electricity from renewable energy sources must be increased by at least 5,400 GWh by 2030. It also contains a package of measures for promoting renewable energy and efficient electricity use. Here the most significant measure concerns cost-covering feed-in tariffs for electricity produced from renewable energy sources. The sum of around 247 million Swiss francs (about US$261.5 million) per annum will be available for offsetting the difference between remuneration and market price.
This form of remuneration is to apply to the following technologies: hydropower (up to 10 MW), photovoltaic, wind energy, geothermal energy, biomass and waste material from biomass. The tariffs for remuneration for electricity from renewable energy sources (green power) have been specified on the basis of reference facilities for each technology and output category. Remuneration will be applicable for a period of 20-25 years, depending on the technology. A gradual downward curve is foreseen for these tariffs in view of the anticipated technological progress and the fact that it will be possible to bring more and more of these technologies onto the market. These reductions will only apply to registered production facilities, which will then receive remuneration on the basis of a constant tariff throughout the entire period of remuneration. Producers who decide in favour of the cost-covering remuneration option cannot simultaneously sell their green power on the free ecological electricity market.

The provisions governing cost-covering remuneration are laid down in the amended Swiss Federal Energy Ordinance and came into effect on 1 January 2009. Facilities that were put into operation after 1 January 2006 can benefit from this form of remuneration, and their operators can register these facilities with Swissgrid (the national network operator). Information about the registration procedure can be found on the Swissgrid website.[5]

Legislation on small hydropower

The framework conditions for hydropower development are defined within different Federal Acts and Decrees. The most important are Bundesgesetz über die Fischerei, (Federal Act of fishery), Gewässerschutz-Gesetz (Federal Act of water protection), Natur- und Heimatschutzgesetz (Federal Act of Nature and Homeland protection), Umweltschutzgesetz (Federal act of environmental protection), Raumplanungsgesetz (Federal Act of spatial planning) and Waldgesetz (Federal Act of Forestry protection).

Water usage rights are awarded by the Cantons, sometimes even at district or community level. It is within their responsibility to assess the legality and sustainability of the project. This decentralization leads to different decision practices from location to location.

Barriers to small hydropower development

In each canton, the procedure to obtain water usage rights is different, which makes it a challenge for investors and planners for every single project. In some cantons, the water usage rights are awarded even at community level (but normally need at least acceptance from the canton). This requires a lot of experience to assess the feasibility of a project and the required steps for implementation.

Since the introduction of the new FIT, the sector is booming and caused work overload at planning offices and public authorities. The water protection stakeholders feared many new water constructions and the loss of the remaining natural open water bodies. Public authorities reacted with guidelines for the assessment of a project, which protects on one hand natural regions but stopped as well sustainable planned projects without considering them in detail.

Due to the high demand for engineering services and hydropower equipment prices rose drastically and stopped projects because of the lack of profitability.

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5. Oceania

5.1. Australia and New Zealand

Niels Nielsen, International Energy Agency Hydropower Implementing Agreement

Introduction to the region

The region is located in the Southern Hemisphere and includes Australia, a country comprising the mainland of the Australian continent as well as the island of Tasmania and numerous smaller islands in the Indian and Pacific Oceans; New Zealand, a country comprising two main landmasses, the North and South Islands, as well as numerous smaller islands; and Norfolk Island, a self-governing territory of Australia.

Both Australia and New Zealand have integrated power systems and electricity markets. Australia's primary electricity generation source is thermal (especially coal), with hydropower providing the largest renewable energy component (table 1). Wind energy is expanding rapidly, with biomass also providing a significant contribution. In contrast, New Zealand's primary electricity generation source is hydropower, with thermal generation providing a smaller contribution. Wind and geothermal power are expanding rapidly, with biomass also providing a significant contribution.

Table 1

Country overview of Australia and New Zealand

Country	Total population (million)	Electricity access (%)	Electrical capacity (MW)	Electricity generation (GWh/year)	Hydropower capacity (MW)	Hydropower generation (GWh/year)
Australia [a]	22.02	~100	49 110	204 000	7 860	12 200
New Zealand [b]	4.33	~100	9 751	43 138	5 252	24 831
Total	**26.35**	**-**	**58 861**	**247 138**	**13 112**	**37 031**

Sources:
a. Australian Energy Regulator[1]
b. New Zealand Ministry of Economic Development[2]

Small hydropower definition

Small hydropower definitions set by the Energy Efficiency and Conservation Authority (ECCA) of New Zealand are shown in table 2. Australia has no official small hydropower definition; however a report by its Clean Energy Council also states a range for small hydropower of up to 10 MW.[4]

Table 2

Classification of small hydropower in Australia and New Zealand

Country	Small (MW)	Mini (MW)	Micro (kW)
Australia	-	-	-
New Zealand [3]	1-10	0.01–1	1-10

Source: Energy Efficiency and Conservation Authority[3]

Regional overview and potential

Australia and New Zealand have only a small proportion of their hydropower generation presently supplied by small scale hydropower, while Norfolk Island does not use small hydropower.

The total installed small hydropower capacity in the region is 310 MW (table 3).[5] [6] In Australia, various governmental programmes that encourage renewable energies have resulted in a limited increase in small scale hydropower development over the past decade. This includes areas in refurbishment, upgrading and redevelopment of existing hydropower plants. This situation will likely continue in the future but only at a low level of activity. In New Zealand, hydropower and other forms of renewables represent the largest share of electricity generation, though only a small proportion of this is supplied by small-scale hydropower.

In Australia, there are many greenfield sites which are physically suitable for small-scale hydropower development, particularly along the Great Dividing Range on the east coast, Tasmania and in northern tropical areas. This remaining potential is not available for development as these areas are protected. In addition, public acceptance, competing uses for water, extreme variations in climate, remoteness of sites and overall high costs of generation and transmission also hinder development.

Table 3

Small hydropower under 10 MW in Australia and New Zealand

(Megawatts)

Country	Potential capacity	Installed capacity
Australia [5]	at least 172	172
New Zealand [6]	760	138
Total	**at least 932**	**310**

Sources: Clean Energy Council[5], New Zealand Electric Authority[6]
Note: Data from 2011.

For New Zealand, the remaining potential is approximately 620 MW (not including sites in the protected areas). Similar to Australia, there are many green field sites that are physically suitable for small-scale hydropower development, but there would also be potential environmental and social issues, with the main barriers to development being the large number of protected areas, competing uses for water and a long and expensive consenting process. However, investigation for new sites is actively being pursued.

Australia and New Zealand have a large number of dams, without any form of electricity generation, which could be retrofitted to add hydropower generation. This is an area for future hydropower development in this region.

In addition, small hydropower generation could be fitted to other existing water resource structures, such as barrages, weirs, canals and other water conduits. These often have very low hydraulic head, so they require the use of specific low head (or in-stream flow) technologies. There are also opportunities to retrofit water supply and waste water schemes that have significant hydraulic head.

Small hydropower represents a very small component of Australia's electricity system and is not expected to play a significant role in the country's energy future. Primary reasons for this are abundant and low cost thermal electricity generation and the great variability in hydrologic regimes. Incentives for renewable energies, in part to combat the potential effects of climate change, are focused primarily on wind and solar power, which are considered to have greater potential.

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5.1.1 Australia

Niels Nielsen, International Energy Agency
Hydropower Implementing Agreement

Key facts

Population	22,015,576[1]
Area	7,741,220 km[2]
Climate	Generally arid to semi-arid; temperate in south and east; tropical in north.[1]
Topography	Mostly low plateau with deserts; fertile plain in southeast;[1] A wide variety of landscapes, with subtropical rain forests in the north-east, mountain ranges in the south-east, south-west and east areas, and a dry desert in its centre
Rain pattern	Average annual rainfall below 600 mm over 80% of the country and below 300 mm over 50%[2]

Electricity sector overview

Australia's primary electricity generation source is thermal (especially coal), with hydropower providing the largest renewable component (figure 1). The installed electricity generation capacity is around 56 GW. The National Electricity Market (NEM) is the wholesale electricity market and the associated synchronous electricity transmission grid, serving five interconnected regions since 1998. These are Queensland, New South Wales, Tasmania, Victoria and South Australia. Tasmania, with predominantly hydropower generation, joined in 2006 when the undersea Basslink interconnector was fully commissioned.

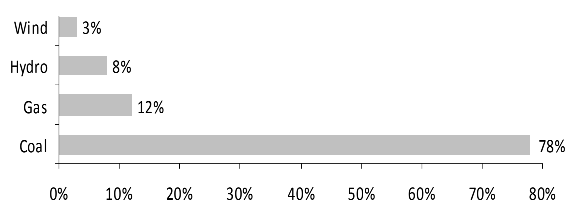

Figure 1 **Electricity generation in Australia**
Source: Australian Energy Regulator[3]
Note: Data from 2012.

Total annual hydropower output in Australia is reduced during periods of prolonged drought. Tasmania accounts for about 30 per cent (2,250 MW) of the installed hydropower generating capacity in Australia, and New South Wales accounts for over half (4,180 MW). The Snowy hydropower scheme, which has a capacity of 3,800 MW, accounts for around half of Australia's total hydropower generation capacity, but a considerably smaller proportion of energy generation. Queensland (640 MW) and Victoria (530 MW) contribute to most of the remainder, with very limited development in Western Australia and South Australia.[4]

Many of Australia's hydropower stations are over 40 years old and have either been refurbished or are in need of refurbishment to ensure their ongoing reliability and availability. Replacement of these aging assets requires significant capital investment. Loss of these generators will make the challenge to increase overall renewable energy generation in Australia even harder.[4] The commercial decision to invest in these aging assets must be balanced with the level of certainty of an ongoing financial return. Renewable Energy Certificates (RECs) will remain critical in providing incentives to upgrade and redevelop aging hydropower plants and ongoing changes to incentive policies must be positive to maintain investor confidence and business case for such investments.

It is predicted that while the installed hydropower capacity will continue to grow, the total contribution of hydropower as a proportion of Australia's overall electricity mix will decrease due to underlying growth in other energy sources such as gas, wind and solar.[5]

Small hydropower sector overview and potential

The oldest operating small hydropower plant in Australia, Mooring in Tasmania (three units, with each at 0.2 MW), was commissioned in 1907. Five other small hydropower plants that are still operating were built between 1926 and 1928. In the 1950s and the 1960s, four additional small hydropower plants were built. Only one hydropower plant, which was built in 1960, has been re-commissioned (1983). No additional information is available on refurbishments of this batch of very old small hydropower plants. Between 1983 and 2010, over 50 small hydropower plants were built, all of which are currently operating. There are now about 60 small hydropower plants in Australia with an installed capacity between 0.11 MW to 10 MW, and a total installed capacity of 172.2 MW (figure 2). Recently completed plants and plants which are under construction and have obtained construction permits, are shown in table 1.

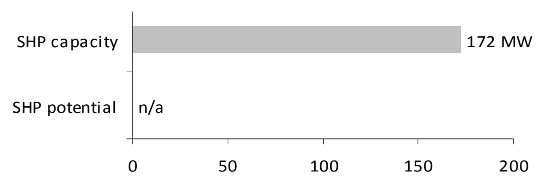

Figure 2 **Small hydropower capacities in Australia**

The low and variable rainfall pattern in Australia and limited areas of high elevation, combined with high temperatures and high evaporation rates, result in a small technical and economic hydropower potential. Most sites with potential for large-

Table 1
Small-scale hydropower development in Australia as of 2010

Development	*Additional capacity (MW)*	*Additional electricity generation (GWh/year)*	*Cost (US$ in million)*	*Status*
Hydro Tasmania				
Lower Lake Margaret mini hydropower	3.2	21	13.2	Commissioned in June 2010
Lake River pipeline	8	-	2.05	Commissioned in Sept. 2010
Upper Lake Margaret	8.4	50	14.7	Commissioned in October 2009
Melbourne Water				
Six mini hydropower stations	7	40	-	Completed
Dandenong, Boronia, Wantirna and Mt Waverley Reservoirs	<0.5	-	-	Construction to begin in 2012
Sugar loaf mini hydropower station	4	-	-	Commissioned in Feb. 2010
Delta Energy				
Glennies Creek	0.63	~2.8	~ 1.1	Development application has been approved. Project is on hold
Windamere Dam	0.63	~2.1	~1.1	As above
ACTEW Corp				
Murrumbidgee to Googong Transfer Project (mini hydropower)	-	One fifth energy required for pumping	-	Awaiting for approval, construction planned for 2010
Eraring Energy				
Burrinjuck power station mini hydropower	4	-	-	Feasibility studies commissioned
Warragamba power station mini hydropower	1	-	-	As above
Hume power station mini hydropower	1-2	-	-	As above

Source: Clean Energy Council [5]

scale hydropower potential have already been developed or are located in protected areas.

Greenfield sites that are physically suitable for small hydropower development exist particularly along the Great Dividing Range on the east coast and in northern tropical areas. However, there are no published inventories of hydropower potential, either on a national or regional basis. Development opportunities have been identified by private companies that include new sites, the redevelopment of old projects and retrofitting of existing dams used for irrigation and water supply. The potential for growth in this area has neither been fully assessed nor publicly documented.

The global financial crisis has presented challenges in securing affordable finance particularly for early stage development of new projects. Smaller developers are also finding it hard to find a counterparty ready to enter into a Power Purchase Agreement (PPA) on reasonable terms.[4] Many small hydropower projects, where upgrade, refurbishment, or modernization has been shown to be attractive, have not gone ahead due to the lack of funding.

According to the Clean Energy Council, water policy will play a key role in the future development of hydropower in Australia. State and federal government water policy would seek to balance the requirements of water for different purposes including environmental protection, industrial and agricultural uses, power generation and domestic use. The competition for water resources would ultimately affect the future availability of water for hydropower generation. This applies to all sizes and purposes of hydropower.[5]

Renewable energy policy

The commencement of the Mandated Renewable Energy Target (MRET) of the Federal Government in April 2001 provided new funding to refurbish Australia's aging hydropower infrastructure and to introduce new small hydropower schemes. However, this has not facilitated any significant increase in small hydropower development.

The Australian Government also operates a national Renewable Energy Target (RET) scheme that was revised in 2011. The scheme is designed to achieve the government's commitment to a 20 per cent share of renewable electricity by 2020. Small scale renewable projects no longer contribute to the national target but still produce Renewable Energy Certificates (RECs). The price of certificates from small scale projects has been more volatile, trading at values between US$20 and US$40.[3]

Barriers to small hydropower development

- Variability of hydrologic regime and of rainfall patterns have been reported to significantly affect the production capability of existing plants and to influence investment decisions of project developers.
- Fluctuating price of RECs, uncertainties on carbon pricing.
- Incentives in retaining ageing small hydropower schemes.

- Limited access to finance.
- Opposition by environmental groups.

Embedded generators i.e. generating plants, including some mini-hydro asset owners, with a capacity of lower than 5 MW (or lower than 30 MW and exporting less than 20 GWh/year to the grid) and usually connected to the distribution grid have previously experienced barriers to enter the National Electricity Market (NEM).[5] The barriers are:

- Variable connection requirements depending on the relevant jurisdictional regulator.
- Complex approval requirements.
- Complex registration and data collection processes.
- Disproportionately high costs for registration and high ongoing fees.
- Limited reward for reducing the need for network investment.
- Fees for providing ancillary services.

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5.2.2 New Zealand

Niels Nielsen, International Energy Agency
Hydropower Implementing Agreement

Key Facts

Population	4,327,944[1]
Area	267,710 km[2]
Climate	Mild and temperate maritime climate, with sharp regional contrasts. Mean annual temperatures ranging from 10°C in the south to 16°C in the north. Conditions vary sharply across regions from extremely wet on the West Coast of the South Island to almost semi-arid in Central Otago and the Mackenzie Basin of inland Canterbury and to subtropical in Northland.
Topography	Two main landmasses and numerous smaller islands; Predominately mountainous with some large coastal plains
Rain Pattern	Most areas have between 600 and 1,600 mm of rainfall, spread throughout the year with a dry period during summer. Over the northern and central areas more rainfall is recorded in winter than in summer, whereas for much of the southern part of New Zealand, winter is the season of least precipitation (rain and snow).[2]

Electricity sector overview

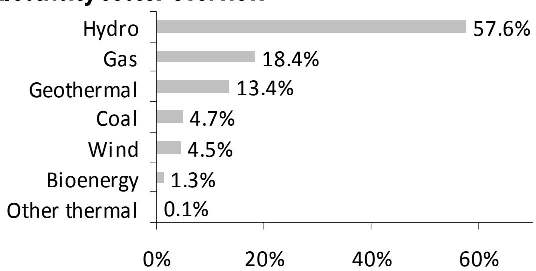

Figure 1 **Electricity generation in New Zealand**
Source: Ministry of Economic Development[3]
Note: Data from 2011.

In 2011, 43,138 GWh of electricity were produced in New Zealand, with a total installed capacity of 9,751 MW.[3] New Zealand's wholesale market for electricity operates under the Electricity Industry Participation Code, and is overseen by the market regulator. Since 1987, a step-by-step industry reform has led to the separation of the monopoly elements of generation, transmission, distribution and retailing, to create competitive markets in energy generation and electricity retailing, while imposing regulation on the natural monopolies of transmission and distribution. -

Hydropower accounts for nearly 58 per cent of national electricity generation (figure 1). Most of New Zealand's hydropower is generated on the South Island, and all geothermal generation is located on the North Island.

Small hydropower sector overview and potential

The New Zealand Energy Efficiency and Conservation Authority (EECA) has classified small hydropower to be in the capacity range of 1 MW to 10 MW, mini-hydro in the range of 10 kW to 1 MW and micro hydropower is usually less than 10 kW and used for domestic applications. Small hydropower (under 10 MW) contributed 11.2 per cent to overall electricity production of New Zealand in 2011.[3]

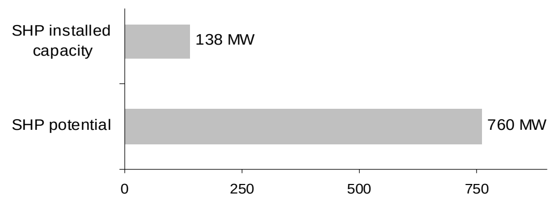

Figure 2 **Small hydropower capacities in New Zealand**

In 2012, the average small hydropower plant in New Zealand was over 50 years old. This is calculated based on data from the New Zealand Electric Authority. However, it is not known which plants have been renovated or upgraded.[4]

The installed small hydropower capacity is about 140 MW, with a typical annual electricity generation of 638 GWh. This is based on the summarized information from the New Zealand Electricity Authority on 55 small hydropower plants, the information of another four plants was not available.[4]

In 2007 the number of domestic grid integrated micro-hydropower facilities in New Zealand was unknown, but understood to be low. Most applications of micro-hydropower provided a cost-effective alternative to grid extension in the case of remote off-grid applications or other remote power options (such as diesel generators). In 2007, there were at least 10 suppliers of micro hydropower generators and related equipment active in New Zealand.[5]

Several reports and studies contain information on hydropower projects, including small hydropower.[6] The EECA (2004) commissioned a series of studies to assess the renewable energy potential in different regions across New Zealand, including hydropower. Regional summaries of existing and potential small hydropower projects are listed in table below. It shows a summary of the regional assessments, with a total small hydropower potential of 622 MW, excluding sites in conservation zones. Environmental

Impact Assessments are required for small hydropower plants.

Most viable mini-hydro opportunities with capacities between 0.1 and 5 MW have been developed in the country. A large number of projects are still technically feasible yet not economically viable. It is expected that a few projects could compete with the wholesale price of electricity and may be subject to resource consenting issues.[5]

In addition, the EECA (2007) commissioned a business-as-usual renewable uptake study with projections up to 2030. This study forecasted that in the absence of significant government policies and incentives, installed capacity of mini-hydro will increase from 32 MW (15 plants) to over 50 MW. Total installed capacity of micro-hydro will increase from 0.1 MW (50 plants to about 4 MW) Grid-connected domestic and distribution-scale renewable energy (electricity) systems in New Zealand have experienced limited uptake to this date. Systems at the district level are generating modest amounts of electricity and domestic-scale renewable electricity is virtually non-existent. It is at the district level where most of the significant gains are expected.[5]

Table 1

Remaining small hydropower potential up to 10 MW in New Zealand

(Megawatts)

Regional assessment (Year)	*Number*	*Remaining potential*
Auckland REA 2007	..	..
Bay of Plenty REA 2007	12	11.07
Canterbury REA 2006	21	65.70
Hawke's Bay REA 2008	14	53.00
Manuwatu-Wanganui REA 2007	26	111.36
Marlborough District REA 2006	3	12.50
Northland REA 2006	13	35.25
Otago REA 2008	25	104.90
Taranaki REA 2006	7	24.20
Tasman REA 2006	1	0.25
Waikato REA 2006	9	22.60
Greater Wellington REA 2007	12	41.20
West Coast REA 2008	33	140.2
Total	**176**	**622.23**

Source: Author's calculations based on New Zealand Electric Authority[4]

Note: Excludes conservation zones. REA – Renewable Energy Assessment

Renewable energy policy

The New Zealand Energy Strategy 2011-2021 retains the target of 90 per cent of electricity to be generated from renewable energy sources by 2025. The economic competitiveness of new renewable electricity generation will be enhanced by a price on carbon. The accompanying New Zealand Energy Efficiency and Conservation Strategy 2011-2016 (NZEECS) consists of the objective of an efficient, renewable electricity system supporting the country's global competitiveness. It includes working on system requirements of smaller-scale generation technologies.[7]

Barriers to small hydropower development

- No governmental policy on small hydropower;
- No government subsidies for small hydropower developers;
- Administrative barriers (long approval process);
- High construction costs.

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5.2 Pacific Island Countries and Territories – Melanesia, Micronesia, Polynesia

Lara Esser, International Center on Small Hydro Power

Introduction to region

The Pacific Island Countries and Territories (PICTs) include three designated UN regions, Melanesia, Micronesia and Polynesia. These regions comprise 22 island countries or self-governing/overseas territories.

While there is an abundance of renewable energy resources, the PICTs remain almost completely dependent on imported fossil fuels for meeting their energy needs. Moreover, those island countries with large rural populations face a particularly difficult challenge when it comes to rural electrification. Due to their unique geography, long distances which separate sparsely-populated areas, and small markets, it is difficult to achieve cost savings through economies of scale in electricity production.

Table 1

Overview of Pacific Island Countries and Territories

Country	*Population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Melanesia							
Fiji[a]	0.890	48	84	269	801	130	456
New Caledonia[b]	0.260	43	--	500	1 800	78	448
Papua New Guinea[bc]	6.310	87	12	582	2 965	216	>598
Solomon Islandsb[cd]	0.584	81	17	28	78	0.12	~1
Vanuatu[cef]	0.256	74	34	12	69	1.2	5
Micronesia							
Federated States of Micronesia[gh]	0.106	77	Chuuk 46 Yap 70 Pohnpei 87 Kosrae 100	28	69	2	0
Polynesia							
French Polynesia[i]		49	-	190	670	~46.5	172
Samoa[j]	0.194	80	98	42	110	> 12.5	48
Total	> 8.600			1651	6 562	486.4	> 1728

Sources:

a. Fiji Electricity Authority[2]
b. World Atlas & Industry Guide[3]
c. Secretariat of the Pacific Islands[4]
d. Solomon Islands country report[5]
e. Vanuatu Energy Unit[6]
f. UNELCO GDF Suez[7]
g. Federated States of Micronesia[8]
h. International Renewable Energy Agency[9]
i. US Energy Information Administration[10]
j. Samoa country report[11]

A comprehensive Pacific regional energy assessment was undertaken in 2004 by the Pacific Islands Renewable Energy Project (PIREP) with the support of Global Energy Facility (GEF), United Nations Development Programme (UNDP), Secretariat of the Pacific Regional Environment Programme (SPREP) and the Pacific Islands governments.[1] After 2004, the Pacific Islands Energy Policy (PIEP) and an associated Strategic Action Plan, Pacific Islands Energy Policy and Strategic Action Plan (PIEPSAP) formulated a critical energy policy and implementation plan for the region. Renewable energy is among the 10 areas of development addressed in this initiative, with the aim to increase the share of renewable energy resources in the energy mix in the Pacific Islands.[12] Similarly, the Framework for Action on Energy Security in the Pacific (FAESP) and its associated Implementation Plan for Energy Security in the Pacific (IPESP 2011-15), includes four key priorities, namely resource assessment, investment in renewable energy; capacity development, and increase in the share of renewable energy in the energy mix.[12]

Solar energy applications are feeding to the grid in various islands such as Nauru, Niue, Samoa and Tuvalu. Hydropower is contributing considerably to the main grids in Fiji, Papua New Guinea and Samoa; wind energy is developed in Fiji and Vanuatu; and geothermal energy applications can be found in Papua New Guinea. Furthermore, in many PICTs there is a growing deployment of off-grid systems based on renewable energy. [12]

As climate change impacts can increasingly be felt, and petroleum prices continue to rise and trade deficits grow, the current energy situation is not sustainable for the future.[13] The PICTs, of which many are small island states, are susceptible to external economic fluctuations, natural disasters and environmental shocks (e.g. tropical cyclones, flooding, drought and earthquakes). Sea level rise is also of serious concern, particularly for some of the islands of the Federated States of Micronesia and Kiribati and for all of the Tuvalu islands.[1]

The switch to renewable energy and energy independence, to mitigate climate change and also to provide greater economic stability to PICTs is thus important. At the same time, the investments made into various renewable energy technologies should consider the changing environment due to the effects of climate change. In the case of small hydropower, this means the effect on water availability particularly during the dry season.

Small hydropower definition

There seems to be no official small hydropower definition, but hydropower up to 10 MW is considered small. Therefore, this section on the PICTs will focus on all installations up to 10 MW. In Fiji, schemes with capacities up to 1.5 MW are referred to as mini hydropower, and schemes with capacities up to 100 kW are referred to as micro hydropower.[14]

Regional overview

Eight of the twenty-two countries have adopted small hydropower, i.e. Fiji, New Caledonia (self-governing territory of France), Papua New Guinea , Solomon Islands, Vanuatu, Federated States of Micronesia, French Polynesia (overseas territory of France) and Samoa. These countries or territories all have a tropical climate, as well as mountainous areas which are suitable for small hydropower. While New Caledonia and Vanuatu's weather is influenced by trade winds, Papua New Guinea, Fiji and Solomon Islands are influenced by monsoon and Micronesia has heavy year-round rainfall and typhoons. Non-mountainous islands or low-lying atoll islands, such as the Cook Islands, Tuvalu, Kiribati and others, have very little or no hydropower; the hydropower potential of these countries has not been assessed and is not treated in this report.

While all five countries of Melanesia use small hydropower, most countries/territories of Micronesia (i.e. Guam, Kiribati, Marshall Islands, Nauru, Northern Mariana Islands, and Palau), and Polynesia (i.e. American Samoa, Cook Islands, Niue, Pitcairn, Tokelau, Tonga, Tuvalu and Wallis and Futuna Islands) do not use small hydropower.

The total installed capacity of small hydropower in the eight examined countries is more than 100 MW, while the potential is at least 300 MW. This is a conservative technical feasible potential that could be developed based on existing feasibility studies if finance were available. For example, on Solomon Islands, a very general study by Japan International Cooperation Agency (JICA) showed a small hydro potential of 326 MW, but only a study that considered 11 MW based on 62 sites that are technically and economically feasible was used. Also the Government of Fiji has made a list of 100 potential projects according to priority, but its total capacity was not available and could not be assessed.

Table 2
Small hydropower up to 10 MW in the Pacific Island Countries and Territories
(Megawatts)

Country	*Potential capacity*	*Installed capacity*
Melanesia		
Fiji	14.7	~10.0
New Caledonia	27.1	9.4
Papua New Guinea	153.0	20.2
Solomon Islands	11.3	0.3
Vanuatu	4.0	1.3
Micronesia		
Micronesia	8.9	2.0
Polynesia		
French Polynesia	65.0	47.0
Samoa	22.0	11.9
Total	**305.7**	**102.1**

Sources: See country reports
Note: New Caledonia has 26.4 MW of small hydropower in planning. Data from 2011/2012.

It was particularly difficult to obtain recent small hydropower information. However, one can see that hydropower plays an important role in the electricity generation in Samoa (44 per cent), Fiji (57 per cent), New Caledonia (25 per cent) and Papua New Guinea (20 per cent).

In the case of Papua New Guinea, hydropower potential is substantial, as a large part of the country is mountainous and receives substantial rainfall. Information on specific sites is limited, due to the absence of systematic hydrological surveys.[3] A 1985 study reported a 6-MW potential, however the *Hydropower Atlas and Industry Guide 2011* noted a 153 MW of small hydropower potential. Vanuatu and Micronesia neither have comprehensive hydropower resource assessments, nor any past small hydropower feasibility studies available.

The development of small hydropower has been relatively slow in the region. For many years there was not much small hydropower development, except at micro-scale on the Solomon Islands with the help of Appropriate Technology for Community Environment - Village First Electrification Group[i] (APACE–VFEG). More recently, there have been some activities of which a non-exhaustive list is given below:

- The Government of Fiji developed a Master plan for small hydropower in 2002. Small hydropower expansion is planned through small micro/pico-hydro rural electrification schemes;[15]
- In New Caledonia, the government plan includes small-scale hydropower schemes in the future as part of the medium term plan to promote renewable energy. Therefore another 17 MW are planned for the next 10 years;
- In Papua New Guinea, Papua New Guinea Power (PNG Power) has a Programme of Activities for Renewable Energy under validation at the United Nations Framework Convention on Climate Change (UNFCCC) under the Clean Development Mechanism (CDM). Once approved, it will be easier to finance small hydropower plants under 15 MW;
- In Vanuatu, the Asian Development Bank (ADB) under a Renewable Energy Programme funded Talise (75 kW) hydropower project. This project also received funding from an Italian-Austrian fund managed by International Union for Conservation of Nature. However, currently, lack of funding is hindering phase two of the project, which involves laying the transmission lines to the villages;[16]
- International finance also plays a role in the small hydropower development in the Pacific region. In 2010, ADB has been involved in the Town Electrification Programme (Tranche 1) of Papua New Guinea; and the World Bank has a 10-year project that also includes the support of micro hydro-Pacific Islands Sustainable Energy Finance Project (2007-2017). The project aims to significantly increase the adoption and use of renewable energy technologies in participating Pacific Island states through a package of incentives to encourage local financial institutions to participate in sustainable energy finance in support of equipment purchase. However, while the progress towards achieving the development objectives has been positive in Fiji, where financial intermediaries have lent US$2.2 million to households and small businesses to purchase and install renewable energy systems or improve energy efficiency, little progress has been made in other participating countries and activities in Papua New Guinea, Solomon Islands, and Vanuatu have been suspended. According to the Implementation Status Report (2011), Fiji is expected to continue its own investments and activities, and to also provide technical assistance and information sharing to the other islands.
- A UNDP/GEF funded project called the Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP), aims to reduce the growth rate of greenhouse gas emissions from fossil fuels in the PICTs through the removal of barriers to the widespread and cost effective use of feasible renewable energy technologies. The project is being implemented in 11 PICTs. The project component A1.2 Conduct of renewable energy resources survey includes a hydro resource assessment costing US$310,000.[17]

However, several challenges remain in order to proceed further on small hydropower development in the PICTs. Finance is a major barrier in implementation of projects that already have feasibility studies but await funding, such as the case in Vanuatu. Capacity for the construction of small hydropower in the PICTs exists, however organizations with external funding sources often bring their own experts who do not understand the PICTs region very well, stay short term and do not spend enough time in the rural areas.[5] In the future, as many of the projects are in the micro range, it is hoped that community approaches such as developed and implemented by APACE to ensure sustainable development can be implemented.

Note

i. APACE is an environmental NGO in Australia. Unfortunately, the APACE VFEG is no longer active, but it still maintains their old projects. More information is available from www.apace.uts.edu.au/.

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Melanesia

5.2.1 Fiji

Lara Esser, International Center on Small Hydro Power

Key facts

Population	890,057[1]
Area	18,272 km^2 (land area), 104,000 km^2 (total area)[2]
Climate	Tropical marine, only slight seasonal temperature variation
Topography	Three hundred and twenty islands (only one third are inhabited); mostly mountains of volcanic origin
Rain pattern	Rainfall is usually abundant during the wet season (November to April), especially over the larger islands, and is often deficient during the rest of the year, particularly in the dry zone on the north-western sides of the main islands. Annual rainfall in the dry zones averages around 2,000 mm, whereas in the wet zones, it ranges from 3,000 mm around the coast to 6,000 mm on the mountainous sites. The smaller islands receive between 1,500 mm and 3,500 mm.[3]

Electricity overview

The total installed capacity of all Fiji's power plants is 269 MW (2011). A small part of the total capacity are plants independent of the national electricity utility Fiji Electric Authority (FEA), and operated by villages, and the Public Works Department.[5]

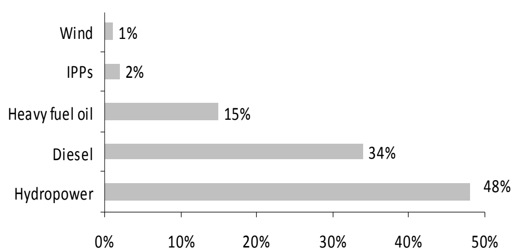

Figure 1 **Electricity generation in Fiji**
Source: Fiji Electricity Agency[4]
Note: Data from 2010.

In 2010, 48 per cent of electricity production came from hydropower (figure 1). The majority of hydropower plants are publicly owned. About 60 MW of FEA's own generating capacity are hydropower. Fiji is well endowed with resources for development of both large- and small-scale hydropower projects. The technically feasible hydropower potential in Fiji is estimated to be 1,089 GWh/year, and so far about 36 per cent of the potential has been developed.[5]

Small hydropower sector overview and potential

Fiji has had a history of small hydropower production dating back to the 1920s (figure 2). Schemes with capacities up to 100 kW are referred to as micro hydropower, and capacities up to 1.5 MW are mini hydropower.[2]

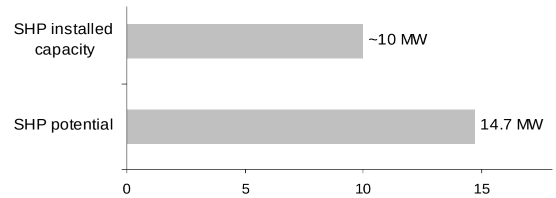

Figure 2 **Small hydropower capacities in Fiji**

The Fijian Department of Energy (DoE) is carrying out monitoring and evaluation of potential sites. The DoE has published preliminary data collected from roughly 200 sites around the country. The total installed micro-hydropower capacity is about 960 kW (84 per cent at Wainikeu/Wainiqeu, a system operated by the FEA). It is estimated that the four additional sites where the DoE is planning to install monitoring equipment might represent a combined 500 kW potential.[6]

In the beginning of 2011, a feasibility study was carried out for a small hydropower plant on Fiji's third largest island, Taveuni. The project will be built to reduce its reliance on diesel-powered generators. The dam site is on a creek interspersed with high falls, in the forests behind Somosomo village.[7] There is a proposed project at Somosomo on Taveuni island with a capacity of 700 kW in a run-of-river configuration. China is providing a US$10-million grant to fund the construction of the hydropower scheme.[8]

In the case of Fiji, if the three bigger installations at Wainikasou and Vaturu are excluded, there are still a number of mini or micro hydro sites with an installed capacity of approximately 960 kW as shown in the table. Eighty-four per cent of this is at the Wainiqeu/Wainikeu system operated by FEA and connected to the Vanua Levu grid.

Small hydropower projects in Fiji

Project/ system	*Location (island)*	*Installation year*	*Capacity (kW)*
Wainiqeu	Vanua Levu	1992	800
Nasoqo	Viti levu	1984	4
Bukuya	Viti Levu	1989	100
Vatukarasa	Viti Levu	1993	3
Koro	Kadavu	1994	20
Muana, Cakaudrove	Vanua Levu	1999	30

Source: APCTT-UNESCAP[9]

Currently, there are at least two Clean Development Mechanism financed small hydropower plants in Fiji.

The Vaturu project (3 MW, 86.8 per cent design efficiency, 20,000 MWh/year) is located at Sabeto city in Nandi province. It commenced construction in June 2004 and started operation in January 2005. The Wainikasou project (6.5 MW, 90 per cent design efficiency, 18,000 MWh) is located at the central highlands of Viti Levu in an area called Waimala-Naidasiri. The Wainikasou project commenced operations in May 2004.[10]

Renewable energy policy

The target for renewable energy electricity generation is 90 per cent by 2015.[10]

The Fiji Department of Energy (FDOE) is responsible for national energy policies, energy efficiency and renewable energy development and rural electrification. Its mission is to facilitate the development of a resource-efficient, cost-effective and environmentally sustainable energy sector in Fiji.[2]

In 2006, the National Energy Policy (NEP) was approved by the cabinet. It provides a common framework for both the public and private sector to work towards the optimum utilization of energy resources, for the overall growth and development of the economy. The policy focuses on four key strategic areas: national energy planning, energy security, power sector development, and renewable energy development.[6]

Based on the results of the Hydropower Assessment Program, hydropower was incorporated into the renewable energy policy as an electrification option.[2]

Barriers to small hydropower development

- Most parts of the islands are subject to dry seasonal periods or dry periods between high rainfall events. The generally steep topography in areas where hydropower potential sites might be expected, might lead to rapid runoffs and landslips, unless there is a considerable groundwater feed to the stream, discharge falls off rapidly to some base flow, which may be very limiting as far as firm power production is concerned;
- Very intense rainfall events, particularly during the passage of tropical cyclones near or over the islands, may result in severe flooding in the streams which introduces certain problems affecting the design, operation and maintenance of diversion and intake structures;
- During flood discharges, streams carry a bed load of cobbles, gravel and sand as well as floating debris, which cause potential problems in small intake works.

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5.2.2 New Caledonia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	260,166[1]
Area	18,580 km^2
Climate	Tropical; modified by southeast trade winds; hot, humid[1]
Topography	A main island (mainland) and a number of smaller islands coastal plains with interior mountains
Rain pattern	During the warm season (mid-November to mid-April), frequent tropical depressions and cyclones produce large amounts of precipitation. After a brief transition, the cool season (mid-May to mid-September) begins, with lower rainfall. This is followed by another transition period (mid-September to mid-November) with generally clear weather and increasing southeasterly trade winds[2]

Electricity overview

New Caledonia's economy is vulnerable in terms of energy security due to its very high dependence (80 per cent) on fossil fuels imported for the production of electricity (figure 1).

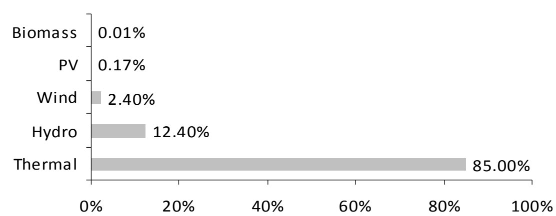

Figure 1 **Electricity generation in New Caledonia**
Note: Data from 2010 and does not include Électricité et eau de Calédonie capacity.[3]

The largest electricity producer in New Caledonia is La Société Néo-Calédonienne d'Energie (ENERCAL), which has mainly thermal and hydropower facilities that cover 98 per cent of the demand of the country.[3] Ninety-six per cent of the capacity is grid connected, and 78 per cent is fossil-fuel based.

A rural electrification fund, established in 1983 is the tool for institutional development and rural electrification. It was replaced in December 2002 by a fund with the same purpose, and revised by Resolution No. 33/CP dated 7 October 2010.[4]

Small hydropower sector overview and potential

The total installed small hydropower capacity in New Caledonia is estimated at 9.4 MW (11 small hydropower stations), with an annual generation of 40 GWh.[5]

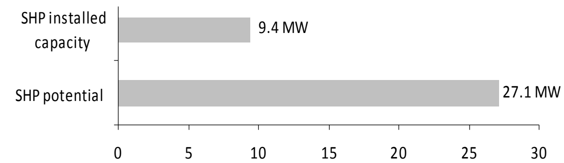

Figure 2 **Small hydropower capacities in New Caledonia**
Note: Small hydropower potential based on installed and planned capacity

The estimated small hydropower potential is 300 GWh/year and 17.7 MW of small hydropower capacity is planned at four plants with a total generation of 70.2 GWh/year. These plants will be developed in the Mount Panie area, known locally as Ouaieme.[5]

Renewable energy policy

The New Caledonian Division of Industry, Mines and Energy (DIMENC) is responsible for the planning and implementation of the country's energy policy. The division promotes projects allowing energy savings or development of new energy sources, such as renewables.[6]

A multi-year programme for investments, Programmation Pluriannuelle des Investissements (PPI) for the production of electricity (2008-2015) was proposed to the Congress in 2009. It includes the expansion of capacity to at least 15 MW of hydropower, 18 MW of solar, 42 MW of wind and 210 MW of coal. In the end, the country's Congress did not approve the programme because it was assessed that New Caledonia did not have all the tools necessary to ensure the proper implementation of the PPI.[4]

Pricing conditions and duration of contract relating to the purchase of electricity generated by wind power are regulated by Resolution No. 407 (November 2003). The contract duration is 15 years, divided in two periods and the purchase price is defined (and not updatable) for each period. Period 1 (the first seven years) is 11 XPF/kWh; Period 2 (the following eight years) ranges from 9 to 11 XPF/kWh.[4]

New Caledonia has planned to promote renewable energy and the establishment of small-scale hydropower schemes are considered for the future. The transmission company intends to purchase power at a fixed price that is still to be determined.[5]

Barriers to small hydropower development

The PPI, which would have included the support for 15 MW of hydropower, was not approved by the New Caledonian Congress in 2009.

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5.2.3 Papua New Guinea

Lara Esser, International Center on Small Hydro Power

Key facts

Population	6,310,129[1]
Area	462,840 km[2]
Climate	Tropical; northwest monsoon (December to March), southeast monsoon (May to October); slight seasonal temperature variation[1]
Topography	Over 600 islands, immense physical variety and various types, e.g. alluvial, continental, coral, raised coral and volcanic. Mostly mountainous islands with coastal lowlands and rolling foothills[1]
Rain pattern	On the mainland, mean annual rainfall ranges from less than 2,000 mm to 8,000 mm in some mountainous areas.[2]

Electricity sector overview

Papua New Guinea Power (PNG Power) is responsible for the generation, transmission and distribution of electricity throughout the country. Papua New Guinea Power operates three main interconnected systems, namely Port Moresby, Ramu (Lae-Madang-Goroka-Mount Hagen) and the Gazelle Peninsula, which are mainly based on fossil fuels (figure 1). It also runs 19 other smaller provincial systems. There are approximately a hundred small rural supply systems called C-centres – the number varies depending on the source – at the government administration centres, electrified through isolated diesel, small hydropower and occasionally photovoltaic (PV) systems.[1]

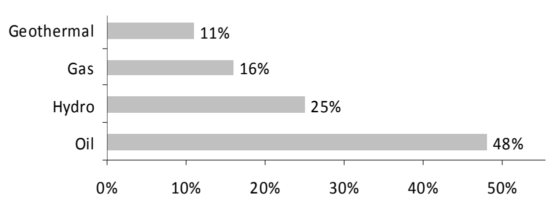

Figure 1 **Electricity generation in Papua New Guinea**
Source: Clean Energy Portal[3]

Rural electrification policy guidelines were developed in 1993 to address a number of issues, including the low rural electrification rate (under 10 per cent of households), high costs and high government subsidies to C-centres, exorbitant costs of grid connections and the relative effectiveness of electrification at religious mission's stations compared to government initiatives. The guidelines advocated decentralized diesel or petrol generators, micro- and mini-hydropower systems where feasible, and PV. A 2001 draft of the National Rural Electrification Policy noted that rural electrification was a national priority under the government's development strategy and structural adjustment programme.

The Government has begun the process of preparing a National Electricity Policy, which will focus on private sector participation and competition, particularly in generation activities and rural electrification.[3] The Electricity Industry Policy was adopted in December 2011; its key elements focus on attracting the private sector to contribute to new power generation facilities, increasing movement towards cost-reflective pricing and transferring the regulation of the sector to the Department of Petroleum and Energy (DPE).[4]

Small hydropower sector overview and potential

There are currently nine small-, mini- and micro-hydropower plants in operation, with a total capacity of 20.2 MW. Several projects are in the phase of planning. The small hydropower potential has been estimated at about 153 MW, covering more than 79 schemes (figure 2).[5]

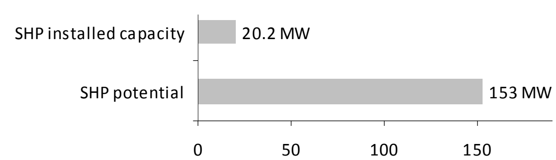

Figure 2 **Small hydropower capacities in Papua New Guinea**

ELCOM (now Papua New Guinea Power) carried out numerous feasibility studies to replace small diesel systems with small hydropower in the 1980s to 1990s, but none were developed due to high costs.

The Energy Division of Department of Minerals and Energy (DME) had assessed 45 potential hydro sites near C-centres by 1987, completed 14 feasibility studies and commissioned three small hydropower systems (capacities ranging between 60 kW and 300 kW) by 1992. Apparently none have been constructed since then. Church missions, NGOs and community organizations have built a number of small hydropower systems but documentation is imprecise. The Pacific Islands Renewable Energy Project (PIREP) mission estimates that there may have been as many as 200 single household size pico-, micro- and mini-hydropower systems installed in rural Papua New Guinea between 1960 and 2004, of which perhaps 20-25 per cent are still functioning, about 20 to 25 systems on Bougainville and roughly the same number throughout the rest of Papua New Guinea. Many more are planned if funding can be found.[2]

A 1985 New Zealand Aid (NZAID) supported a DME assessment of mini-hydro potential near to 110 load centres in 17 provinces. Investigations were carried out at 31 centres, and the rest was examined through desk study. Although the main focus was the power generation potential in the vicinity of C-centres, the study considered the resource potential in the vicinity of the nearby population centres as well. It identified 6 MW of mini hydro potential, more than half of which was concentrated in North Solomons province. Other promising locations were in Madang, Morobe, Eastern Highlands and Southern Highlands provinces. In some locations, the economic viability was judged to be low or uncertain due to low demand and/or cheaper power through grid extension or other renewable energy sources.[2]

A future energy scenario for Papua New Guinea shows tremendous potential for further commercial energy production from renewable indigenous resources, including hydropower development. In the capacity range of 1-10 MW, 6 MW of potential capacity could be realized. Five hundred new micro hydro systems (<100 kW) with an average capacity of 22 kW could be realized.[2]

The Country Partnership Strategy 2011-2015 for Papua New Guinea released by the Asian Development Bank provides recommendations for rural electrification and technical assistance for micro-hydropower projects.[3]

Renewable energy policy

Currently there is no legislation or policy exists in Papua New Guinea calling for an increased production of energy from renewable sources.[2] However, the Energy Division of the Papua New Guinea Department of Petroleum and Energy is involved in a renewable energy programme that promotes the use of local energy resources, such as solar, hydro and wind. International donor agencies are involved in the energy sector review and the creation of strategies for a rural electrification programme.[2]

The technical potential for renewable energies in Papua New Guinea is enormous but much of the resources is located in remote locations with limited demand and is not readily exploitable. The University of Papua New Guinea, University of Technology, and the Government's Energy and Forestry Departments have assessed rural renewable energy potential between the early 1980s and 1994. There is only limited information since then.[2]

Legislation on small hydropower

Environmental Impact Assessments are to be carried out for all projects related to the development of the physical environment, according to the Environment Act. Results are submitted to the Environment and Conservation Department.[5]

Barriers to small hydropower development

Financing of new small hydropower projects is a challenge. Papua New Guinea Power has a Town Electrification Investment Programme prepared for validation under the Clean Development Mechanism Programme of Activities for small scale renewable energy projects, which includes small hydropower.[6] If registered this could assist in attracting part of the funding if the certified emission reductions can be sold at a reasonable price[i] but other investment sources would also be required, such as through the private sector, supported through the framework of the Electricity Industry Policy.[7]

Note

i. The market for CDM certified emission reductions (CERs) has shrunk significantly, the future outlook of the CDM and achievable price levels are unclear.

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5.2.3 Solomon Islands[i]

Peter D. Lynch, Pelena Energy, Australia

Key facts

Population	584,578[1]
Area	28,896km[2]
Climate	Tropical monsoon; few extremes of temperature and weather[1]
Topography	An archipelago of 992 islands. Mostly rugged mountains with some low coral atolls[1]
Rain Pattern	Average annual rainfall within the range of 3,000 to 5,000 mm. Places on the southern sides of the larger islands tend to have a rainfall maximum between June and September.[2]

Electricity Sector Overview

A 2009 study indicated that 15.6 per cent of Solomon Islanders had access to electricity, an increase from 12.7 per cent in 2007. Furthermore, 8.5 per cent of the population indicated the use of solar electricity although the type or size is not clear; 4.8 per cent indicated use of a private generator (assumed to be fuelled by petrol or diesel) and 3.7 per cent used other undefined supply of electricity. In total, 32.7 per cent of the population indicated access to some form of electricity with the majority of this from private generation. In general, electricity generation is diesel-based (figure 1).

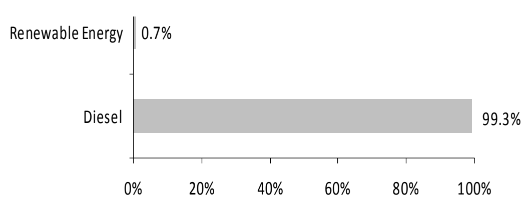

Figure 1 **Electricity generation in Solomon Islands**
Source: International Renewable Energy Agency[3]

The Solomon Islands Electricity Authority (SIEA) is an autonomous, government-owned entity. Under the Electricity Act of 1969, it is responsible for the generation, transmission, distribution and sale of electrical energy throughout the Solomon Islands. In preparation for a 15-MW peak capacity hydropower plant, Tina River Hydropower Scheme[ii], a framework is being defined for negotiation and contracting of an independent power producer who will build and run the scheme.[4]

It is highly likely that Solomon Islands will never have a single integrated electricity grid network due to the many islands and the deep oceans in between. However, the climate and geography of the country is ideally suited to the development of independent power systems and multi-generator mini-grids.

Small hydropower sector overview and potential

The mountainous nature of the majority of the country offers significant micro hydropower potential (figure 2). There is little access to modern energy sources and the nation is listed as a Least Developed Country (LDC) under the UN system.

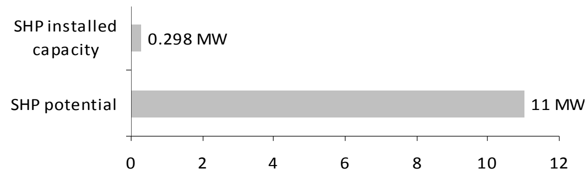

Figure 2 **Small hydropower capacities in Solomon Islands**

There are nine hydroelectric systems with capacities below 150 kW, of which five were implemented by an Australian environmental NGO, Appropriate Technology for Community and Environment (APACE). Six plants are currently operational and are all community-owned. Two government-operated systems are currently 'suspended', primarily due to technical issues. The oldest remaining micro-hydropower system, at the Atoifi Adventist Hospital, has experienced frequent technical problems and is currently undergoing repairs.

The success of the majority of currently operating micro-hydroelectric systems in Solomon Islands is significantly due to the efforts by APACE, and its work in researching procedures and technologies to allow access to the technology by the rural people of Solomon Islands.[5]

No complete study has been undertaken to determine the total micro hydropower potential of Solomon Islands. However, some studies are presented below.

The Japan International Cooperation Agency Master Plan 2000 funded a study for power development in Solomon Islands, including hydro. A total of 130 potential hydropower sites were identified, with a total hydro potential of 326 MW, including Lungga and Komarindi hydropower projects and other previous studies. A summary of the sites identified in the report are listed in table 2 below.[6] The majority of the identified potential hydro sites were assessed from desktop or 'map studies' using area/ contour/rainfall methods.

Table 1
Micro-hydropower systems in Solomon Islands

Year of comissioning	*Location*	*Ownership*	*Turbine*	*Installed capacity (kW)*	*Comment*
1952 [a]	Fauabu [b]	Melanesian Mission	Turgo – Gilkes	10	Not operational
1973 [a]	Atoifi	Adventist Hospital	Pelton – Gilkes	30	Ceased operation around 1980
1986	Atoifi	Adventist Hospital	Pelton – Hydro Systems	36	Under repair
1983 [a]	Iriri	Community	Pelton – Apace	3	Ceased operation 1997
1984	Malu'u	SIEA (government)	Crossflow – SKAT	16	Suspended (Land and technical issues)
1993 [a]	Vavanga	Community	Crossflow – Apace	2	Ceased operation in 2001
2004	Vavanga	Community	Pelton - Pelena	8	Operating
1995	Manawai	SIEA (government)	Pelton - Canyon	16	Operating
1996	Buala (Jejevo)	Community	Pelton – Andritz	150	Operating
1997	Ghatere	Community	Crossflow	8	Incomplete and damaged
1999	Bulelavata	Community	Crossflow – Pelena	24	Operating
2003	Raea'o	Community	Pelton – Pelena	30	Operating
2004	Nariao'a	Community	Pelton – Pelena	30	Operating
2010	Masupa	Community	Pelton - Pelena	40	Operating

Notes: Table last updated in October 2010. SIEA - Solomon Islands Electricity Authority. a. decommissioned systems b. unconfirmed.

Table 2
Potential small hydropower sites in Solomon Islands

Islands	*Number of sites*	*Micro (kW)*	*Mini (kW)*	*Small (kW)*	*Total (kW)*
Guadalcanal	49	-	1 210	236 100	237 310
Malaita	23	90	2 700	28 000	30 790
Santa Isabel	6	-	610	4 100	4 710
New Georgia	23	320	4 840	-	5 160
San Cristobal	12	20	371	25 500	25 891
Choiseul	15	140	2 030	20 030	22 200
Santa Cruz	2	50	260		310
Total	130	-			326 371

Source: based on JICA's 2000 study Master plan study of power development in Solomon Islands: final report (Page 5-18)

In 1996, the German Agency for Technical Cooperation (GTZ) supported the study of three mini-hydropower schemes in the Solomon Islands. GTZ supported the construction of the Jejevo (Buala) Hydropower scheme (Santa Isabel Province), but did not fund the construction of the Huro and Rualae Mini-Hydropower Schemes in Makira and Malaita Provinces respectively. Consultants have recently been engaged to re-evaluate these projects.

Pelena Energy has been in negotiations with the Solomon Islands Government to privately fund and develop micro hydropower systems in various parts of the country. These projects would be based around the community construction model with income generating and partnering with Pelena Energy for technical and management support. Negotiations are continuing.

Renewable energy policy

There is no specific renewable energy policy in Solomon Islands. The Energy Division under the Ministry of Mines, Energy and Rural Electrification is currently responsible for energy sector policy formulation, legal and regulatory development and institutional strengthening. The Solomon Islands National Energy Policy (SINEP)[iii] was endorsed in 2007 and was valid for 10 years. It has 12 main strategic key priorities, one of which is renewable energy. The SINEP is currently being reviewed.

Barriers to small hydropower development

- Lack of funding availability for small hydropower project execution;
- Engineering designs extracted from foreign projects where transportation infrastructure is typically more widespread and of greater capacity than in Solomon Islands. These designs are flawed in the context of the logistical demands of Solomon Islands. The designs are inappropriate and commonly not funded due to the high cost, as determined from restrictive international tendering processes with little scope for input from experienced local designers;
- Lack of transparency in procedures;
- Lack of incentives for private investment in the electricity market of Solomon Islands, particularly for locations outside of the traditional jurisdictions of the government-owned SIEA;
- Perception problem, particularly by the dominant aid industry, that the only path for rural electrification is through aid funding;
- Undermining of government departments, agencies, and authorities by foreign aid

organizations and foreign government programmes such that trained Solomon Island engineers and technicians are frequently consigned to token management positions and never gain practical training opportunities or supportive input;

- A distinct lack of understanding of the rural areas by foreign aid organizations and foreign governments.

Note that local capacity or technology availability is specifically not regarded as a constraint for the development of micro-hydropower in Solomon Islands.

Notes

i. Lynch, P.D. (2010). Micro-hydroelectricity in Solomon Islands – Current Status. Paper for Symposium on Renewable Energy Technologies Fiji National University. October.

ii. The Tina River Hydro Development Project feasibility study is in the final stages of completion. As a result of the feasibility study, the project's functional design is proposed to consist of a 57m-high roller-compacted-concrete dam and a 15 MW peak capacity power station. The power station will be connected to the dam by a power conduit consisting of a 250 m long tunnel and three parallel, 750m-long, penstocks. A saddle dam on the left abutment will act as an auxiliary spillway. Transmission will be through a double-circuit, 33kV line to the Lungga diesel power station.

iii. The 12 strategic areas of the SINEP are: Management, Coordination, Renewable Energy, Energy Efficiency, Energy Conservation, Petroleum, Transport, Environment, Legislations, Regulations, Financing and Gender.

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5.2.5 Vanuatu

Lara Esser, International Center on Small Hydro Power

Key facts

Population	256,155[1]
Area	12,200 km[2]
Climate	Tropical; moderated by southeast trade winds from May to October; may be affected by cyclones from December to April.[1]
Topography	80 islands, 65 populated. Mostly mountainous islands of volcanic origin; narrow coastal plains[1]
Rain pattern	Moderate rainfall from November to April; Annual rainfall 2,300 mm[2]

Electricity sector overview

The Ministry of Lands and Natural Resources oversees the Department of Energy, Mines and Minerals. There are two utilities with concession contracts: Union Electrique du Vanuatu (UNELCO) operates the concessions in Malekula, Port Vila and Tanna; and Vanuatu Utilities and Infrastructure Ltd (VUI) operates the concession for Luganville. Power is reliable in communities that have access to it, but the availability of electricity outside major urban centres is very limited.

Rural electrification remains an ongoing challenge, with just 27 per cent of Vanuatu's population connected to electricity, largely confined to urban centres. In Port Vila and Luganville connection rates are around 75 per cent, while access rates in rural areas are significantly less than average.[4]

Power generation in Vanuatu is predominantly from diesel (figure 1). As there are no exploitable sources of fossil fuels in Vanuatu, all diesel fuel must be imported. Other significant sources of power generation include a 3-MW wind farm servicing Port Vila, blending coconut oil with diesel (approximately 20 per cent blend in diesel generators in Port Vila) and a 1.2-MW hydropower scheme contributing to the electricity supply to Luganville (Sarataka Hydropower Scheme).[5] The Government of Vanuatu has given out three geothermal prospecting licences.[5]

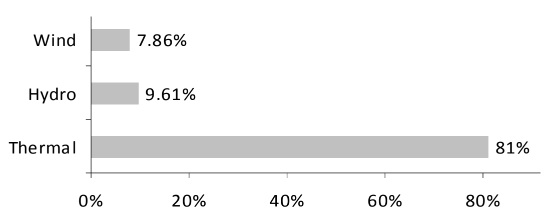

Figure 1 **Electricity generation in Vanuatu**
Source: Union Électrique du Vanuatu[3]

Small hydropower sector overview and potential

Currently there is only one operating hydropower plant in Vanuatu. It is owned by the Government, called Sarakata (1.2 MW). A 75-kW micro hydropower plant at the Talise River (Maewo Islands) and its associated power transmission infrastructure is currently under construction.

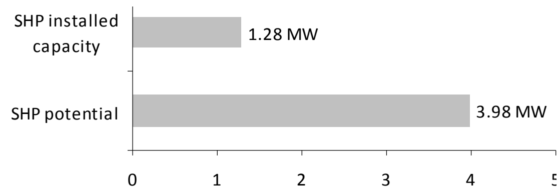

Figure 2 **Small hydropower capacities in Vanuatu**

Vanuatu has considerable technical potential for hydropower schemes, but its porous geological structure makes it unsuitable for dam construction. Useable hydropower resources have been identified on many islands in Vanuatu including Vanua Lava, Santo, Maewo, Malekula, Epi and Tanna.

While suitable hydropower resources have been identified, only a few sites have been monitored and a few hydropower schemes have been developed, the most significant and largest one being the Sarakata scheme.

Vanuatu has some hydropower potential for urban grids and rural demand. Studies suggest a technical potential on Efate (e.g. 1.2 MW at Teouma) but with prohibitively high development costs. The European Union has investigated micro-hydro potential for 13 sites on 6 islands with about 1,500 kW of available power. Four sites are promising (Lowanau in Tanna, Mbe Tapren in Vanua Lava, Waterfall in Pentecost and Anivo in South Santo) and may be studied further.

The Vanuatu Renewable Energy Projects (VREP), approved by the Sustainable Energy Programme for the Pacific Small Island States (SEPSIS) and funded by the Italian and Austrian Governments, is implemented through the International Union for the Conservation of Nature (IUCN). The three project components are:
a) Wind resource assessment;
b) Talise mini hydropower project;
c) Re-habilitation of existing solar PV systems.

The total budget approved for the VREP projects was one million US dollars. However, a Pacific Islands Greenhouse Gas Abatement through Renewable Energy Project (PIGGAREP)-funded feasibility study carried out by GHD Australia in October 2009 estimated the cost to construct the Talise micro hydropower project at 70 per cent of the total budget approved for the three VREP projects. Therefore, the

Vanuatu Government anticipated financial insufficiency and has been sourcing potential donor assistance to complete the Talise project, which was split in two phases:
Phase 1: Hydro generation (civil structure works, electro-mechanical equipment installation works)
Phase 2: Transmission and distribution (transmission grid lines installation works)

On 18 May 2011, the Government of Vanuatu Energy Unit officially contracted Pelena Energy of Australia to implement Phase 1. The Government needs an additional US $500,000 to implement Phase 2.

Renewable energy policy

The Vanuatu National Energy Policy Framework (VNEPF) endorsed in 2007 aims to raise the welfare of ni-Vanuatu through the provision of reliable and affordable energy services to 20 per cent of rural population by year 2017.[i] However, the Government has not yet translated this into concrete policies promoting renewable energy development, and the Revised Rural Electrification Policy 2000 still remains in draft form, along with the Draft of Vanuatu National Energy Policy Framework.

The Rural Electrification Plan which UNELCO was commissioned in 2006 to develop and to outline a review and analysis of alternative technologies for rural electrification in off-grid areas, proposing mini-grid diesel generation with coconut oil conversions as a primary option, with consideration for localised use of solar PV, hydropower and wind where suitable resources exist.[4]

In 2011 and 2012, Vanuatu developed an Energy Road Map with technical assistance from the World Bank. This document focuses on the electricity and petroleum sectors. Under renewable energy it includes a target of 40 per cent renewable energy electricity production by 2020 and two new potential hydropower sites in Malekula and Santo.

In addition, renewable energy is highlighted in the Government planning document ‘Planning Long, Acting Short’. The Government Policy Priorities for 2009-2012, which includes energy sector priorities to explore, expand and invest in renewable energy sources.

The Environmental Management and Conservation Act (2002), implemented by the Environment Unit of the Ministry of Lands and Natural Resources, is Vanuatu’s primary legislation governing environmental protection. Under this Act, any proposed activity that is likely to impact on the environment must comply with environmental impact assessment requirements.[4]

Barriers to small hydropower development

The primary barriers to renewable energy identified in the Draft Framework include:[4]

- High capital costs.
- Lack of government support i.e. political will;
- Lack of in-country capacity.
- Issues related to land ownership.
- Lack of commitment from project recipients.
- Lack of capacity building on project management.
- Disputes amongst projects recipients.

Note

i. Ni-Vanuatu is a demonym that means ‘the people of Vanuatu’.

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Micronesia

5.2.6 Federated States of Micronesia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	106,487[1]
Area	702 km^2 (land area), occupying <2.6 million km^2 of the Pacific Ocean
Climate	Tropical; located on southern edge of the typhoon belt prone to occasionally severe storms[1]
Topography	Approximately 607 islands (among which 74 are inhabited). The islands vary geologically from high mountainous islands to low, coral atolls; volcanic outcroppings on Pohnpei, Kosrae, and Chuuk[1]
Rain Pattern	Heavy year-round rainfall, especially on the eastern islands. Rainfall varies geographically, with a low record of 300 mm on drier islands to over 1000 mm per year in the mountainous interior of Pohnpei. Wet season is from June to October and dry season is from November to May.[1 2]

Each of the four states of the Federated States of Micronesia (Micronesia) - Yap, Chuuk, Pohnpei and Kosrae - maintains considerable autonomy for their development strategy.[2] Yap, Pohnpei and Kosrae have extended electrical power distribution lines reaching about 95 per cent of the population. In Chuuk, the utility company only provides electrical power to the island of Weno. Other islands rely on private systems, as the utility's generators have broken down.[4] Around 55 per cent of all households in Micronesia had electrification from some source (2000 census). See table 1.

The energy sector is overwhelmingly dependent on the import of petroleum for commercial energy use i.e. transport, electricity, business and households (figure 1).[2]

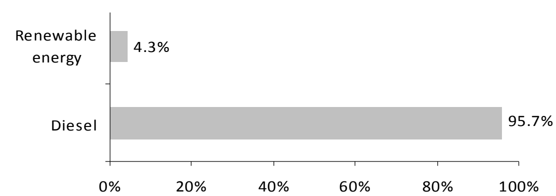

Figure 1 **Electricity generation in the Federated States of Micronesia**
Source: International Renewable Energy Agency [3]

Electricity sector overview

Table 1
Electrification access in Federated States of Micronesia
(Percentage)

States	*Chuuk*	*Yap*	*Pohnpei*	*Kosrae*
% Household electrified (2000 census)	33	59	68	99
% Household electrified (main island)	75	100	98	98
% Household electrified (2009 estimate)	46	70	87	100

Source: Micronesian Department of Resources and Development[2]

The Government aims to provide affordable and safe electricity to all the households in the main island centres by 2015. It also aims to have an electrification rate of 80 per cent of rural public facilities by 2015 (Strategic Development Plan 2004-2024).[2]

State-owned corporations control power generation in Micronesia. Each island state has its government-owned incorporated electric utility authority, i.e. Pohnpei Utilities Corporation (PUC), Kosrae Utility Authority (KUA), Chuuk Public Utility Corporation (CPUC), and Yap State Public Service Corporation (YSPSC).[4]

Capacity concerns and unreliable electricity production problems have made most major businesses and government offices in Chuuk purchase and operate their own electrical generators.[4] Renewable sources, such as copra from coconut or solar energy for cost-effective photovoltaic (PV) and solar water heating use, have been implemented but their use could be further increased.[4] Between 2007 and 2009, the European Union funded REP-5 project installed over 100 kWp of grid-connected and off-grid solar PV across the four states.[i] A 1.5-MW wave energy development project was launched in October 2011 in Kosrae.

Small hydropower sector overview and potential

During the Japanese occupation in World War Two, several small hydropower installations were developed. In post-war years they were not maintained and provided little energy. Since 2008, the increasing demand for electricity and higher generation costs have led to renewed interest in hydropower development.

In 1988, the Nanpil river hydropower system was commissioned on Pohnpei. While the installed capacity is 2.06 MW (maximum output of 1.8 MW), technical problems prevent it from reaching its full capacity (figure 2). It is currently not in operation due to penstock damage.[5]

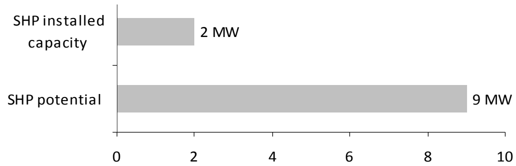

Figure 2 **Small hydropower capacities in the Federated States of Micronesia**

Some surveys indicated additional small hydropower potential sites, but these were not economically feasible at the time of the survey. In light of the current higher fuel prices, the economics should be recalculated. A study by the United States Army Corps of Engineers in 1981 identified numerous potential hydropower sites on Pohnpei: one on Senipehn River and three on Lehnmasi River. Due to the lack of road access, the relatively high cost for site development and the distance from existing grids, they were not developed. Their total peak potential is approximately 4-5 MW, with an average of 2-3 MW. During the dry months, less power would be produced.

On Kosrae, sites have limited hydropower potential and are unlikely to be cost effective for development. The Malem River in Kosrae was proposed as a site for development of a 35 kW hydropower plant in the late 1980s, but land tenure issues stalled the plans and the project was never materialized.[5] However, further study of pico hydropower as stand-alone systems to power houses located near rivers should be further studied. Yap and Chuuk have no identified hydropower sites.

Renewable energy policy

The Energy Division of the Micronesian Department of Transport, Infrastructure and Communication is responsible for planning and implementing energy programmes at the state level. The Department of Economic Affairs (DoEA) is the lead organization for climate change, petroleum imports, and legislation pertaining to utilities. Furthermore, the Sustainable Development Council, established in the mid-1990s, meets monthly and deals with energy issues related to sustainable development.[4]

The Strategic Development Plan 2004-2024 includes a number of references to energy by 2020:

- To decrease the import of petroleum fuels and their use by 50 per cent through improved energy efficiency, energy conservation, elimination of energy subsidies, and public education; and
- To generate 10 per cent of electricity in urban centres and 50 per cent in rural areas using renewable energy sources (solar power, wind, and/or solar/wind hybrids) through incentives and public education.[3]

The major goal of the policy is to become less dependent on imported sources of energy, by having an increased share of renewable energy sources and cross-sectoral energy conservation and efficiency standards in place. Therefore, by 2020 the share of renewable energy sources will be at least 30 per cent of total energy production, while energy efficiency will increase by 50 per cent.

A new energy policy and energy action plans were endorsed in 2012 and have the following targets:

- Renewable energy: thirty per cent energy supply from renewable energy sources by 2020;
- Energy efficiency: enhance supply side energy efficiency by 20 per cent by 2015 and increase the overall energy efficiency by 50 per cent by 2020;
- Conventional energy: regional bulk purchase, centralized storage and coordination to secure and obtain efficiency by 2015.

To achieve its goals, the Government had initiated the National Energy Work Group. This group is chaired by the energy division and works closely together with the energy sector in the four Micronesian states.

Additionally, the National Government has prepared its own energy action plans which, in combination with the various states' action plans, will delineate a road map to assist the nation in achieving its goals and objectives.

Several activities have been delineated under priorities one, two and three:

- Rehabilitation measures to refurbish and put back online existing hydropower turbines.
- In-depth reassessment for the capacity expansion of the Nanpil River Hydropower Plant.
- In-depth reassessment of feasibility of hydro-power potential development of all mini- and micro-hydropower schemes, including Lehnmesi and Senpehn rivers, for power generation.
- Completion of design of viable hydropower schemes leading to implementation and commissioning.
- Conduct of feasibility study on building hydropower plant in Kosrae.
- Construction of hydropower plants based on findings and recommendations of study.

Barriers to small hydropower development

- There is currently no effective national energy planning, as the Micronesian Congress decided that energy should be dealt with at the state level. From the late 1990s to 2004, national energy matters were handled on a part-time basis by staff of the Department of Economic Affairs (DoEA);[5]
- There is no clear energy role for the DoEA and no formal links between the office and the four states on energy matters;[5]
- Pohnpei has high interior rainfall on both islands, approximately 35 streams have small catchments. According to the Micronesian National and State Energy Action Plans[2], these streams are not generally practical for base load hydropower without using expensive and environmentally problematic storage ponds. A trade-off between reliability of power delivery and cost of installation would need to be made. In some cases drinking water reservoirs have been used as storage ponds to secure more constant water supply.

Note

i. The Support to the Energy Sector in Five ACP Pacific Island Countries (REP-5) programme was a 9th European Development Fund (EDF9) multi-country initiative which funded renewable energy and energy efficiency projects in five Pacific Island Countries, including FSM. Source: www.rep5.eu

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Polynesia

5.2.7 French Polynesia

Lara Esser, International Center on Small Hydro Power

Key facts

Population	274,512[1]
Area	4,167km[2] (land area 3,521 km[2])
Climate	Tropical, but moderate[1]
Topography	Thirty-five mountainous volcanic islands and about 183 low-lying coral atolls in five archipelagos
Rain pattern	Hot rainy season is from November to June, cool dry season is in July to October.[2] Average rainfall is 1,800 mm per year.[3]

Electricity overview

Electricity production is mainly carried out by the company Electricité de Tahiti (EDT). EDT owns 15 power stations (188.8 MW), all powered by diesel fuel on the main island of Tahiti as well as three power stations on the Marquesas Islands (Îles Marquises). Hydroelectric generation is the largest form of renewable energy on the archipelago (figure 1).[5]

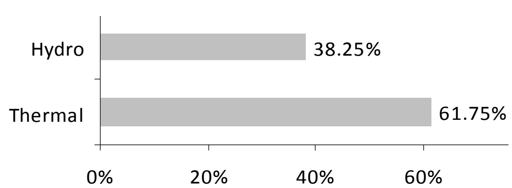

Figure 1 **Electricity generation in French Polynesia**
Source: Institute d'Emission d'Outre Mer[4]
Note: On Tahiti only.

In August 2010, a hybrid thermal/photovoltaic (PV) plant was inaugurated on the atoll Ahe, allowing the population to have cleaner, perennial power, and to be less dependent on fossil fuels. Financed by the 9th European Development Fund, the plant is the first of a series of three hybrid plants which combine thermal power generation with PV technology.[4] Six wind turbines were installed in Makemo, however, the irregularity and availability of strong winds is an issue, as well as the economic viability.

In April 2010, the Council of Ministers authorized the completion of 27 PV power projects with a total installed capacity of 10,520 MWp, close to 10 per cent of the power demand during peak daily consumption.

French Polynesia also plans to expand the use of marine energy. An experimental wave plant was installed in 2008, a tidal pilot plant exists since 2010 and a financing agreement for the feasibility study of a proposed floating thermal plant was decided in 2010 as well, based on a system of energy production using the temperature differential to convert water into electricity.[4]

According to the Inter-ministerial Council on Overseas France, at its meeting in November 2009, an energy self-sufficiency target for overseas territories was set for 2030.

Small hydropower sector overview and potential

There are 15 small hydropower plants in operation, ranging in size from 100 kW to 12 MW (figure 2).[6]

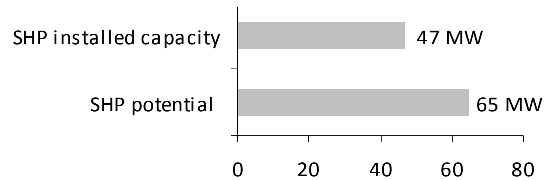

Figure 2 **Small hydropower capacities in French Polynesia**
Source: International Journal on Hydropower and Dams[6]

Small hydropower potential is under study, including capacity expansion potentials of updating existing ageing plants. The cost of producing a kWh of hydropower is about US$0.11.[6] The theoretical (technically feasible) hydropower potential is 300 GWh/year, and the technically and economically feasible hydropower potential is 250 GWh/year (equivalent to 65 MW).[6]

Renewable energy policy

Since June 2009, individuals and small businesses can sell electricity produced by their solar panels for 45F Communauté Financière du Pacifique (CFP) per kWh In addition, a fiscal incentive was introduced in April 2010 in favor of future producers of PV electricity, who will be exempt from VAT, licence, tax transactions and territorial solidarity contribution.[4]

Barriers to small hydropower development

About 70 per cent of the technically feasible small hydropower potential has already been developed, leaving only a small range of potential to be developed.

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5.2.8 Samoa

Rapa Young, Electric Power Corporation, Samoa

Key facts

Population	194,320[1]
Area	2,900 km^2
Climate	Tropical[1]
Topography	Two main islands (Savaii, Upolu) and several smaller islands and uninhabited islets; narrow coastal plain with volcanic, rocky, rugged mountains in interior[1]
Rain Pattern	Two distinct seasons: a wet season from November to April and a dry season from May to October. On average, 75 per cent of Samoa's total annual rainfall occurs in the wet season. Northern and western shores receive about 2,500 mm and inland areas about 7,500 mm a year[2]

Electricity sector overview

Samoa has one of the highest electrification rates in the Pacific region; with the last census in 2006 showing approximately 98 per cent of the population with access to electricity. The households with no access to electricity are mostly scattered on both the main islands and in remote rural areas.

The Samoan Electric Power Corporation (EPC) is a state-owned power utility company which is mandated to generate, distribute and sell electricity in Samoa. A recent amendment to the electricity legislation has now opened up the market for independent power producers to generate and sell electricity to the network, which is currently being handled by EPC. The amendments also include the appointment of a regulator for the electricity sector.

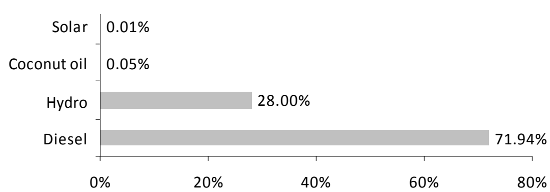

Figure 1 **Electricity generation in Samoa**
Source: Samoa's Ministry of Finance[3]
Note: Data from 2010.

Electricity supply for the main island Upolu is provided by a central thermal (diesel) power station and five small hydropower stations. The other main island, Savaii, is fully powered by a diesel station. One of the smaller islands Apolima has a centralized solar PV mini grid system (figure 1). EPC is in the process of building a 20-MW diesel power station on Upolu to provide additional generation capacity for the country.

The National Energy Coordinating Committee, a ministerial level committee which oversees the energy sector, has received renewable energy project proposals from overseas investors to generate electricity in Samoa from renewable sources. This has led to two power purchase agreements with EPC by independent companies, for renewable energy projects (solar and biomass).[3]

Small hydropower sector overview and potential

There are five hydropower plants on the island of Upolu providing about 40 per cent of Samoa's total electricity production. Afulilo Dam is the only reservoir-type plant, while the rest are all run-of-river plants (table).

Small hydropower plants in Samoa

Plant	*Type*	*De-rated capacity (MW)*
Afulilo dam	Reservoir/dam	4.0
Lalomauga	Run of river	3.5
Fale o le fee	Run of river	1.6
Alaoa	Run of river	1.0
Samasoni	Run of river	1.8

Various studies have been carried out over the last 30 years to look at other potential hydropower sites (figure 2).

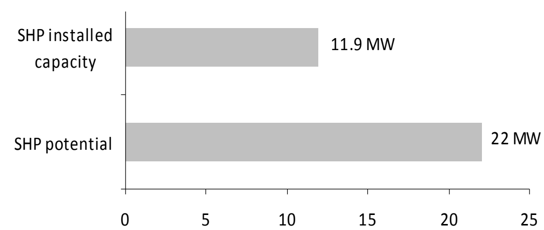

Figure 2 **Small hydropower capacities in Samoa**

In the last few years, the EPC, with the assistance from various donors, including the Asian Development Bank and the PIGGAREP[i] project, has embarked on a comprehensive Hydro Data Collection Program, which involves the installation of monitoring equipment at potential hydropower sites to collect relevant hydrological data.

Feasibility studies have also been carried out as part of EPC's Power Sector Expansion Project, which is jointly funded by the Asian Development Bank, Japan Bank for International Cooperation and AusAID (Australian AID). The EPC is looking at developing five small run-of-river hydropower sites in the next few years based on the results of these feasibility studies.

Renewable energy policy

The Samoa National Energy Policy (SNEP) outlines the government of Samoa's target in promoting renewable energy. The SNEP looks at 'increasing the share of production from renewable sources by 2030' to reduce its dependence on imported fossil fuels and to reduce greenhouse gas emissions.

The International Renewable Energy Agency Policy Brief (2012) reports that the target for renewable energy electricity generation is 20 per cent by 2030, this is additional to the current share.[4]

Several projects looking at integrating renewable energy into energy production are being carried out by energy stakeholders, including the Ministry of Finance's Energy Unit, the Ministry of Agriculture, the Ministry of Natural Resources and Environment, the private sector as well as the Electric Power Corporation.

Barriers to small hydropower development

- Lack of monitoring data on water resource potential around the country;
- Resistance of communities to allow hydropower development in local river systems;
- Existing hydropower schemes in Samoa have experienced decreasing load factors due to change in climate and in part to removal of vegetation in the catchments. Some reforestation is proposed along with investigating means to add storage with flood retention schemes upstream of existing facilities.[5]

Note

i. The PIGGAREP is a product of a Global Environment Facility and United Nations Development Programme-funded preparatory exercise, the Pacific Islands Renewable Energy Project (PIREP). The PIREP was completed in 2006 and the implementation of the PIGGAREP commenced in 2007. The global environment and development goal of PIGGAREP is the reduction of the growth rate of GHG emissions from fossil fuel use in the PICTs through the removal of the barriers to the widespread and cost effective use of feasible renewable energy technologies.

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List of tables

List of figures

Figures continued

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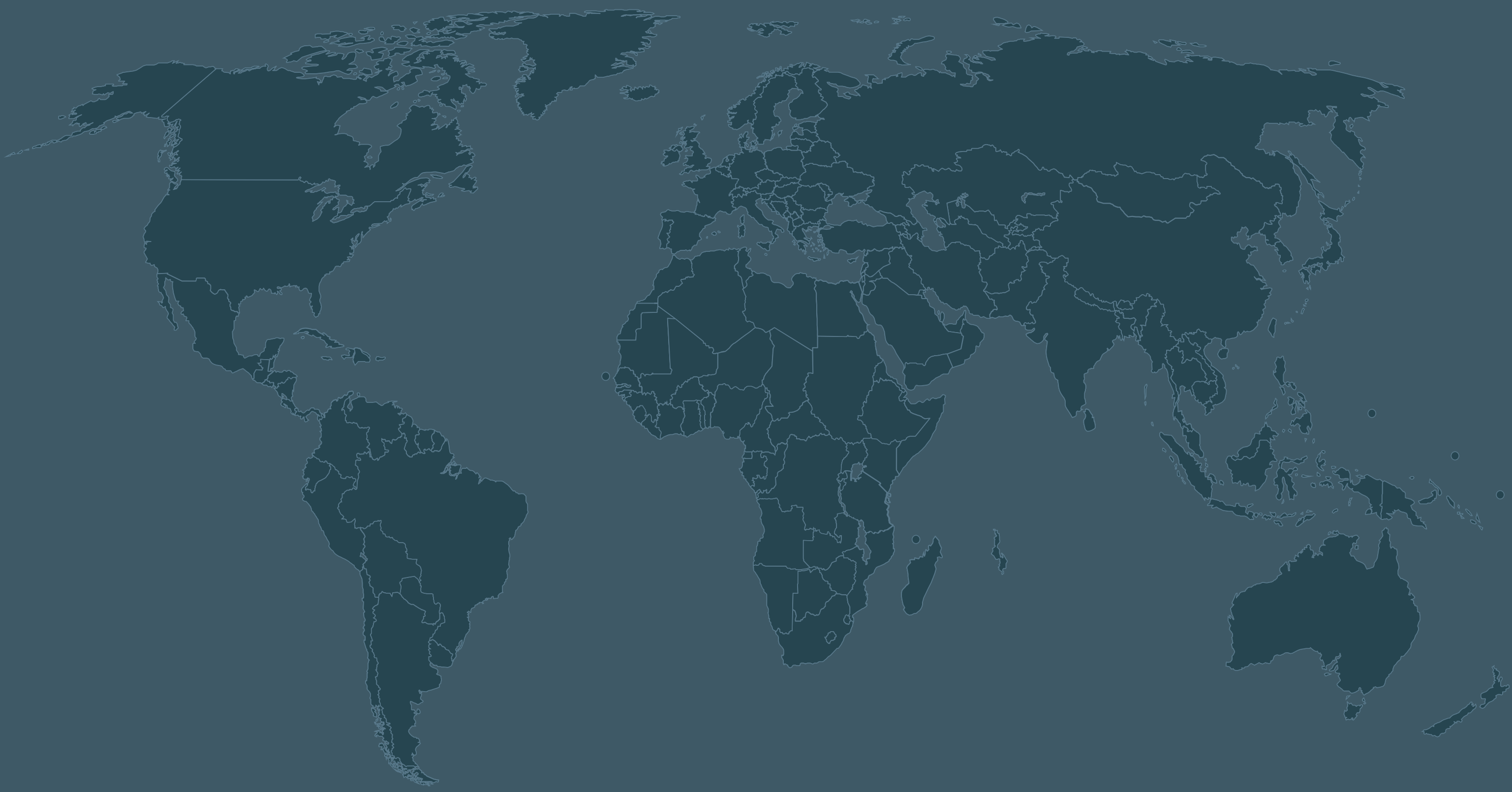

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