



Development
Progress

Case Study Report

Environment



JOINING THE GRID Sustainable energy in Brazil

Peter Newborne and Bryn Welham

Overseas Development Institute

203 Blackfriars Road
London SE1 8NJ

Cover image: © Fernando C. Vieira/Grupo CEEE

The Institute is limited by guarantee
Registered in England and Wales
Registration no. 661818
Charity no. 228248

Contact us

developmentprogress.org
developmentprogress@odi.org.uk
T: +44 (0)20 7922 0300

Sign up for our e-newsletter

developmentprogress.org/sign-our-newsletter

Follow us on Twitter

twitter.com/dev_progress

Disclaimer

The views presented in this paper are those of the author(s) and do not necessarily represent the views of ODI.

© Overseas Development Institute 2014.

Readers are encouraged to quote or reproduce material for non-commercial use. For online use, please link to the original resource on the Development Progress website. As copyright holder, ODI requests due acknowledgement and a copy of the publication.

Contents

Acknowledgements	7
Acronyms	7
Abstract	9
1. Introduction	10
1.1 Why Brazil?	10
1.2 Brazil context	11
1.3 About this case study	13
2. What progress has been achieved?	14
2.1 Increase in energy availability for economic development	14
2.2 Access to energy sources that are affordable, reliable and clean	18
2.3 Evolution of the renewable energy mix	22
2.4 Energy efficiency and energy intensity	30
3. What are the factors driving change?	33
3.1 Sustained high-level political consensus on key energy policies	33
3.2 Financing environment for promotion of key aspects of sustainable energy	37
3.3 Improvements in electricity-sector regulation	39
3.4 Improvements in the design and management of large hydropower plants	40
3.5 Long-term public and private investment in ethanol-related R&D	43
4. What are the challenges?	45
4.1 Managing exploitation of the significant oil and gas reserves	45
4.2 Maintaining long-term policy coherence and the independence of sector regulators	46
4.3 Improving strategic planning for further expansion of large hydropower	46
4.4 Managing demand while balancing supply from variable and intermittent sources	49
5. What lessons can we learn?	50
References	53

List of tables, figures and boxes

Tables

Table 1: Final energy consumption by sector by tonne of oil equivalent (ktoe) and percentage	17
Table 2: Access to electricity (% of population) in Brazil compared with LAC/UMICs	18
Table 3: Access to non-solid fuel (% of population)	20
Table 4: Block tariff structure for residential customers, 2013 (in Brazilian reais per kWh)	22
Table 5: Percentage of renewable energy, in total final energy consumption (TFEC)	25
Table 6: Comparative energy use (kg of oil equivalent per \$1,000 GDP at constant 2005 PPP)	30

Figures

Figure 1: Composition of primary energy production: 1990-2010 10 ³ toe (tonne of oil) equivalent	15
Figure 2: Total electric power consumption: 1990-2010	15
Figure 3: Electric power consumption per capita (kWh)	16
Figure 4: Dependence on 'external energy': 1990-2010	16
Figure 5: Average rates of growth of GDP and energy consumption, by period	17
Figure 6: Brazil: GDP growth, year on year (3-year rolling average)	17
Figure 7: Final energy consumption in industry, overall and industry sectors, in 10 ³ toe (tonne of oil) equivalent	18
Figure 8: Evolution of different elements in domestic energy supply – percentages	24
Figure 9: Evolution of different elements in domestic energy supply – volumes, 10 ³ toe	24
Figure 10: Evolution of renewable and non-renewable elements in domestic energy supply: 1990-2012	25
Figure 11: CO ₂ equivalent emissions (metric tons per capita)	25
Figure 12: Energy-related CO ₂ emissions per GDP (kg per \$2,000)	26
Figure 13: Electricity production from hydroelectric sources, 1990-2010 (% of total)	26
Figure 14: Electricity production from different sources, 1990-2010 (% of total)	27

Boxes

Box 1: Improvements in the quality of life in a remote rural community in the Amazon	21
Box 2: Government programmes to expand electricity access	37
Box 3: Tucuruí hydropower plant – 1980s	40
Box 4: The environmental licensing system in Brazil	48



Tucuruí Dam spillway, Tocantins River, Brazil. Photo: © Eneida Castro

Acknowledgements

This case study was written by Peter Newborne and Bryn Welham, respectively Research Associate and Research Fellow of the Overseas Development Institute (ODI), with Emilio Lèbre La Rovere, Professor Titular at the Federal University of Rio de Janeiro (Coordinator of the Environmental Sciences Laboratory (LIMA), part of the Energy Planning Programme (PPE) at the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering at the Federal University of Rio de Janeiro). Andrew Scott and Susan Nicolai at ODI provided oversight.

The authors gratefully note the contributions of Fernanda Fortes Westin and Rômulo Neves Ely, doctoral researchers at LIMA-PPE, who gathered supporting research material and also accompanied the ODI researchers during their visit to Brazil.

The authors also thank Thais Soares and her colleagues at Energia Sustentável do Brasil for the opportunity to visit the site of the Jirau hydropower project near Porto Velho in Rondônia State and for their presentation of the socioeconomic and environmental activities supported by the project.

Further, the authors thank the other individuals – government officials, representatives of private companies and civil society organisations – who kindly gave their time to participate in key informant interviews as well as the

experts' roundtable, as well as supplying information and documentation to supplement the data obtained by the researchers during the course of this study.

The authors would also like to express their gratitude for the two peer reviewers' detailed comments on an earlier draft: Professor Luiz Augusto Horta Nogueira, Titular Professor at the Instituto de Recursos Naturais da Universidade Federal de Itajubá, and Pedro Bara Neto of WWF's 'Living Amazon' Initiative.

The authors are also grateful for the comments and information provided by ODI colleagues: Kate Bird, Katy Harris, Amanda Lenhardt and Annalisa Prizzon, as well as for the administrative and logistical support of Maria Bernardez throughout.

The case study report was funded by the Bill & Melinda Gates Foundation as part of 'Development Progress', a four-year research project that aims to better understand, measure and communicate what has worked in development and why. Its findings and conclusions are those of the authors and do not necessarily reflect the positions or policies of the Bill & Melinda Gates Foundation. For more information, contact Peter Newborne (p.newborne.ra@odi.org) and Bryn Welham (b.welham@odi.org.uk), or Susan Nicolai (s.nicolai@odi.org.uk).

Acronyms

ANEEL	National electricity regulator (Agência Nacional de Energia Elétrica)	GNI	Gross national income
ANP	National petroleum, natural gas and bio-fuels regulator (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis)	GHG	Greenhouse gas
BNDES	Brazilian National Development Bank (Banco Nacional de Desenvolvimento Econômico e Social)	GW	Gigawatt
CDE	Energy Development Account (Conta de Desenvolvimento Energético)	HSAP	Hydropower Sustainability Assessment Protocol
CO₂	Carbon dioxide	IBAMA	National environmental regulator (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis)
CNPE	National Council for Energy Policy (Conselho Nacional de Política Energética)	IEA	International Energy Agency
EMBRAPA	Brazilian Enterprise for Agricultural Research (Empresa Brasileira de Pesquisa Agropecuária)	ktoe	Kilotons oil equivalent
EPE	Research and planning arm of MME (Empresa de Pesquisa Energética)	kW	Kilowatt
ESBR	Sustainable Energy of Brazil (Energia Sustentável do Brasil)	kWh	Kilowatt hour
FHC	Fernando Henrique Cardoso	LAC	Latin America and Caribbean
FUNAI	National agency for protection of indigenous people (Fundação Nacional do Índio)	LnC	Light for the Countryside (Luz no Campo)
GDP	Gross domestic product	LPG	Liquefied petroleum gas
		LpT	Light for All (Luz para Todos)
		MME	Ministry of Mines and Energy (Ministerio de Minería y Energía)
		MW	Megawatt
		ONS	Operator of the national interconnected power system (grid) (Operador Nacional do Sistema Elétrico)
		PDSB	Social Democratic Party (Partido da Social Democracia Brasileira)

PPP	Purchasing power parity	PV	Photo-voltaic
PROCEL	National programme for electrical energy conservation (Programa Nacional de Conservação de Energia Elétrica)	R&D	Research and development
PRODEEM	National programme for energy development of states and municipalities (Programa de Desenvolvimento Energético de Estados e Municípios)	SHP	Small hydropower
PROINFA	Programme of incentives for alternative electricity sources (Programa de Incentivo às Fontes Alternativas de Energia Elétrica)	TFEC	Total final energy consumption
		TPES	Total primary energy supply
		UMIC	Upper middle-income country
		WCD	World Commission on Dams
		WWF	World Wildlife Fund

Abstract

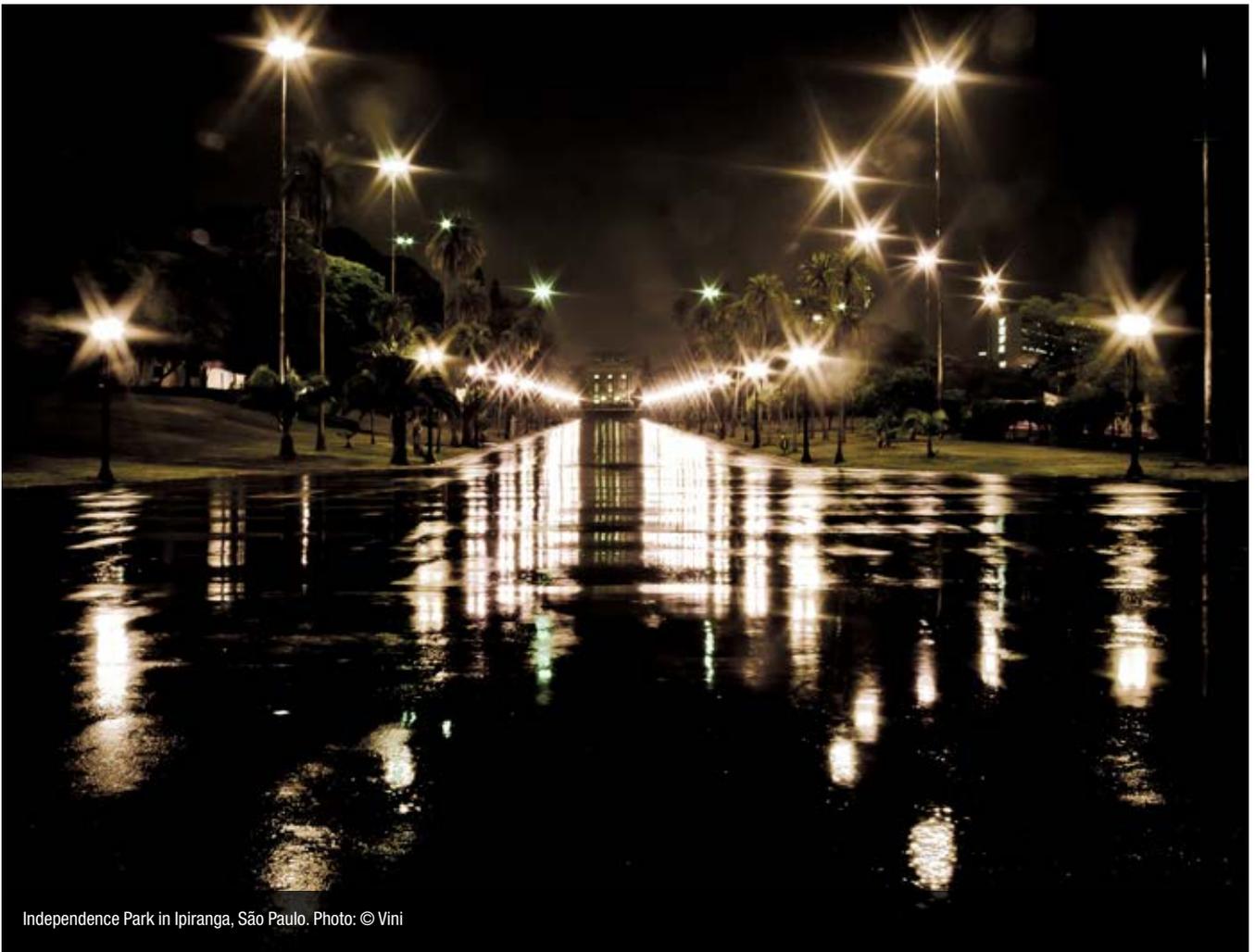
Between 1990 and 2010, Brazil more than doubled its energy supply and added 55 million more electricity users, supplying electricity to over 90% of all households while using more renewable energy and emitting less greenhouse gas than comparable countries. Its development of ethanol has resulted in the development of 'flex-fuel' car engines that can use both petrol and bio-fuel.

This impressive progress was achieved by a combination of sustained leadership, responsive regulation, public and private investment in research and technology, and government programmes to provide affordable electricity as part of wider poverty-reduction efforts.

Brazil still faces a number of challenges, however. The proportion of renewable energy in its energy mix is declining, and is likely to drop further as new oil and

gas deposits become available. Improvements in the design and management of (individual) large hydropower plants have not been matched by the government setting out a persuasive case to the public for the proposed further major expansion of hydropower. Wind and solar power currently make a small contribution, despite wide acknowledgement of their potential and some recent increases in capacity.

A key lesson from Brazil's experience is that growth in energy supply needs to be matched with credible demand-management measures. The country has made little progress in improving energy efficiency, which means that more energy is being produced and consumed than is necessary. Amid the achievements, this is a serious gap in energy policy.



Independence Park in Ipiranga, São Paulo. Photo: © Vini

1. Introduction

1.1 Why Brazil?

Brazil is an example of striking divergence from the ‘norm’ of energy development among upper middle-income countries (UMICs) and is often cited as an example of good practice in the development and implementation of energy policy.

In the 1990-2010 period – the focus of this study¹ – Brazil made further progress in providing electricity connections to the population, particularly in rural areas. It also met a growing energy demand with a substantial renewable element in its energy mix – particularly hydroelectric power and products from sugarcane – while emitting significantly less greenhouse gas (GHG) per capita than other Latin American and Caribbean (LAC) countries. This progress was achieved alongside consistent investment in the development of national skills and capacity to make such a transformation. Brazil also went further than almost any other country in developing a market for ethanol-based fuel products at the same time as significantly reducing energy imports. These achievements were recognised in the 2013 review by the World Bank and

United Nations of the steps towards ‘Sustainable Energy for All’ (SE4ALL, 2013), in which Brazil is praised as one of the ‘fast-moving’ countries.

This report describes how Brazil has made these advances. Brazil’s story of sustainable energy – a term used here to refer to energy that is available, accessible, affordable and environmentally sustainable – has certainly been one of progress in interesting respects. The capacity of its policy makers to plan and provide additional energy supplies to serve its economy and expand people’s access to electricity is surely a leadership example for other countries to emulate.

There are several important lessons, however, to be drawn from the Brazilian experience. The research on which this report is based found that the country’s record is more nuanced than its international reputation suggests. In relation to one of the three global objectives identified by SE4ALL (energy efficiency), Brazil’s record is poor and, in the case of a second (access to electricity), its progress between 1990 and 2010 was from an established base that was already higher than in neighbouring countries.



Vila Madalena, Sao Paulo. Photo: © Fernando Stankuns

1 This report also highlights significant developments from 2011 onwards.

Meanwhile, the current administration's reversals of previous progressive policy directions run counter to the earlier consistent leadership in the sector. In other words, despite the benefits secured for Brazilians in terms of their wellbeing and quality of life, the advances in energy have not come without problems and some failures. This combination of progress and setbacks makes Brazil an interesting case study for the 'Sustainable Energy' area of the Development Progress Project.

1.2 Brazil context

Energy development in Brazil has had to keep pace with an economy that has been growing substantially. The period between 1990 and 2010 saw an increase of 40% in gross national income (GNI) per capita (at purchasing power parity (PPP) of US\$ 2005), from \$6,984 to \$9,891 (World Development Indicators, 2013). This is in the context of population growth over the same period, from 144.82 million in 1990 to 190.75 million in 2010 (IBGE, 2013). Recently, despite continued growth, the rate of population increase has more than halved in relation to previous decades (IBGE, 2013).² Intense urbanisation occurred in Brazil from 1940 to 1991: the urban population grew from 13 to 111 million, comprising over 75% of the total population by 1990. The rural population increased in the same period by a relatively modest amount, from 28 million in 1940 to 29.8 million in 2010 (MME, 2007b; IBGE, 2013). The distribution of many rural communities in Brazil presents a major challenge in terms of providing access to energy, as discussed in Section 2.2.

In terms of access to electricity, Brazil is ahead of the LAC average and at similar levels to other UMICs. As well as providing power for household uses, access to energy expands livelihood opportunities and strengthens people's resilience in the face of climate change (Gaye, 2007), as well as supporting better education outcomes (children and students being able to study after dark)³ and enabling access to TV, radio and other media that can contribute to greater social and political integration.

'Brazil is now one of the world's top eight energy producers/consumers' – Energy Information Agency

The production and consumption of energy can, however, have serious consequences for the natural environment. Any assessment of energy's contribution to development progress in Brazil must, therefore, take account of its impact upon environmental sustainability. Although Brazil consumes a high proportion of its energy from renewable sources, between 1990 and 2012 the proportion of renewables in the country's overall energy mix decreased (EPE, 2013), with a corresponding increase in the share of non-renewable fossil fuels, especially natural gas for thermal power plants.⁴ The role of thermal plants as a reserve source of power is discussed in Section 2.3.

Hydropower is the largest source of electricity supply in Brazil, above levels in other LAC countries and much higher than the UMICs' global average. While the volume of domestic electricity supply from hydropower has doubled in the past two decades, the proportion of electricity produced by hydropower in Brazil gradually decreased between 1990 and 2010 (SE4ALL, 2013). In Brazil, and internationally, the environmental and social implications of large hydropower projects have been subject to increasing attention, in line with evolving regulation and practice (as discussed in Section 3.4). While Brazil has been improving its technical capacity in hydraulic engineering, there has been less attention given to developing its own technology and skills in wind and solar power.

Brazil has certainly a noteworthy story to tell on the use of bio-fuels (ethanol and bagasse).⁵ It has been a world leader in the use of ethanol as a liquid fuel, with a history of fuel development stretching back many decades. Brazil uses ethanol both as a blending agent with traditional petrol, and also as a liquid fuel in its own right. It has also developed 'flex-fuel' engines capable of running on both petrol and ethanol. The waste product of ethanol and sugar production – bagasse – can also be burned to generate thermal power. Sugar mills often engage in 'co-generation' whereby bagasse is burned in steam-power plants to operate the mill, and surplus electricity is, since 1987, sold back to the national grid (UNICA, 2012).

Brazil's size (nearly 8.5 million km²) and population make it the largest country in South America – three times the area of neighbouring Argentina and approaching that of the USA.⁶ Brazil has a generous natural resource endowment in terms of arable land and an extensive network of rivers. Such resources made it possible to develop hydropower and cultivate bio-fuels (including ethanol), within the limits of multiple, and sometimes

2 The population was increasing between 1940 and 1980 at an average rate of 2.6% per annum, which meant a tripling of the total population in that period, from some 41 million to 120 million. By 2011 population growth had dropped to 1.1% per annum.

3 As illustrated below, in section 2.2 (Box 1).

4 'Thermal' power plants use heat sources such as fuel (coal, natural gas, diesel etc.) combustion to produce electricity (as do nuclear reactors).

5 Bagasse refers to the lignocellulosic by-product resulting from the sugarcane milling for juice extraction, used as solid fuel.

6 The area of the USA is 9.16 million km².

competing, claims on the use of land and water.⁷ Moreover, the continental shelf along the Atlantic coast has been found to hold substantial offshore oil and gas deposits.

Brazil's large territory also brings certain disadvantages. Although electricity-generation plants are predominantly located inland, most of the population lives near the coast and in the regions of the south-east, north-east and south. Rapid urbanisation contrasts with dispersed rural populations, for example, in very remote locations in the north (particularly in the Amazon), where indigenous populations pursue largely traditional and distinct ways of life. The size of Brazil means that electricity transmission has to cover long distances.⁸ The national grid extends for over 100,000 km (EPE, 2013). The comparison with smaller countries is illustrated by the map of the Ministry of Energy and Mines (MME) and its research and planning arm, EPE (MME, 2007a: 210), overlaying the Brazilian national grid on a map of Europe. This map is reproduced on page 19.

This system is 'inter-connected', but it is not a closed loop, causing some regions at the end of the transmission line to suffer fluctuations in electricity voltage. Similar to piped water, customers near the limits of the network are more likely to suffer interruptions to supply. The issue of energy losses in transmission is considered in Section 4.3.

Development in Brazil over the last two decades has moved in line with political transition. The military dictatorships of the 1960s and early 1980s (under which only controlled elections were held and for which results were frequently manipulated), gave way to a new multi-party system with several successful democratic elections and a handover of presidential power between political parties in 2002. The 1988 Constitution established a modified federal republic, comprising 26 States plus the Federal District of Brasília, with executive,⁹ legislative and judicial branches. While the Constitution provides for significant devolution of power to the states, the federal government maintains a strong role, which is seen in the energy sector in particular. The Constitution also delegated formal powers to municipalities, although their ability to exercise those powers in practice varies according to the financial and human resources at their disposal (an illustration of this is noted in Section 3.4). Under Article 23 X of the Constitution, the government is responsible for 'combating the causes of poverty and social exclusion', including under Article 21 XII (b), a specific obligation regarding energy access. Article 231 relates to the protection of indigenous lands. The national indigenous foundation, *Fundação Nacional do Índio* (FUNAI), established by a 1967 law, is the national agency responsible for overseeing its implementation, which includes responding on behalf of indigenous communities

to large energy projects. Political power in Brazil still tends to be concentrated at federal level as well as in the densely populated states of the north-east, south and south-east. The relevance of the political transition in Brazil to the energy sector – particularly to planning for major energy infrastructure – is discussed in Section 4.3.

Until the 1980s, Brazil's economy was inward-looking and preoccupied with domestic affairs. The economy was relatively closed with a focus on the extraction of primary commodities and a policy of import-substitution industrialisation aimed at avoiding foreign dependency through domestic industrial production. The oil shock of the 1970s caused a huge rise in the price of oil and a corresponding increase in foreign debt. The country's debt crisis in the 1980s provoked an austerity programme, decline in growth rates, and very high inflation. With the economic stabilisation following the '*Plano Real*' in the early 1990s, and the liberalisation of the economy in the same decade that began under President Fernando Collor de Mello and was continued by President Fernando Henrique Cardoso (known as 'FHC'), the country opened up and overseas investment gradually returned, including in energy projects.

Further, since 2003, under the presidency of Luiz Inácio Lula da Silva (known as Lula) and the current president, Dilma Rousseff, and following the economic stabilisation achieved under the FHC administration, there has been a strong emphasis on socially inclusive economic development and ensuring that the benefits of rising living standards reach the poorer segments of the population, as discussed in relation to government programmes in Section 3.1.

Total gross domestic product (GDP) now places Brazil among the world's largest economies, albeit with higher levels of income inequality than most other middle-income countries. The south, central-west and south-east regions of Brazil are richer, and the north and north-east are poorer. Although this inequality has gradually reduced, from a Gini index of 0.61 in 1990 to 0.519 in 2011 – a 50-year low (Ipeadata, 2013) – in 2009 11% of Brazilians lived in poverty (below \$2 per day) and 2.2% in extreme poverty (below \$1.25 per day). The extent of energy poverty, in terms of households that still lack access to electricity, is discussed in Section 2.2.

Brazil's emergence as one of the world's biggest economies has been accompanied by increasing awareness of its growing global influence and greater international role and responsibilities. Under Lula's administration, South–South development and technical cooperation were pursued. Now, Brazilian environment ministers regularly meet their counterparts in meetings with other 'BASIC' (Brazil, South Africa, India and China) nations. Brazil is a member

7 For example, the land-use implications of expansion of sugarcane cultivation for production of biofuels (and food) are discussed in section 2.3.

8 The distances between the extreme points of the country are: north–south: 4,394 km; east–west: 4,319 km.

9 The president is both the head of state and the head of government, with a four-year mandate and a maximum of two terms.

of the G20 and G77, hosted the 2012 Rio+20 global environmental conference and pushed for a greater role for the G20 in managing global affairs. Brazil's international profile is rising still further as host of the 2014 football World Cup and the 2016 Olympic Games in Rio de Janeiro.

1.3 About this case study

This report first describes key changes that have taken place in Brazil's energy sector over the past two decades in order to explain the progress that has been made. The report identifies advances in three areas: (1) increased energy availability for economic development, (2) the expansion of access to energy services,¹⁰ and (3) the evolution of the renewable element in Brazil's energy mix. The country's record in energy efficiency and energy intensity is also discussed in Section 2.4.

This report analyses these above issues in depth, paying particular attention to the power sector, as well as the remarkable story of ethanol, with somewhat less emphasis on other aspects, such as oil and gas. Such is the breadth of energy policy and practice in a large country that this research has necessarily had to be selective.¹¹

Second, the report sets out a number of 'drivers' of progress and seeks to identify the factors that made it possible. It reviews Brazil's achievements – including some setbacks and failures – to identify lessons that other countries might apply in their efforts to achieve sustainable energy.

The research team for this Development Progress study comprised researchers based in the UK and Brazil. All were

involved in analysing available primary and secondary data and literature. Key data sources in Brazil were the MME/EPE (e.g. annual national energy balances) and the national electricity regulator, ANEEL. Where there were differences between Brazilian and international data, the former were preferred. The UK-based team visited Brazil for two weeks to conduct, alongside their Brazilian colleagues, 22 key informant interviews and an expert roundtable including government officials and representatives of private companies and civil society. The trip also included a visit by two of the researchers to the site of the Jirau hydropower plant in Rondônia State, as well as to Porto Velho, the principal city of Rondônia. The UK-based team drafted this report, with advice and significant inputs from the Brazilian experts.

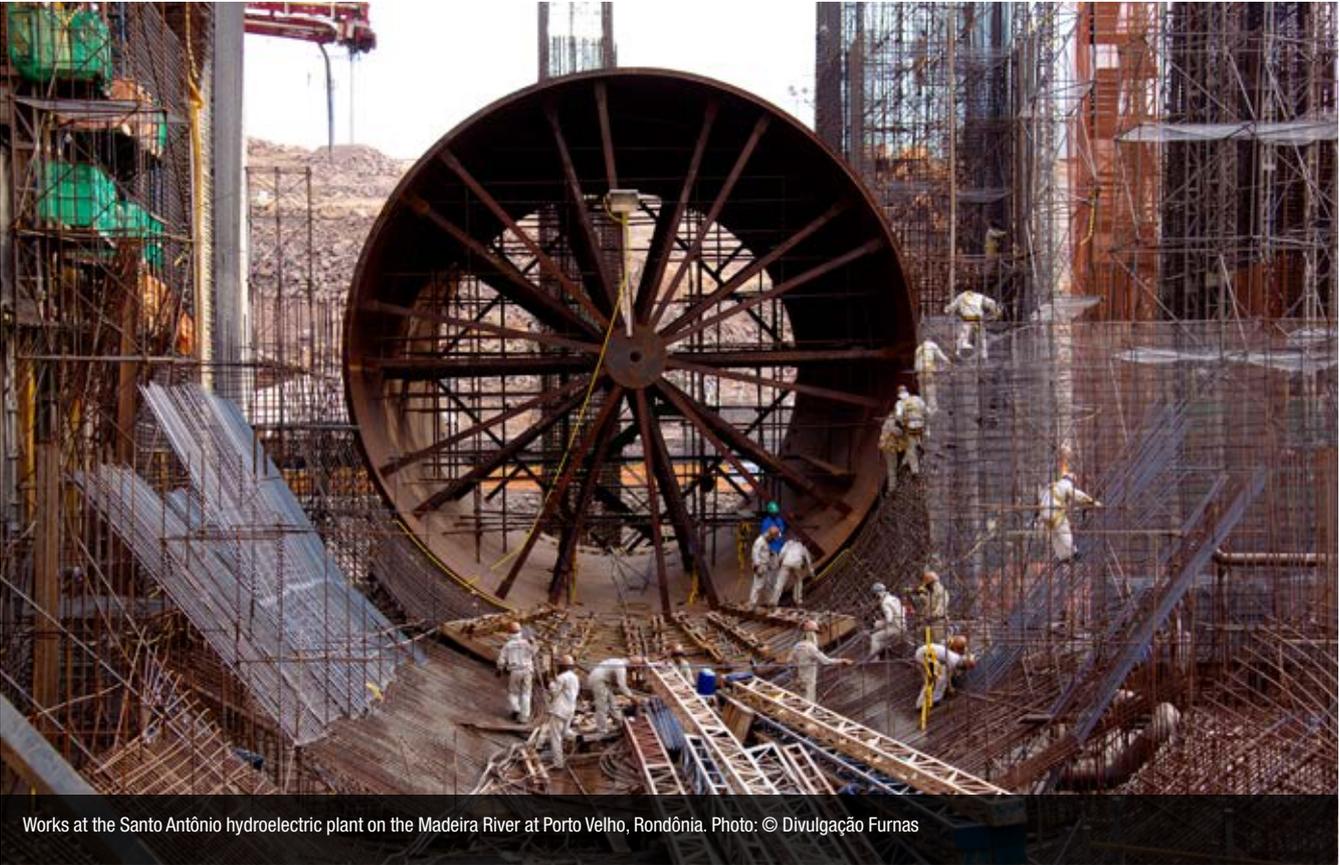
The report is organised as follows:

- **Section 2** describes the progress that has been achieved in Brazil's energy sector since 1990, focusing on overall energy availability and consumption, levels of access to energy and the renewable energy mix. It also discusses the extent of Brazil's efforts to date in relation to energy efficiency, as well as the evolution of energy intensity.
- **Section 3** analyses the key drivers of this progress.
- **Section 4** looks at the challenges Brazil confronts in continuing to provide sustainable energy.
- **Section 5** provides some conclusions and lessons that other countries could draw from Brazil's experience in the period from 1990 to 2010 and beyond.

10 The term 'modern' energy services as adopted by Sustainable Energy for All (describing the variety and range of different forms of energy use for domestic, productive and community services) is not generally used by energy specialists in Brazil, who tend to adopt the terms 'commercial' and 'non-commercial' sources.

11 Nuclear energy could, for example, be the subject of a future study.

2. What progress has been achieved?



Works at the Santo Antônio hydroelectric plant on the Madeira River at Porto Velho, Rondônia. Photo: © Divulgação Furnas

This section describes the evolution of Brazil's energy sector over the past two decades, focusing on:

- the increase in overall energy availability and consumption
- the extension of access to electricity at the household level
- the renewable energy mix, and
- energy efficiency and intensity.

The progress in the first three areas is contrasted with the lack of progress in the fourth.

'Brazil has achieved a high share of renewable energy in its total domestic consumption' – Sustainable Energy for All, 2013

2.1 Increase in energy availability for economic development

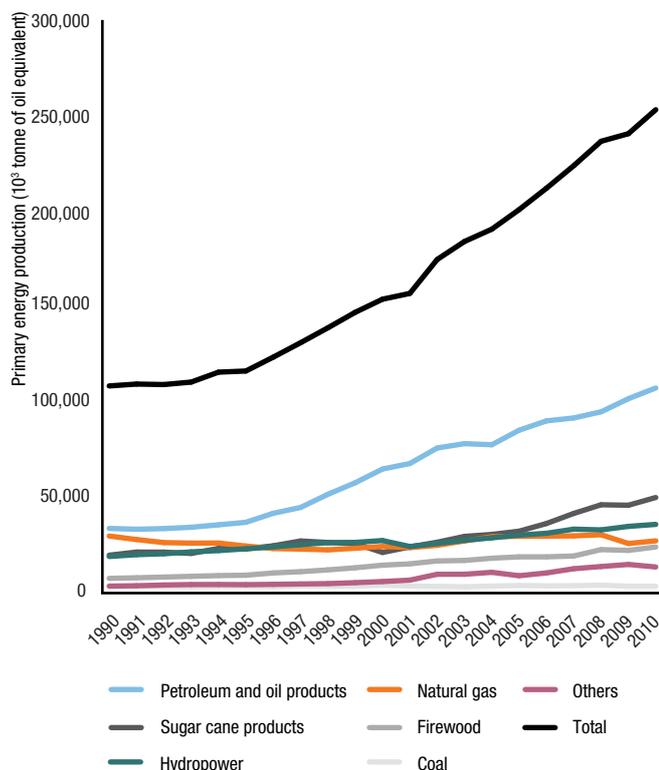
2.1.1 Growth in energy production

Brazilians growing up in the 1960s and 1970s were used to power cuts. A well-known samba song about Rio de Janeiro refers to water shortages during the day and power cuts at night. Since then, the country has expanded the national electricity supply to meet increased demand. Given its growing population and economy, energy production gains have had to 'run in order to stand still'.

In 2010, Brazil produced a total of 253,553 kilotons oil equivalent (ktoe) of energy from all sources, imported 71,895 ktoe and exported 46,232 ktoe (net imports: 25,663 ktoe) (EPE, 2011). This places Brazil as one of the world's top eight energy producers/consumers (EIA, 2013). Total primary energy supply (TPES)¹² was 297,960 ktoe,

¹² TPES equals production, plus imports, minus exports, minus international bunkers, plus or minus stock changes.

Figure 1: Composition of primary energy production: 1990-2010 10³ toe (tonne of oil) equivalent



Source: EPE, 2011

and total final energy consumption (TFEC)¹³ was 224,252 ktoe, compared to 143,224 for TPES and 117,582 for TFEC in 1990 (EPE, 2011). This means that supply has effectively more than doubled.

All of Brazil's energy sources saw a steadily increasing trend in volumes of use between 1970 and 2010, as shown in Figure 1.

2.1.2 Increase in energy consumption

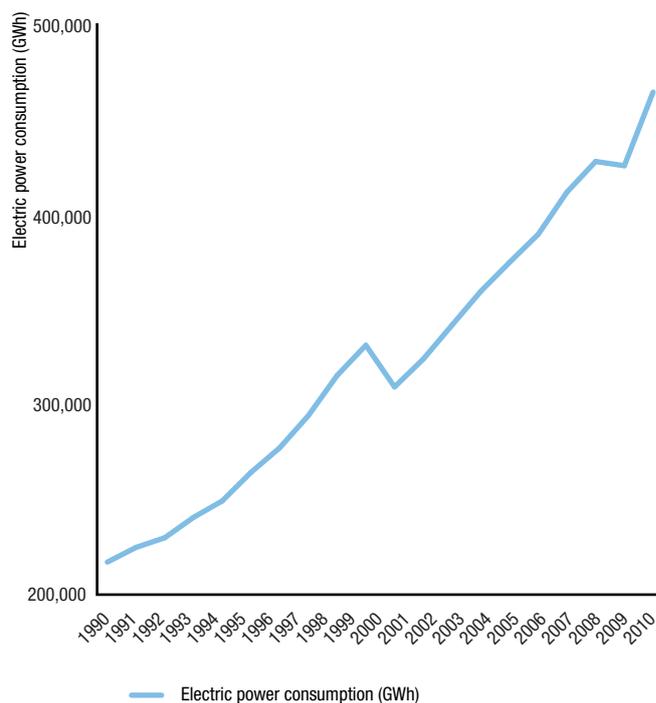
This increased energy production is evidenced¹⁴ by the steady increase in electricity consumption (see Figure 2) in relation to other LAC countries (see Figure 3, overleaf) (the increase is a little less than in UMIC countries).

From 1970 to 2005, per capita electricity use increased at an average annual rate of 6.6% (MME 2007a: 85), although there was a noticeable decline during the power crisis of 2000-2001 when electricity was rationed – see Section 3.3.

2.1.3 Reduction in energy imports

What makes Brazil's significant expansion of energy and electricity generation more noteworthy is that it has been achieved at the same time as further reductions in

Figure 2: Total electric power consumption: 1990-2010



Source: World Development Indicators, 2013

energy imports. Figure 4 (overleaf) shows that between 1990 and 2010, the dependence on 'external energy' declined from 25% to less than 10% of the country's total production. As discussed in Section 3, this was due to a number of decisions regarding the energy sector, including investment in increasing domestic oil production, developing domestically produced ethanol as an alternative to imported petrol and substantially increasing the amount of electricity generated from domestic renewable sources. The discovery and beginnings of extraction from domestic deep-sea oilfields in 2011 may well reduce this further.

2.1.4 Forecasting future energy demand

As for future increases in energy demand, the MME/EPE use GDP growth forecasts as the measure of how energy availability, including electricity, should grow. The MME's forecast in the 2030 Plan (MME, 2007a) is that electricity demand will grow by 4.1% per annum, corresponding to a 4.1% average GDP growth per annum as in Scenario 'B1', the second highest of four possible scenarios of Brazil's future development trajectory. MME/EPE figures (Figure 5, overleaf) show that between 2000 and 2012, GDP and electricity consumption have grown at the same average rate of 3.4%.

13 Final energy consumption covers all energy supplied to the final consumer for all energy uses. It is usually disaggregated into the end-use sectors: industry, transport, households, services and agriculture.

14 The relationship between electricity production and consumption is discussed in section 4.3.

Figure 3: Electric power consumption per capita (kWh)

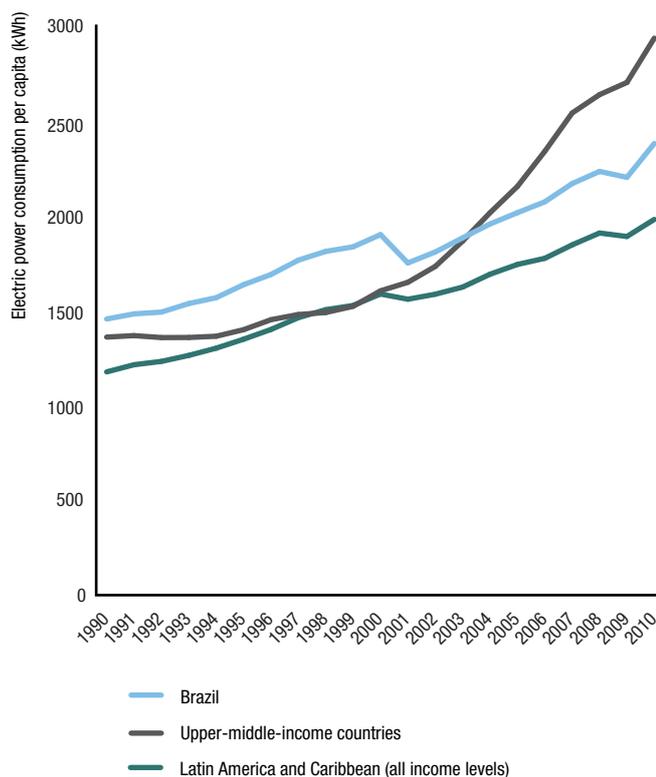
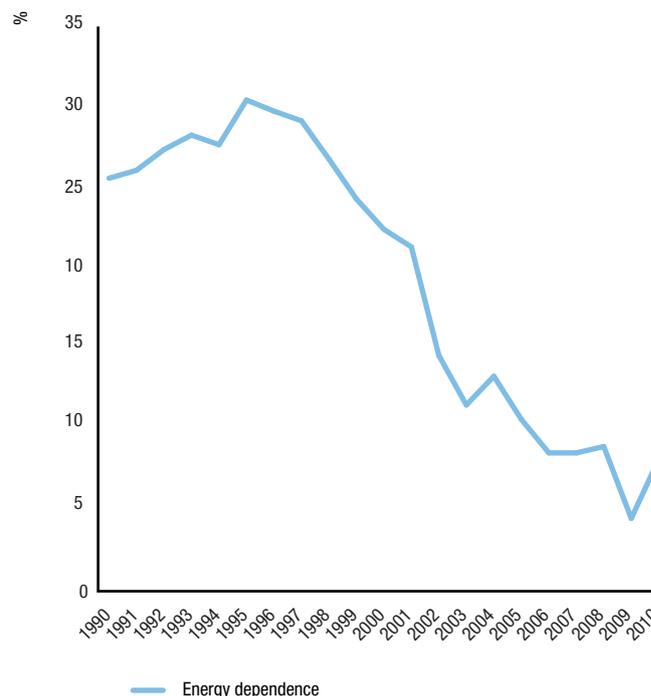


Figure 4: Dependence on 'external energy': 1990-2010



Source: EPE, 2011

Source: World Development Indicators, 2013

Note: One million kWh are equivalent to 1 GW hour. Unless otherwise stated, the source of data in Section 2 is the World Bank's World Development Indicators.

That is with the benefit of hindsight. The difficulty of forecasting future economic conditions makes the projection of future national economic performance an inherently uncertain exercise. Figure 6 shows the substantial fluctuations in annual GDP growth since 1990. The averages for 1990-2000 and 2000-2010 came out at 2.4% and 3.4% respectively.

Looking back further, the increases in electricity consumption in the 1970s and 1980s exceeded economic growth. During the economic crisis in the 1980s, energy consumption was increasing at over three times the rate of national growth.¹⁵ This figure compares with the average for the 1990s, when the ratio of GDP growth to consumption growth was 1:1.73. From 2000-2012, the ratio was (when averaged out) 1:1.

2.1.5 Uses of energy

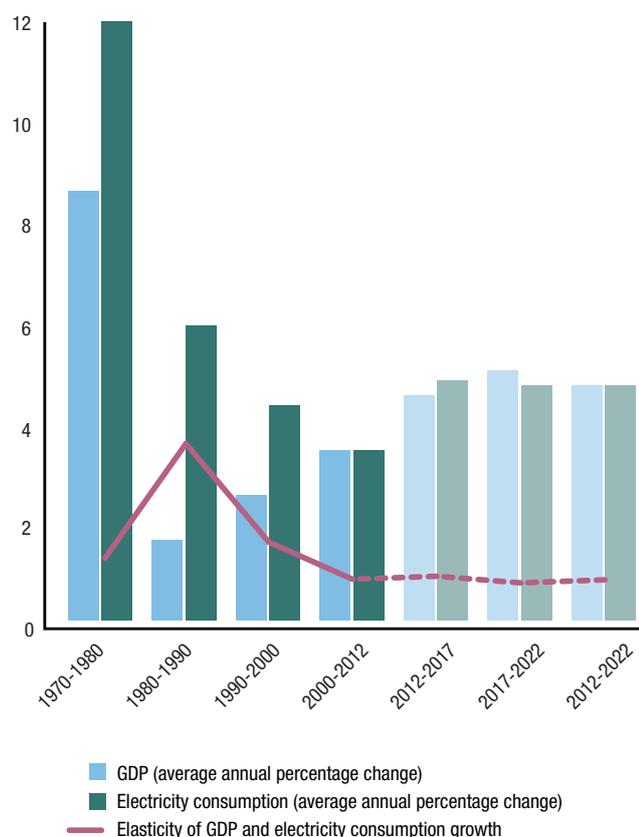
As for the uses for which this energy serves, Table 1 shows final energy consumption in Brazil by sector. Throughout the period from 1990 to 2010, industry was the largest energy-consuming sector, at 38% of total national consumption in 2010 and industry is forecast by the MME to constitute 42% of total consumption in 2030 (MME, 2007a: 46). The service sector was catching up (see Table 1), although its forecast share in 2030 is 25% (MME, 2007a: 46).

As shown in Figure 7 (page 18), industrial energy use has increased in absolute terms during the two decades 1990 to 2010. As for consumption by particular parts of industry, the 'Food/drinks', 'Pulp and Paper', and 'Cement and Ceramics' sectors stand out as areas in which energy use has increased substantially over the two decades. Other key energy-consuming industrial activities are mining, aluminium, steel, and civil construction (EPE, 2013). Production of aluminium, for example, including the heavily energy-intensive smelting processes, doubled in the ten years from 2004 to 2013 (Massarente et al., 2013, citing figures produced by the Brazilian Aluminium Association).

What this means in terms of energy efficiency and energy intensity is considered in Section 2.4.

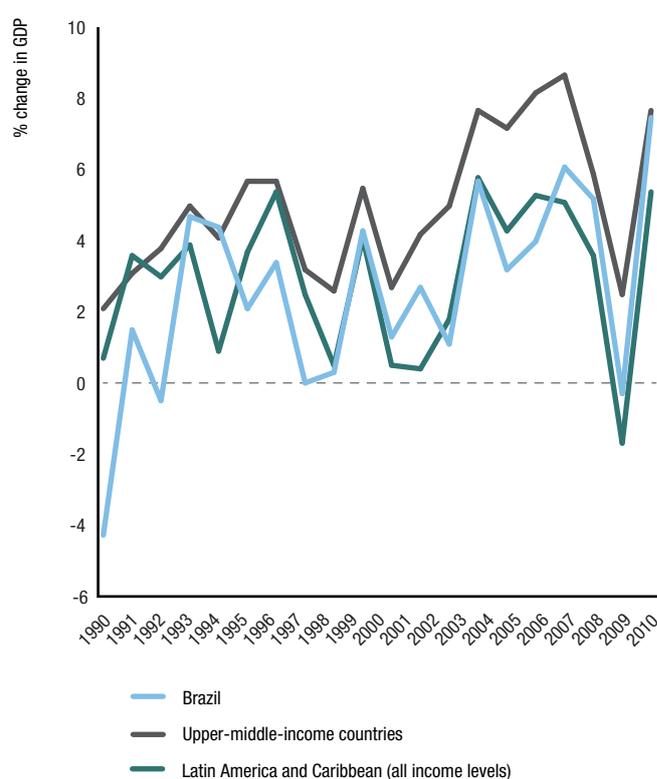
¹⁵ It is not clear why this occurred in the 1980s, whether for example, due to higher than forecast growth in energy-intensive industries, more households and businesses being connected, or other factors. As noted above, in the period of focus of this study, 1990-2010, the actual levels of growth in energy consumption were much closer to the forecast rates of increase.

Figure 5: Average rates of growth of GDP and energy consumption, by period



Source: EPE (www.epe.gov.br/mercado/Documents/S%C3%A9rie%20Estudos%20de%20Energia/20130117_1.pdf)

Figure 6: Brazil: GDP growth, year on year (3-year rolling average)



Source: World Development Indicators, 2013

Table 1: Final energy consumption by sector by tonne of oil equivalent (ktoe) and percentage

	1990	2000	2010	2012
Final energy consumption	159,702	221,914	223,508	236,744
Services	45,511 28.49%	9,713 4.37%	80,086 35.83%	90,767 38.33%
Agriculture (including cattle)	7,259 4.54%	9,713 4.37%	10,029 4.48%	10,362 4.37%
Industry	65,718 41.15%	89,724 40.43%	85,567 38.28%	88,966 37.57%
Energy (energy used in producing energy)	13,181 8.25%	14,202 6.39%	24,263 10.85%	22,888 9.66%
Residential	27,730 17.36%	37,728 17%	23,562 10.54%	23,761 10.03%

Source: EPE, 2013

2.2 Access to energy sources that are affordable, reliable and clean

This section reviews the progress Brazil has made on extending household access to electricity, both in terms of physical availability of a connection, and in making such access affordable for poorer households.

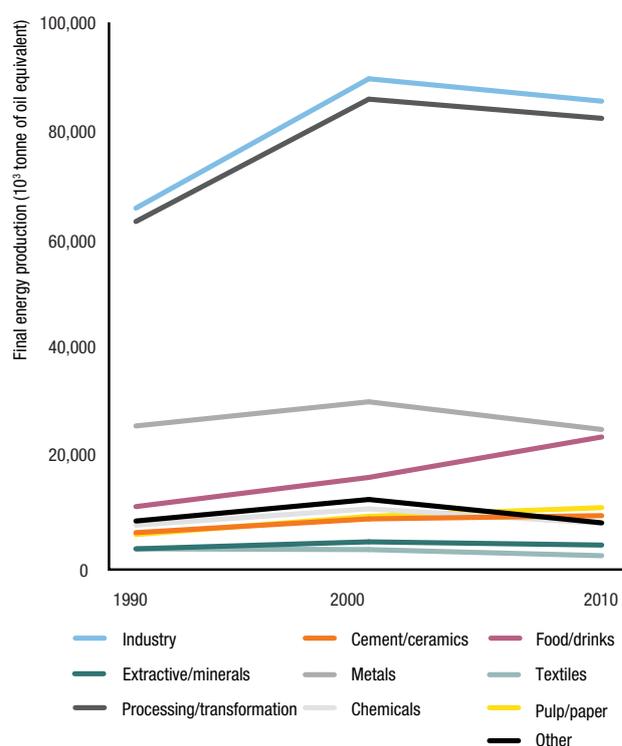
2.2.1 Extending access to electricity

Overall, between 1990 and 2010, Brazil made progress in extending access to electricity, particularly to rural households, which also increasingly used non-solid fuel. Rural households in Brazil are typically poorer than their urban counterparts, and live in more dispersed locations. The exact extent of the increase in access in Brazil has, however, been measured differently by different bodies – see Table 2.

Applying these percentages to the recorded national population in 1990 and 2010 (noted in Section 1.1) points to a total increase in electricity access of 55 million people. As shown in Table 2, in 1990 92% of Brazilian households already had electricity. The progress achieved between 1990 and 2010 therefore started from a strong base. By 2010, according to the Brazilian national census, urban electricity access stood at 99.1%, while SE4ALL, cited in Table 2, suggests that coverage had reached 100%. Access in the slums (*favelas*) of Rio de Janeiro, São Paulo and other cities includes illegal connections. The current government's programmes to 'pacify' the *favelas* of Rio¹⁶ aims to gradually register households as paying customers of electricity and other services.

As for rural connections, the task of the past 10 years has been to extend electricity to communities in remote areas (Pereira et al., 2010). While that positive trend is clear, there is, as one energy specialist stated to the authors, 'a serious lack of consistent information on the number of connections; reliable and up-to-date data are lacking'. The figures available from SE4ALL (Table 2) suggest that rural access was at 94% in 2010, although the 2010 census gives the lower rural coverage figure of 89.7%. In either case,

Figure 7: Final energy consumption in industry, overall and industry sectors, in 10³ toe (tonne of oil) equivalent



Sources: EPE, 2013: 131; EPE, 2001: 80

increased access to electricity means that fewer rural people depend on candles and lamps for lighting (MME, 2009) and fewer need to use diesel or oil-powered generators (for those that can afford them).

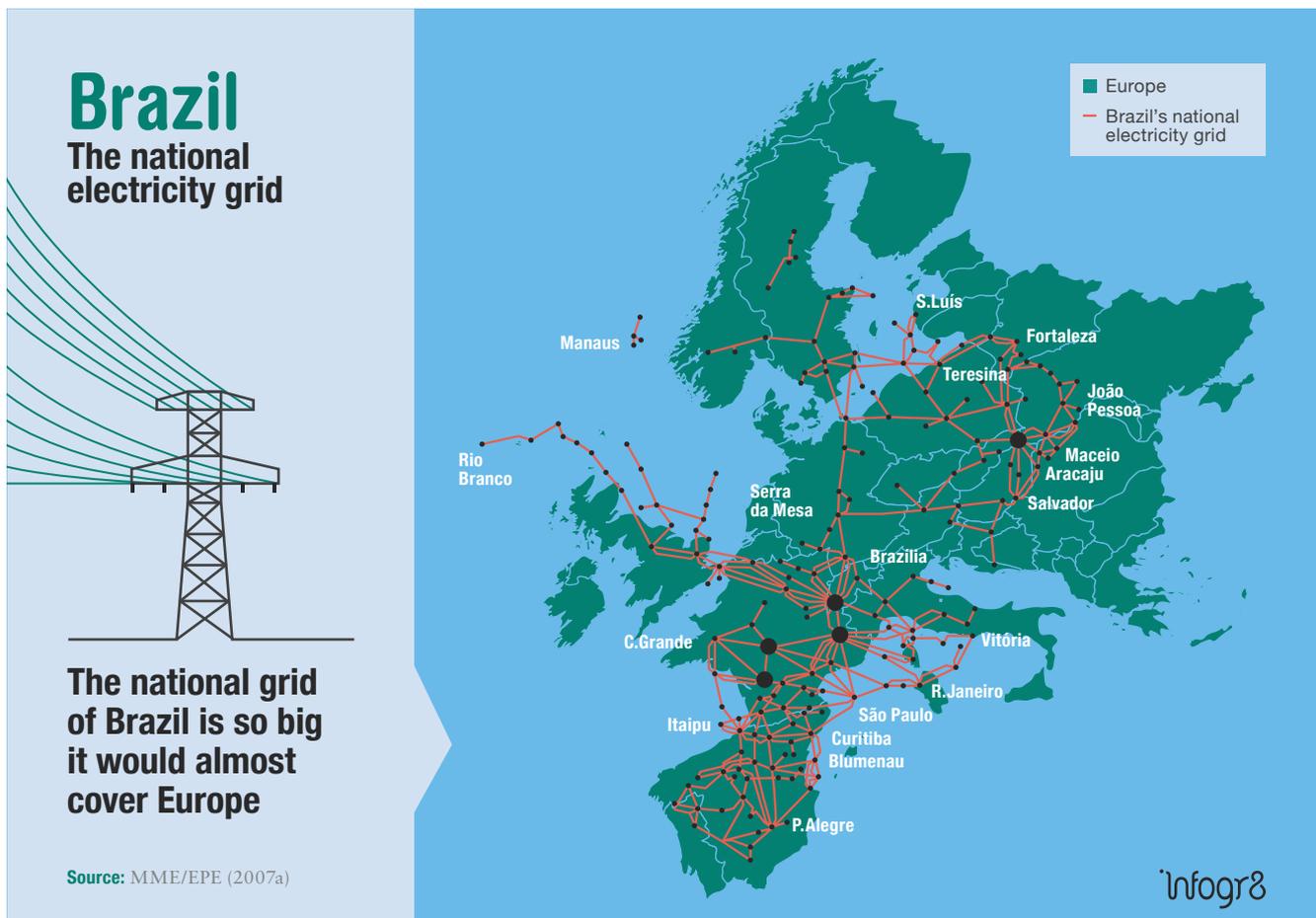
Brazil's success in extending access to electricity places it above the LAC average, and at similar levels for other UMICs (see Table 2). In terms of absolute numbers, whereas in 2000 some 2 million Brazilian households had no electricity connection, by 2010 that figure had dropped to 700,000, of which 200,000 (i.e. 29%) were below the

Table 2: Access to electricity (% of population) in Brazil compared with LAC/UMICs

Year	Brazil	LAC	UMICs
1990	92%	88%	93%
2000	97%	92%	96%
2010	99%	95%	98%
	Rural = 94% - 89.7%*	Rural = 84%	Rural = 96%
	Urban = 100% - 99.1%*	Urban = 98%	Urban = 99%

Sources: SE4ALL, except where marked with an asterisk where the source is the 2010 national census

16 A twin programme exists in Paraná called the Unidade Paraná Seguro (Safe Paraná Unit).



poverty line (IBGE, 2010a). Government figures recorded the total number of households connected to electricity at 56,595,007 in 2010 (IBGE, 2010a).¹⁷ The remaining 700,000 households (6%) represent many of those most difficult to reach. The challenge posed by connecting them, in order to attain the goal of universal access, is considered below. The government programmes, *Luz no Campo* ('Light in the Countryside') launched in 1999 and *Luz para Todos* ('Light for All'), created by the Lula government in 2003-2004, are described in Section 3.1.

2.2.2 Access to non-solid fuels

Brazil has also made substantial progress in expanding access to non-solid cooking fuels (Table 3, overleaf). Historically, wood was the principal energy source for rural populations and still met the fuel energy needs of 48% of Brazilian households in 1970. Between 1970 and 2005, the consumption of wood fuel declined by an average of 2.9% per annum (MME, 2007a: 86).¹⁸

The percentage of the Brazilian population with access to non-solid fuel shown in Table 3 corresponds to an increase of 3.2 million people a year between 1990 and 2010,

totalling 62.5 million over the whole period (as a point of comparison, the population of the UK is around 63 million).

2.2.3 Energy options for isolated communities

There are physical limits to grid expansion. Lower energy use by rural as opposed to urban consumers, and in many cases low rural household incomes, make extending the grid to rural areas costly and often impractical (Zeriffi, 2008). Other energy options are needed to supply small remote communities, for example, those living in the Amazon region with rivers and difficult terrain between them. The reliability and simplicity of installation and operation of diesel generators makes them a valid alternative for power production in isolated sites, although the logistics of supplying and distributing fuel may be complex. As a fossil fuel, diesel produces GHG emissions that contribute to global climate change, as well as having potentially negative health effects (e.g. exhaust fumes cause respiratory problems).¹⁹ As one energy specialist commented, however: 'Considering the typical installed capacity and load factor, GHG emissions from diesel generators operating in isolated places are minor, almost

17 IBGE, 2010, see: www.censo2010.ibge.gov.br/sinopse/index.php?dados=P13&uf=00

18 See www.prolenha.org.br/sbfe/arquivos/disseminacao-de-fogoes-a-lenha-eficientes-felipe.pdf.

19 Similar health problems arise from use of wood for cooking.

negligible. Meanwhile, the health impacts of diesel generators operating in those conditions are avoidable’.

Another possible option is decentralised, off-grid generation – mini/micro grids or ‘stand-alone’ or ‘isolated’ systems (GVEP, 2011) powered by renewables – small hydropower (SHP),²⁰ solid biomass and vegetable oils and biodiesel, or solar, or ‘hybrid’ systems combining elements of those. A study commissioned by MME reported on appropriate technologies for use in the Amazon, giving example projects. Those included four pilot SHP projects in Pará and Rondônia States (MME, 2008: 62-66), supplying power at 50-60 kW for 40-55 families. Small hydropower is site-specific in that it has to be installed at locations where a river drops in level (on a slope, or at a falls). The authors of the MME study note the success of three of the four pilot SHP projects (MME, 2008: 68), but also emphasise the importance of operation and maintenance being undertaken by the communities. The authors suggest that the Amazon region is highly suited to installation of SHP schemes, (MME, 2008: 68), but a second commentator cautioned against the widespread use of SHP in areas of high biological diversity: ‘The environmental impacts of SHP may be high for migratory species in rivers’.

A further study has been carried out on the community of Santo Antônio, in the district of Breves, Pará State, in the Amazon, with the support of an energy utility company, Celpa, and the Federal University of Pará (see Box 1). This example illustrates the challenges and a possible mix of energy solutions in remote rural contexts, as well as the benefits of electricity supply for the entire community.

Such perceptions of the benefits of electricity access (from mini-grids or the grid itself) are echoed in the findings of a government survey of the results of the government electricity-expansion programme, *Luz para Todos*, as

discussed in Section 3.1. One energy specialist commented on the challenge of reaching remote communities:

The search for alternatives to conventional diesel generators goes on. Replacing those in distant places is still very difficult, despite the efforts of pilot schemes like the one in Pará. Unfortunately, with few exceptions of places where SHPs can be implemented and limited other technology niches (solar panels), there is not yet an economically feasible and reliable renewable technology to use renewable energy to generate power in these isolated sites.

2.2.4 Affordability

Once connected, affordability is a key issue for low-income households. If they fail to pay the electricity bill for over two months, the power companies have the right to disconnect them. To counter this, low tariff bands for low-usage consumers are intended to enable poorer households to afford electricity.

The ‘residential low revenue’ charges are shown in Table 4, page 22. This is a comparison of tariffs charged to residential customers in six regions in Brazil, which reflects the discount for low-income households. This is an ‘increasing block tariff’ structure, with a 65% discount for the first tranche of electricity consumed each month up to 30 kilowatt hours (kWh), with successive tranches thereafter at 40% and 10% discounts for 30-100 kWh and 100-220 kWh respectively.

The households qualifying for the highest discount rate are those targeted by the ‘*Bolsa Família*’ (family grant) social-protection programme. This government scheme provides conditional cash transfers to 12.7 million families in Brazil, or 50 million people – representing about 26% of the population in 2010.²¹ The *Bolsa Família* is part of the ‘Brazil without Misery/Extreme Poverty’ plan, designed to eradicate extreme poverty in the country by 2014. Households with incomes equal to or less than the monthly

Table 3: Access to non-solid fuel (% of population)

Year	Brazil	LAC	UMICs
1990	81%	73%	53%
2000	89%	81%	64%
2010	94% Rural = 64% Urban = >95%	86% Rural = 57% Urban = 94%	71% Rural = 36% Urban = 85%

Source: SE4ALL

20 ‘Small’ hydropower plants (SHP) in Brazil, are, according to the national electricity regulator, ANEEL, those with installed capacity greater than 1 MW and less or equal to 30 MW, with reservoir areas of less than 3 km². Below 1 MW, there are ‘mini’, ‘micro’ and ‘pico’ plants. Those compare with large hydropower plants above 30 MW (referred to as ‘usinas’ or factories).

21 See World Bank website: www.worldbank.org/en/country/brazil/overview.

Box 1: Improvements in the quality of life in a remote rural community in the Amazon

The Santo Antônio project provides two types of renewable energy: a biomass power plant and solar photo-voltaic (PV) panels. The former serves a mini-grid for the majority of the Santo Antônio community on one side of the river, where homes are clustered in one area. The individual solar panels have been installed on four houses on the other side of the river. The biomass plant is used to provide power from 07.00 to 23.00 each day. It also provides electricity for two churches, a school, snack shop and a sawmill. The mini power plant burns the wood residues, and the heat from this process is transferred to a steam boiler. The steam is used to spin a turbine, which generates electricity. The mini power plant provides 15 kW and each PV system has 170 watts-peak (compared to the 5,000 watts provided by the main grid, sufficient to run all household appliances). The community cooperative operates the biomass power plant. Alongside the owner, two people work at the plant in eight-hour shifts. Operation and maintenance of the plant is expected to cost R\$11,500 a year (around \$5,000), plus the salary of the operators (R\$45,000 – around \$19,500), who have been trained in basic maintenance.

Households pay for actual use of electricity, based on monthly meter readings. For the biomass energy, consumers pay R\$0.25 per kW hour of electricity, and are estimated to have monthly costs of R\$10-30 (around \$4-12). For the solar PV systems, the expected cost to the consumers is R\$10-15 a month (around \$4-8). The annual cost of energy for the owner of the sawmill is much lower than it would be to produce an equivalent amount of energy using diesel fuel at R\$11,500 (\$5,000) for biomass energy compared to over R\$200,000 (\$87,000) for diesel fuel). A key factor in the choice of Santo Antônio for the pilot was that the community was well organised, and the sawmill owner provided strong leadership for operation and maintenance.

All the community members who were asked what the project had brought said that electrification had improved their quality of life. It had allowed them to have light and use energy at night, as well as using energy to make household tasks easier. Watching TV (those households benefitting from the mini-grid), for on average four hours a day, meant they were 'more informed about the world'. The school, they said, no longer lacked electricity and the sawmill employed three community members. One person commented (a point confirmed by other community members) that the project would be even more successful if, in addition to the sawmill, 'the community is able to use electricity for a [further] productive activity' to supplement their incomes. Suggestions included an ice factory and açai (palm) production (although this would point to the need for a higher kW system).

Source: Plovnick, 2010

minimum salary are entitled to the state benefits, *Bolsa Família*, and potentially to other welfare programmes such as *Brasil Carinhoso*, providing education, health and nutrition programmes for pre-school children in poor households. Registration with the *Bolsa Família* provides a unique registration number, the 'passport' for other state benefits and automatically provides eligibility for the social tariff for electricity.

Although every utility company in Brazil is obliged to offer differentiated tariffs for low-income customers, (the 65%, 40% and 10% rates noted above), the actual rates differ substantially from region to region (see Table 4, overleaf).²² For example, the price of electricity in São Paulo (lowest) is 61% of that in Rio de Janeiro (highest), with the differences largely due to different levels of state government tax, according to the interview with one energy specialist.

Household energy consumption averages 158.9 kWh per month in Brazil (EPE, 2013). Applying the differentiated tariff structure means an average monthly

electricity bill would incorporate the 65%, 40% and 10% tranches, resulting in a bill of R\$41.16 (\$17.80) in Rondônia, and R\$51.95 (\$22.58) in Rio de Janeiro (including the discounts). Applied across a full year, this represents 4.2% and 5.6% of per capita GNI in 2012²³ and amounts to 6% and 8% of the 2013 minimum salary respectively.²⁴ This is above the level of outgoings on electricity identified by a 2008-2009 study, which identified electricity costs as amounting to 3.7% of household budgets for those earning R\$830 (\$360) a month (IBGE, 2010b), the lowest of seven income levels shown in the results of this nationwide survey (IBGE, 2010b). For middle-income earners (R\$2,490-4,150 per month), it amounted to 2.5%. The equivalent percentages for low-income and middle-income families in the north-east, north and south-east regions of Brazil are respectively: 2.8% and 2.1%; 2.7% and 2.9%; 4.2% and 2.5%. These figures underline that, for low-income households in each region, electricity costs represent a significantly higher proportion of their expenditure than for middle-income

22 In relation to the price of electricity in Rondônia, the state in which the Jirau hydropower plant is located, see section 3.4.

23 Using the World Bank Atlas method of GNI per capita (World Development Indicators 2013).

24 The current minimum salary is R\$678.00 (approx \$312). As for the evolution of the minimum salary see Fohla de S.Paulo: www1.folha.uol.com.br/mercado/2013/07/1306719-indice-que-reajusta-salario-minimo-e-aposentadoria-sobre-quase-7-em-12-meses.shtml.

families, although the relative weight of electricity bills is seen to be heaviest for the lowest-income group in the south-east region. The south-east is noted in the report of this study (IBGE, 2010b) as the region where households had the highest levels of monthly spending (on all types of expenditure), compared with the thriftiest (and poorest) north-east and the middle-ranking north.²⁵

The minimum salary is intended to be enough to pay for food, household, transport and health care, adjusted to take account of inflation. An energy bill of between 6% and 8% of household income would represent a significant, although not exceptional, expenditure for poor households.²⁶ Families may have more than one income, but it is clear that electricity and energy costs represent a significant part of household expenditure. As suggested by the widespread street demonstrations in 2013 in Rio de Janeiro and other cities,²⁷ price increases and the cost of living have become major political issues.

2.3 Evolution of the renewable energy mix

This section reviews the evolution of the share of renewable energy in Brazil, including how its renewable energy mix compares with other LAC countries and UMICs. Renewable energy sources, such as hydroelectricity, solar energy, bio-energy, and wind power, are considered to meet the essential criteria of sustainability: they are not substantially depleted by continued use; they do not emit pollutants; and they do not perpetuate substantial health hazards.²⁸

2.3.1 The Brazilian energy mix

Figures 8 and 9 (page 24) show the evolution of the renewable element in Brazilian domestic energy supply between 1990 and 2010, in percentage proportions and absolute terms (volumes) respectively.

Figures 8 and 9 indicate two key points regarding the evolving Brazilian energy portfolio between 1990 and

Table 4: Block tariff structure for residential customers, 2013 (in Brazilian reais per kWh)

Rondônia (north-west) CERON Centrais Eléctricas de Rondônia	Manaus (north) MANAUS-ENERGIA Manaus Energia S/A	Bahia (north-east) COELBA Companhia de Electricidade do Estado de Bahia	Brasília (centre) CEB Companhia Energética de Brasília	Rio de Janeiro (south-east) CERJ Companhia de Electricidade do Rio de Janeiro	São Paulo (south-east) ELETROPAULO Electropaulo Metropolitana Electricidade de São Paulo S/A	Rate of discount for low-income households
Residential						
0.339	0.271	0.293	0.256	0.392	0.238	
Residential low revenue - Monthly consumption						
Equal or less than 30 kWh						
0.115	0.093	0.100	0.087	0.137	0.0816	65% discount
More than 30kWh or equal to or less than 100kWh						
0.197	0.160	0.172	0.150	0.234	0.140	40% discount
More than 100kWh or equal to or less than 220kWh						
0.296	0.240	0.258	0.225	0.351	0.210	10% discount
More than 220kWh						
0.329	0.266	0.287	0.250	0.390	0.233	Discretionary
97.09%	98.06%	97.86%	97.43%	99.54%	97.7%	discount

Source: ANEEL Technical Information (www.aneel.gov.br/area.cfm?idArea=493.) Figures rounded to three decimal places.

25 Further research could usefully shed light on why the lowest-income families in the south-east are spending a higher proportion of their income on electricity than their counterparts in other regions. Is the 4.2% figure above explained by higher electricity prices (overall), by consumption habits in the south-east, or by other factors?

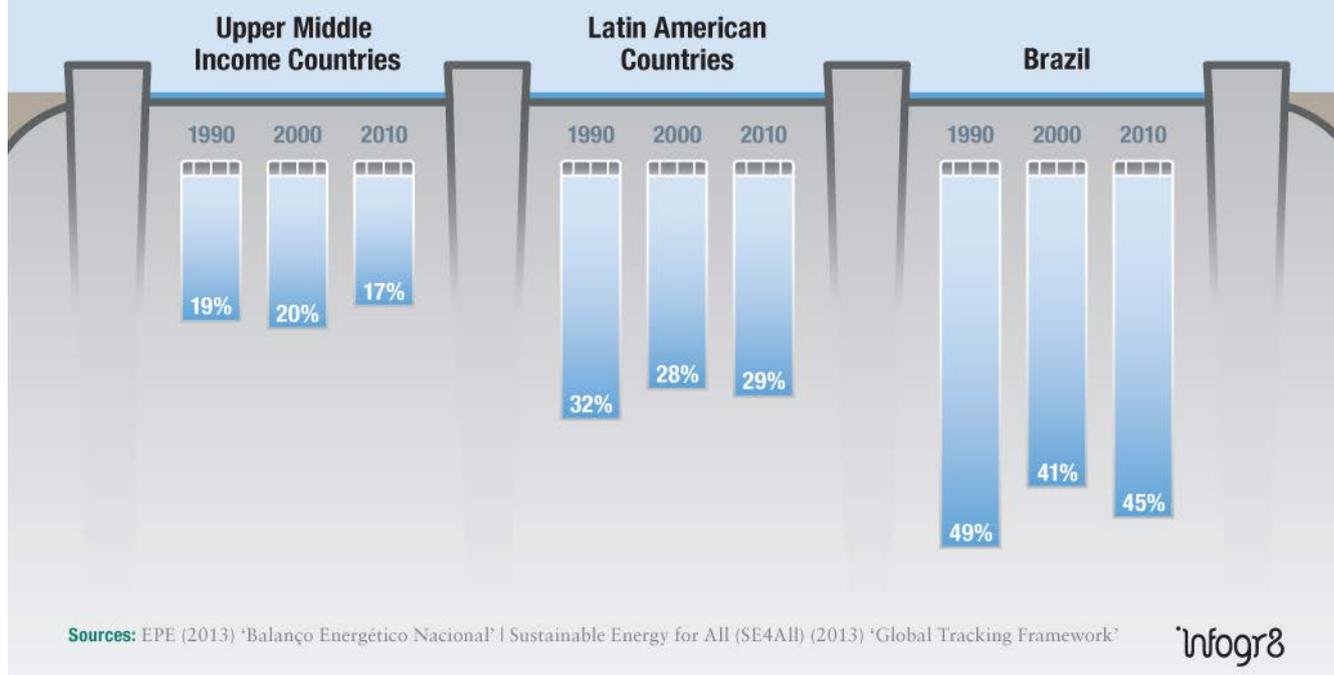
26 In the UK, for example, energy poverty is defined as people paying more than 10% of income for power.

27 The demonstrators expressed demands for better infrastructure (roads, transport, housing, education, health), as well as resentment about political corruption, including among members of the ruling Workers' Party.

28 There is debate about whether large-scale hydropower meets all these criteria. The energy produced by a large hydropower plant in a given context may be 'renewable', but not 'sustainable' in these terms.

Brazil

Maintaining a high proportion of renewable energy



2010. First, the energy mix has varied over time. Energy derived from oil, as a proportion of primary energy supply, has fallen almost as dramatically as the use of cane products has risen. The share of natural gas has risen sharply, whereas hydropower's contribution to energy supply has been relatively stable. These results are what might be expected in a country that is rapidly adding supply and selecting which sources of energy to develop. The results indicate that the sources of energy generation for Brazil continue to evolve. Second, the figures clearly show that, while the relative share of energy from various sources has varied, almost all sources have substantially increased the absolute volume of energy produced, and some very strongly. So, while the relative share of oil's input to the national energy mix has declined, the amount of energy derived from oil over the 20-year period has nonetheless increased by 50% in volume terms.

The data also demonstrate the overall changing balance between renewables and non-renewables in Brazil's energy mix, reflected in Figure 10 (overleaf). Just over one-half (54.9%) of Brazil's energy supply in 2010 was from non-renewable sources, compared to 50.9% in 1990. The share of renewables was 49.1% in 1990. It dropped to 41.2% in 2000, and then increased to 45.1% in 2010. Since 2010,

however, it has fallen again, to 44.0% in 2011 and to 42.4% in 2012, with the trend expected to be confirmed by 2013 figures.²⁹

There are two overall conclusions to be drawn. First, while the two elements in Brazil's energy mix oscillated in the 1990-2010 period, the most recent trend is a mix that is becoming less 'green'. A challenge for Brazil's future energy mix will be to maintain its renewable element as the deep-water oil and gas deposits become available. Second, Brazil is more clearly a country of renewable *electricity* than renewable energy. A discussion of the nature of the role played by thermal plants in electricity generation follows below.

2.3.2 Brazil – compared to its neighbours and peers

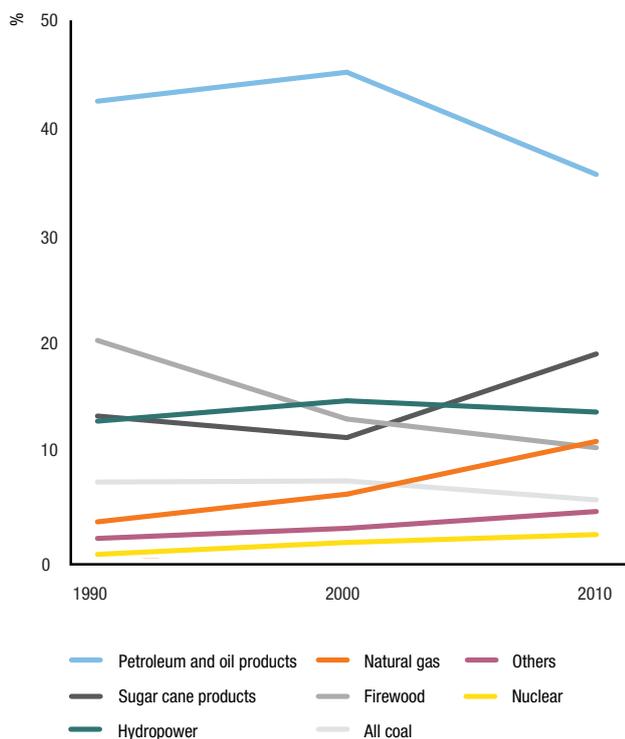
Brazil's shift to a relatively less renewable green energy mix needs to be placed in an international context, since its use of renewable energy still remains higher than in comparable countries. Table 5 shows the percentage of renewable energy in Brazil, in terms of total final energy consumption, compared with LAC countries and UMICs.

2.3.3 Energy-related greenhouse gas emissions

As a consequence of its relatively green energy mix, Brazil has made positive progress regarding its energy-related

²⁹ The 2013 figures are not available at the time of writing.

Figure 8: Evolution of different elements in domestic energy supply – percentages



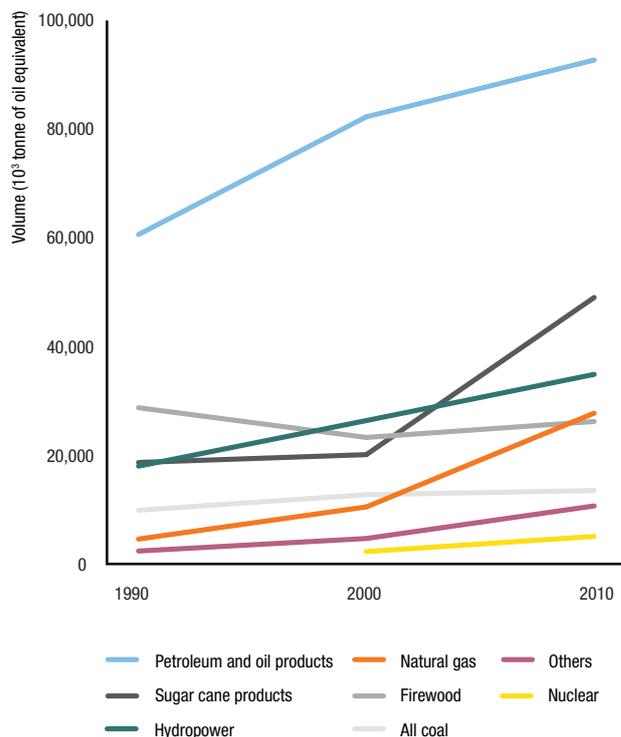
Source: EPE, 2013

GHG emissions. Brazil is a signatory to the United Nations Framework Convention on Climate Change and has pledged to a set of national emissions targets. At the Conference of the Parties in Copenhagen in 2009, the Brazilian government strengthened those commitments, voluntarily undertaking to reduce its overall GHG emissions. This target was formalised in national law and policy in the same year. Most of the emission reductions are being achieved through avoided deforestation in the Amazon region (La Rovere, 2010), because deforestation is the source of most of Brazil's emissions. As one energy specialist commented: 'This was a voluntary commitment, decided upon unilaterally by the Brazilian government. It was not associated with any effective measures'.

As would be expected, the combination of strong commitment to hydropower and ethanol³⁰ has meant that Brazil's energy sector produces low energy-related GHG emissions by comparison with other countries, and vis-à-vis GDP the level has remained remarkably stable over the past two decades. Over the 20-year period, emissions per capita have risen by about a third, compared with the big increase in UMICs (see Figure 11).

Consequently, Brazil has a relatively lower CO₂ intensity energy-related economy, with CO₂ emissions per US\$ of GDP

Figure 9: Evolution of different elements in domestic energy supply – volumes, 10³ toe



Source: EPE, 2013

very low compared to the average for UMICs (see Figure 12, page 26).

The remainder of this section considers the mechanisms by which these positive renewable outcomes have been achieved, and also where Brazil is developing additional renewable options.

2.3.4 Hydropower

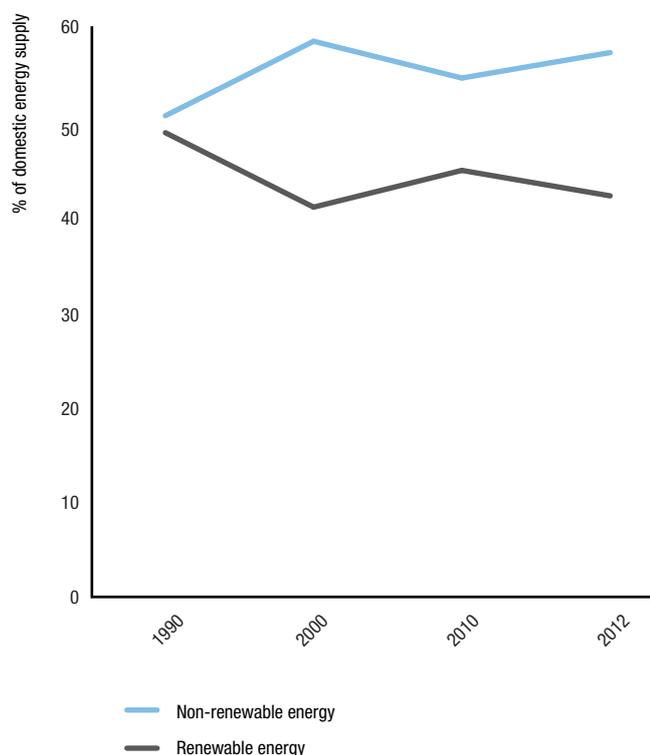
Hydropower accounts for a large proportion of Brazil's electricity supply, noticeably higher than the UMICs' global average and much higher than in LAC countries, as shown in Figure 13, page 26. This extensive use of hydropower is one of the major underlying reasons for the low carbon intensity of Brazil's energy production and overall economy.

As discussed in the previous section on the overall energy mix, although the total amount of electricity generated from hydropower continues to increase as more plants become operational, the proportion of hydropower in Brazil's electricity-generation mix has been slowly decreasing since 1990 (see Figure 14, page 27).

The design and management of large hydropower projects in Brazil has made considerable progress over recent decades including in relation to environmental and social

30 Ethanol is considered zero emissions, as CO₂ is consumed by the sugarcane growth (indirect sequestration).

Figure 10: Evolution of renewable and non-renewable elements in domestic energy supply: 1990-2012



Source: EPE, 2013

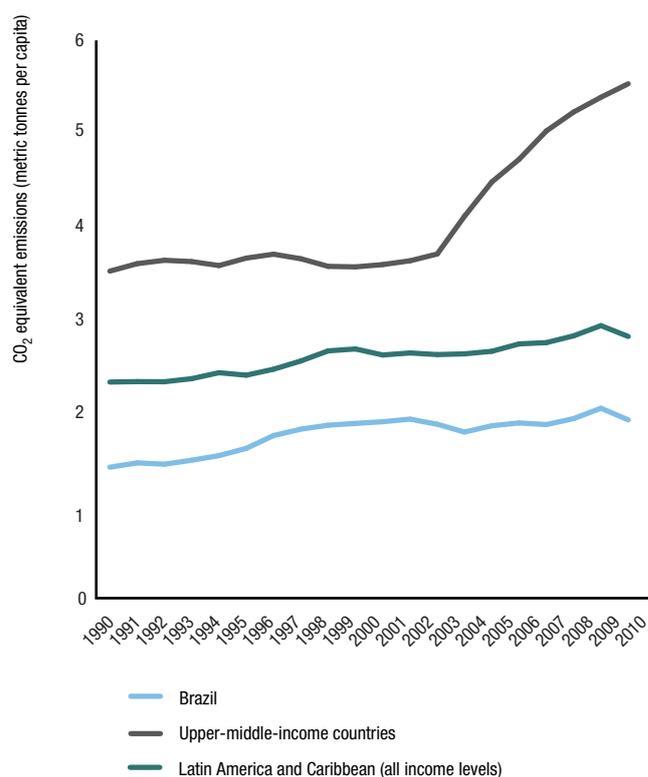
aspects. This does not mean that impacts have been avoided altogether, however, as discussed in Section 3.4. There are also questions about the implications of these projects for regional development, as well as concerns regarding the current mode of national-level planning of major energy infrastructure including large hydropower, as discussed in Section 4.3.

Table 5: Percentage of renewable energy, in total final energy consumption (TFEC)

Year	Brazil*	LAC**	UMICs**
1990	49.1	32.2	18.8
2000	41.2	28.2	19.6
2010	45.1 (2012: 42.4)	29.0	16.7

Sources: * EPE (2013); ** EIA (2013)

Figure 11: CO₂ equivalent emissions (metric tons per capita)



Source: World Development Indicators, 2013

2.3.5 Thermal – as reserve source

Interviewees commented that the rise in the share of electricity capacity produced by thermal – predominantly fossil fuel – power systems in Brazil (Figure 7) is closely tied to the increase in hydropower and wind power – an explicit element of energy policy. Thermal power represents a key reserve energy source, while hydropower depends on river flows and water storage (behind dams) to generate electricity. Seasonal variations in river flows are natural, and in Brazil there are different hydrological ‘seasonalities’ in the north and south of the country. A connected electricity transmission system allows, to some extent (limited by the transport capacity of long-distance transmission lines between the north/north-east and south-east regions), for low availability of water in one region to be compensated by more water in another.³¹ Where hydropower plants have large reservoirs, the water stored acts as a buffer against variability in river flows. Policy decisions to reduce the environmental impacts of hydropower plants have, however, reduced that protection. The large hydropower plants under construction or recently completed in the Amazon – Jirau and Santo Antônio, both on the Madeira River, Belo Monte, currently

31 The extent of variation between low and high river flows is less pronounced in the south than in the north. In the Amazon, for example, the range of river flows within the same year can be 1:10 – meaning the river may be as little as one tenth of its maximum size at certain times. At the location of the Jirau plant on the Madeira river it is 1:8.

Figure 12: Energy-related CO₂ emissions per GDP (kg per \$2,000)

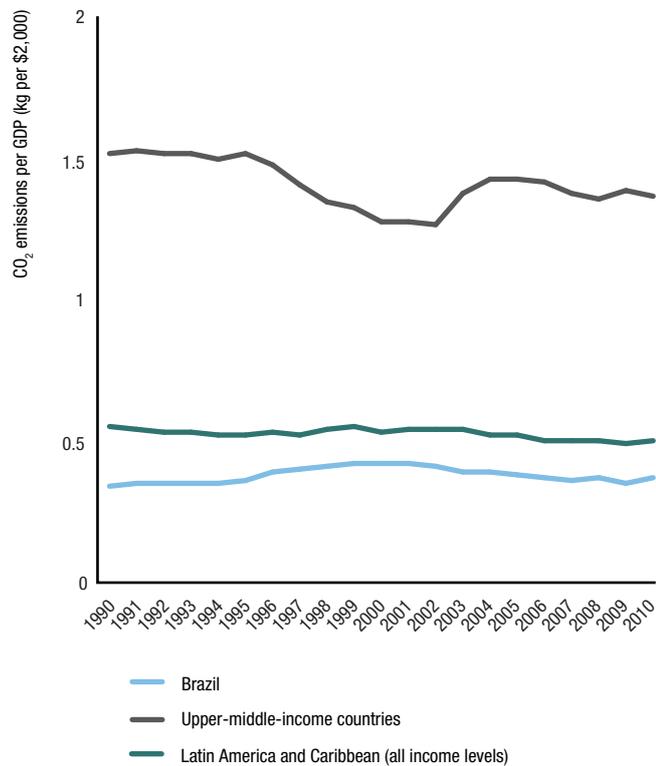
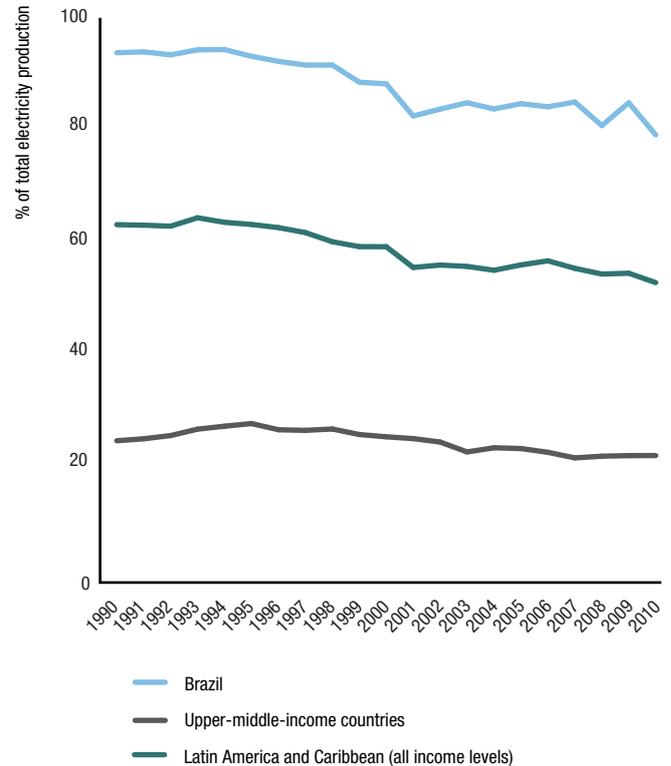


Figure 13: Electricity production from hydroelectric sources, 1990-2010 (% of total)



Source: World Development Indicators, 2013

Source: World Development Indicators, 2013

being constructed on the Xingu River, Ferreira Gomes on the Araguari River, Teles Pires and Colider on the Teles Pires River (EPE, 2012) – have been designed (or re-designed in response to public pressure) with smaller reservoirs, called a ‘run-of-river’ design. That means less land flooded, including in some cases less flooding of indigenous territory and less population displacement. Run-of-river projects, however, allow for less storage of water, and as a result provide the operators of the national grid with lower energy ‘reserves’.

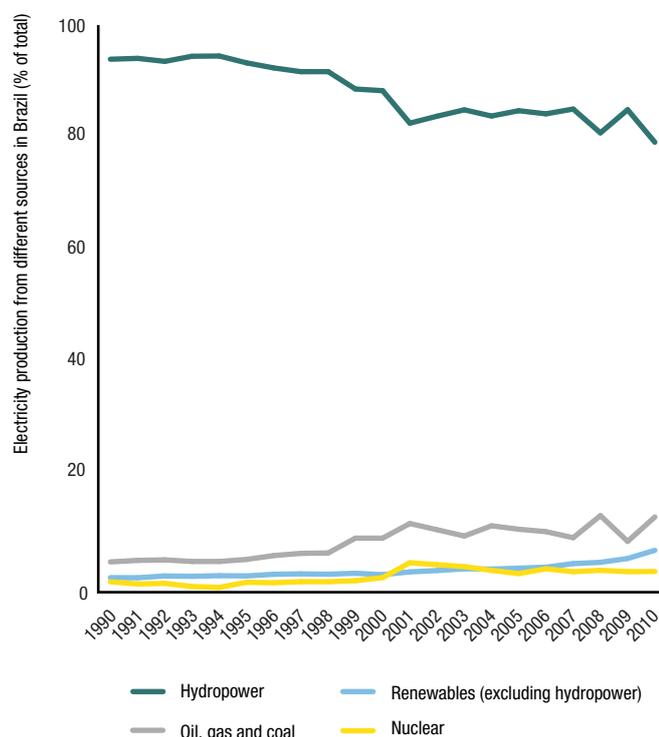
Recently, there has been a pattern of several dry years. Without a hydrological ‘buffer’, the national grid needs to have back-up generation capacity.³² To date, at least, that reserve has principally comprised thermal plants, with the GHG they emit. Thermal plants are generally quicker than hydropower schemes to commission and build (rather than being site-specific, they come ‘off-the-shelf’) and can be located closer to population centres to reduce transmission losses. In other words, there is a trade-off in energy policy between responding to the local environmental and social impacts of hydropower, and pursuing a national environmental policy to mitigate climate change. The more environmentally conscious design of hydropower might,

paradoxically, require commensurate expansion of less environmentally sensitive thermal energy. Furthermore, this installed capacity must also be paid for (even if not regularly used), which pushes up overall system costs. In terms of the extent of redundancy needed to guarantee electricity supply in practice, it is understandable that energy planners (MME/EPE) and the grid manager (ONS) will err somewhat on the side of caution given the legacy of the 2001-2002 blackouts. It appears that high-level politicians encourage this approach. One energy specialist referred to current media interest in the issue of the margin between peak demand and available electrical generation capacity in relation to its relevance in terms of potential risk of power cuts, explaining:

In Brazil, the margin varies. It is usually around 10%, although it sometimes drops to half that, or even less than 5%. The principal problem is a bottleneck in transmission lines, not in available power generation capacity, because the Brazilian grid, contrary to its title as the ‘national inter-connected system’, is not 100% inter-connected. Even when hydropower plant reservoirs in the North region are near full, the electricity

32 Or opt to import a balance of electricity from neighbouring countries.

Figure 14: Electricity production from different sources, 1990-2010 (% of total)



Source: World Development Indicators, 2013

transmission lines have not the transportation capacity required to take this energy to the Centre-Southern region of the country.

As for the margin between peak and base demand, the same energy specialist added:

The “rule of thumb” figure for this ratio used to be 55% when all hydropower reservoirs were large, and now, in the current era of run-of-river plants, it is between 50 and 55%.

2.3.6 Biofuels and biomass – ethanol and bagasse

Over the past 40 years Brazil has made increasing use of ethanol, and to a lesser extent bagasse, in its energy-production mix. Despite the fact they are both combustibles, and therefore release CO₂ during use, the capture of carbon in the growing process means that there is no substantial net impact on emissions (i.e. what is emitted is then captured by the sugarcane growth, leaving an almost net zero effect). Taking into account life cycle, GHG emissions that include the consumption of fossil fuels for ethanol production, and the differences in car engine efficiencies, it is estimated that flex-fuel cars running on ethanol emit only 10% to 20% of the grams of CO₂ per kilometre compared to gasoline (Soares, 2009).

According to the MME/EPE, Brazil’s electricity-generation capacity from bagasse reached 9.17 GW in 2013, comprising 6.86% of the electric energy matrix (ANEEL, 2013). The use of bagasse as a source of energy has seen rapid growth over the past two decades, as technology to extract and develop energy from sugarcane waste products has improved through public and private research (Furtado et al., 2011). Some forecast an even greater role for bagasse-based energy output (Khatriwada et al., 2012). Surplus electricity from sugar mills began to be sold to the national grid in 1987, and some industry observers suggest that there is over 15 GW of potential additional energy in Brazil’s sugarcane industry, the equivalent of three times the output of the Belo Monte hydropower plant (UNICA, 2012).

Ethanol from sugarcane has been vigorously promoted in Brazil through the active use of government policies. This has involved both minimum ‘blending’ requirements for mixing anhydrous ethanol with standard petrol (gasoline), called ‘gasohol’, and the development of hydrous ethanol as a fuel in its own right, and therefore an alternative to gasohol. With the development of technology to allow fuel mixing, the engines in most cars sold in Brazil today are fully flexible between gasohol and ethanol. The system is called ‘flex-fuel’. As a result of these developments, consumption of sugarcane products (of which ethanol and bagasse are a large part) grew by 5.4% per annum between 1970 and 2005, while formal employment in the sector is reported to have significantly increased from 640,000 in 2000 to over one million in 2010 (*Relação Anual de Informações Sociais* data in Dias de Moraes 2007; UNICA/Apex-Brasil, 2013).

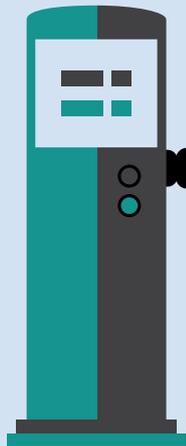
The use of ethanol as a blending agent and its development as a fuel has helped Brazil to reduce its oil imports significantly, as seen in Figure 5, which shows the reduction in dependence on ‘external’ energy. Indeed, it is claimed that Brazil has replaced almost 40% of its petrol needs with ethanol produced from sugarcane (UNICA/Apex-Brasil, 2014). The sustained reduction in oil and energy imports over this period can be considered an additional significant policy achievement.

There have, however, been problems, such as fluctuations in the attractiveness of ethanol compared to petrol, and variations in the relative shares in the national liquid fuel mix. The challenge for regulators is to maintain a system in which both fuels remain competitive for the consumer, but at a price that makes the continued domestic ethanol production economically viable. Significant and prolonged fluctuations in the price and supply of ethanol compared to petrol – as occurred in the 1990s – risk the market turning against ethanol, and potentially leaving the national fleet without supplies of economically viable ethanol fuel.

There are also differing views on the social and environmental implications of the expansion of sugarcane cultivation for biofuels production. The increased ethanol supply has been due in part to greater sugarcane

Brazil

Brazil has replaced almost **40%** of its petrol consumption with home-grown ethanol fuel



1970s OIL SHOCKS

- ◆ Increased domestic production of oil in drive to be self-sufficient and reduce fuel imports.
- ◆ Government policies to expand the market for ethanol as a fuel.

1980s

- ◆ Ethanol-only cars produced and sold.
- ◆ Ethanol production soars.



2003

Fuel-flex cars that run on petrol and ethanol interchangeably developed and make up **90%** of new cars sold.



1990s

- ◆ Petrol prices fall.
- ◆ Ethanol prices rise.
- ◆ Ethanol-only cars fall in popularity.



2010



RESULTS

Substantial reduction in reliance on imported fuel.

Global leader in ethanol fuel development.

Lower CO2 emissions.

BUT challenges in keeping both ethanol and petrol competitive, and managing the social and environmental consequences of ethanol production.

Source: UNICA/Apex-Brasil (2014) 'Brazil: A leader in ethanol production and use'

Infogr8

productivity (e.g. genetic improvements providing more resistant crop types) and in part as a result of expanding the area under production. On the one hand, the conclusions of recent research in São Paulo State (Goldemberg at al., 2008; Maroun et al., 2011), where 60% of Brazil's sugarcane is grown (264 million tonnes of *cana na safra*, in 2006-2007), are that the expansion of the area dedicated to sugarcane cultivation has not resulted in less land for food production. This is for two reasons. First, the new areas were previously used for extensive, low-density cattle grazing (Goldemberg at al., 2008). Second, the prevailing system of rotation allows for growing of food crops alongside the cane (typically at a ratio of 20:80 food–energy). According to this view, productivity gains and appropriate technologies have averted land-use conflicts (Lapola et al., 2014). On the other hand, some commentators point to what they see as the indirect effects of the expansion of sugarcane cultivation. According to Maroun et al. (2011), this led to a sharp rise in land prices in São Paulo State between 2002 and 2010, taking the cost of leasing of land ever more beyond the reach of small farmers (Marques, 2009). The resulting social tensions have included demonstrations and protests against the concentration of agricultural production in large farms that benefits the landowners (Marques, 2009).

In addition to the ethanol issue, Brazil has also begun to foster public support to better exploit other sources of renewable energy such as bio-diesel. The Lula administration launched a programme in 2005 to support technological research and the uptake of bio-fuel (PNPB by its acronym in Portuguese), but these initiatives have not been nearly on the scale of the investment in large hydropower and ethanol.

2.3.7 Wind

In 2010, according to EPE estimates, there was 2.177 GW of total wind-generation capacity in Brazil, rising to 5.050 GW in 2012 (EPE, 2013). In 2013, according to ANEEL, wind power provided 1.6% of the country's electric power (ANEEL, 2013). This represents a relatively low percentage contribution despite wide acknowledgement of its considerable potential. One commentator expressed the view that: 'Wind power is underestimated for its level of competitiveness. That was reflected in 2013 when it accounted for almost 5 GW or two-thirds of all the electrical energy auctioned in Brazil'.

The EPE expects wind energy to rise by 1 GW per year, and over recent years there has been some increase in production. However, EPE's energy planners left it to other countries (e.g. Germany) to develop the technologies to provide wind power at a viable cost. This is in marked contrast to the approach taken to developing a market for ethanol to become a viable liquid fuel, where substantial public and private funds have been invested over the long term. European companies are now coming to Brazil to promote their wind-power technologies. The first

wind-power auction was in 2009: companies successfully bid for the opportunity to construct small wind plants in the north-east, south and south-east. In common with other sources of renewable energy, locations for wind projects are auctioned by EPE by specific region, not specific site. Wind energy can act as a useful counterweight to the seasonal variations in hydropower. Wind levels are, for example, typically high on Brazil's north-east coast during the dry season, at a time when water levels in the São Francisco river basin, some 2,000 km inland, are low (Silva, 2008). Whether this affords opportunities, as a counter-cyclical effect, will depend on the margin of 'redundancy' needed in the national grid – see Section 4.4.

2.3.8 Small hydropower

As for small hydropower (SHP), according to the EPE (2013a: 62), in 2010 there was 3.4 GW of installed SHP generation capacity in Brazil (compared to 2.5 GW in 2008). The figure had risen to 4.25 GW by 2012 and to 4.9 GW in 2014 (ANEEL, 2014), i.e. a two-thirds increase in a four-year period, albeit from a low base. As for future prospects for SHP, the MME/EPE's energy plan to 2030 predicts a total increase of 6 GW of SHP (MME, 2007a) – a further doubling of SHP capacity in the medium term. The energy planners' focus on large hydropower plants – with a vastly greater installed capacity, at 86.71 GW in 2014 (ANEEL, 2014) – reflects the fact that they are essentially designed to supply electricity to urban populations and rural areas close to the grid.

2.3.9 Solar

Solar energy is at a more preliminary stage of development than wind power, providing a further point of contrast with the government's long-term investment in developing technology to promote ethanol as a liquid fuel. To date, the National Energy Balances of the EPE do not quantify the share of solar energy in the total energy mix. The Annual Energy Statistics published by EPE simply record 1 MW of solar energy as part of the installed electrical generation capacity in 2010, rising to 8 MW in 2012 (EPE, 2013a). The EPE is planning to achieve 1.4 GW of solar energy by 2021.

Brazil has great potential to generate electricity from solar power, given the number of regions with high levels of sun radiation. To encourage people to have micro- or mini-solar power generators, in December 2012 the government introduced ANEEL resolution RN 482, which allows households to produce their own energy and feed the surplus into the grid as a means to reduce their bills. To further promote the case for greater investment in solar power in Brazil, the *Carta do Sol* ('letter about the sun') (La Rovere, 2011) was published in August 2011 by the State of Rio de Janeiro Environment and Economic Development Secretariat. Key proposed policies to promote solar power include tax allowances on solar-power equipment and provision of R\$900 million (around \$450 million or 0.02% of 2011 GDP) (World Development

Indicators, 2013) in subsidies for solar (and wind) energy in Rio de Janeiro. Those would supplement the existing concessionary loan facility that the Brazilian national development bank (BNDES) makes available to support solar projects. Solar energy is being used in some new buildings, such as the Maracanã stadium in Rio and five other stadiums built for the 2014 football World Cup.

2.4 Energy efficiency and energy intensity

This section considers Brazil's efforts in relation to energy efficiency. Government policies and actions taken by other parties to save energy can help to reduce demand, meaning that less installed generation capacity is required – and fewer or smaller power plants need to be built. Reduced demand and expenditure could translate into less cost to the treasury and the taxpayer, as well as less displacement and/or disruption of local lives and livelihoods when large energy infrastructure projects are built, such as dams for hydropower.

In contrast with Brazil's strong record in increasing the availability of energy, its efforts in relation to energy efficiency have to date been weak, and there has been little advance in improving energy intensity. Energy intensity is quantified in terms of each unit of energy used per unit of production. The global target set by Sustainable Energy for All – the second of three goals to be accomplished by 2030 – is a reduction in energy intensity.

2.4.1 Energy efficiency

The government-sponsored programmes for energy conservation, the 'National Programme for Electrical Energy Conservation' (PROCEL), and its equivalent for oil products, the 'National Programme for the Rational Use of Petroleum Derivatives and Natural Gas' (CONPET), were begun in the 1970s after the oil shocks. From the outset, both programmes received only modest resource allocations, from Eletrobras and Petrobras respectively. They focused on internal activities of the public companies, (e.g. reduction of losses in transmission/distribution lines and in Petrobras refineries). The principal achievements came from the labelling programme PROCEL imposed on appliances. One energy specialist noted that the current situation is that 'both initiatives are operating at much reduced capacity (with teams largely dismantled) and

some of their activities have ceased altogether. There is no effective overall strategy or coordination'.

The Energy Efficiency Law approved in the late 1990s under Fernando Henrique Cardoso's presidency set out the legal framework still in force that authorises the government to establish mandatory energy efficiency standards for appliances and vehicles. Two positive steps have been the enforcement of stricter standards for electrical motors and the ban on incandescent light bulbs. Such have been the tentative government efforts to date to promote energy savings.

Government and industry sources in Brazil acknowledge that there are major energy efficiency gains yet to be realised. The recent study by the National Industry Confederation (which convenes the state industry associations) put the potential for end-use energy efficiency at an estimated 30%.

The McKinsey report on 'Pathways to a Low-Carbon Economy for Brazil' (McKinsey & Company, undated) also notes that there is scope for efficiency improvements.

2.4.2 Energy intensity

Table 6 shows the energy intensity Brazil from 1990 to 2010 compared with LAC countries and UMICs, expressed in terms of the kg of oil equivalent required to generate \$1,000 GDP, based on constant 2005 PPP.

The levels have changed little since 1990 – in fact, energy intensity in Brazil has marginally increased over the two decades. This performance compares with notable reductions in LAC to a little below Brazilian levels. The relative reduction in energy intensity is even more marked for UMICs, although they remain significantly more energy-intensive than Brazil in absolute terms.

In its energy plan to 2030, MME/EPE forecasts that for the greater part of the planning horizon (2005-2030), energy intensity will increase before starting to decline from about 2025 (MME, 2007a: 196, Figure 8.1). In other words, Brazil is going in the *opposite* direction to that set by Sustainable Energy for All in the second of the three global objectives to be accomplished by 2030. According to that objective, the proxy indicator for doubling the rate of improvement in energy efficiency is doubling the rate of improvement in energy intensity (from a starting point of –1.3% in 2010 to –2.6% in 2030)(SE4ALL, 2013). The

Table 6: Comparative energy use (kg of oil equivalent per \$1,000 GDP at constant 2005 PPP)

Year	Brazil	LAC	UMICs
1990	130.6	144.4	292.0
2000	135.9	136.8	229.5
2010	135.1	132.4	219.3

Source: World Development Indicators, 2013

growth of energy-intensive industries such as aluminium smelting raises the question as to which energy users are to be served by future supply, and what kinds of benefits they will bring to the Brazilian economy and society.

In summary, the MME/EPE does not appear to be rigorously tackling the barriers to improved energy efficiency with the same determination that it applied to other aspects of policy in the energy sector (e.g. the federal programmes to promote access and efforts to support the construction of new power plants). Indeed, government efforts to promote energy savings are becoming weaker, which raises the question of why energy intensity in Brazil is not reducing. Is it because of lack of investment in energy efficiency, or is it due to other factors, such as the kind of energy used, or the structure of the Brazilian economy? If relatively energy-intensive industries grow more than other sectors, the energy intensity overall will

rise proportionally, even when efficient processes are applied. The MME says that the reason for the projected rise in energy intensity is ‘an inertia effect in the first ten years of the planning horizon, principally due to investment decisions in expansion of capital-intensive and energy-intensive industry’ (MME, 2007a: 195). The MME/EPE points to ‘barriers’ (‘institutional, tariff, financial, technological among others’) that it says currently ‘inhibit’ energy savings (MME, 2007a:202). Horta Nogueira (2008) argues that it is possible for countries to achieve improvements in both the quality of life or standard of living and economic growth at the same time as adopting more energy-efficient production processes. It is possible, in other words, for national leaders to plot a route that avoids the conventional energy-intensive path taken by industrialised countries by converting to a service economy, and instead takes a more desirable shortcut.



A city street in Rio de Janeiro. Photo: © Andrew Dent

3. What are the factors driving change?



Workers sit on top of power lines. Photo: © Annette Beatriz

Brazil's progress in sustainable energy development over the past 20 years is primarily due to a combination of factors:

- sustained political leadership
- a favourable financing environment
- improvements in electricity-sector regulation
- better design and management of (individual) large hydropower projects
- long-term public and private investment in ethanol research and development (R&D).

‘The impact of the 1970s oil shocks cannot be underestimated’ – Academic working in the energy sector

3.1 Sustained high-level political consensus on key energy policies

The development of Brazil's energy sector from 1990 to 2010 showed remarkable consistency in overall policy objectives in several areas, maintained across successive administrations. In some policy areas, this consensus goes back to the 1950s and 1960s.

3.1.1 Energy security

A primary policy goal has been energy security. The threat to that security posed by the 1970s oil price shock and the impact of the price rises on Brazil's macroeconomic position made it a priority to reduce imports. Successive Brazilian administrations have, however, set about achieving the country's long-term policy objectives in different ways, in line with Brazil's broader socioeconomic evolution. The closed, inward-looking and 'self-sufficiency'-focused economic policies of the military governments

of the 1970s and early 1980s were reflected in two key areas of energy policy: growth in domestic oil production and ethanol development, and hydropower-led electricity generation allowing for expansion in electricity access. At that time, the oil, hydropower and wider electricity sector were state-owned and vertically integrated, with new construction mostly state-financed. The federal government closely regulated the ethanol market, including prices, albeit in a manner that was designed to expand production by private companies.

Thereafter, in the transition to democracy in the late 1980s, with the opening up and deregulation of the economy in the 1990s, the hydropower and electricity sector were semi-privatised, unbundled and encouraged to seek private finance in a regulated market. The government's role in regulating the ethanol market was substantially reduced, most notably with the eventual abolition of fixed prices in the early 2000s. Petrobras' monopoly in oil and gas production, held since its establishment in the 1950s, came to an end. The newly democratic administrations from the 1990s sought to expand provision of electricity to poor households through increasingly ambitious government-funded programmes. Thus, although the ultimate *objectives* of key parts of Brazil's energy policy have remained unchanged, the means of achieving them have shifted in line with Brazil's changing governance, politics and socioeconomic position. The key elements of this consistent approach are discussed below.

3.1.2 Hydropower as the foundation of electricity supply

The exploitation of hydropower as the 'backbone' of the country's electricity supply – 86% in 1990, 72% in 2010, and 70% in 2012 (EPE, 2013) – is longstanding (de Araujo and de Oliveira, 2003). In the 1960s, the federal government, on the advice of the World Bank and external advisers, concluded that thermal power plants would be more costly than hydropower plants (the 'Canambra' report). Subsequently, in response to the 1970s oil shocks, the military regime reinforced the view that hydropower offered significant benefits compared with other sources of power (de Oliveira 2003). This consensus held throughout the transition to democratic governments.

Several respondents interviewed in the course of this research commented that it is Brazil's resource endowment that made hydropower the obvious choice – the most cost-effective solution to the country's energy needs. Other nations with similar natural resources have not, however, deployed them in the same way: geography and resource endowment cannot strictly be said to 'drive' progress. Brazil's achievement has been in successfully implementing the 'obvious' policy of hydropower as the foundation of its electricity supply. That implementation, as one

expert commented, was supported by an effort by public universities and research institutes to develop Brazil's capacity in hydraulic engineering and associated technical disciplines. The large hydropower developments built during the 1950s and 1960s formed the base of national expertise in these technologies. As this commentator added: 'To have a national resource endowment was not enough; knowledge also had a central role'.

By its very nature, development of large hydropower plants is a long-term investment requiring significant finance. As an indication of scale, between 2003 and 2011 BNDES (the state-owned development bank) alone supported projects to generate, transmit and distribute electricity to the tune of R\$143.7bn (\$62.5bn) (BNDES, 2012).³³ Over a longer timescale, according to the World Bank, the value of energy infrastructure investments involving the private sector totalled \$166bn between 1990 and 2012 (World Bank, 2013). In Brazil, large projects take, typically, 32 months to go through the assessment and approval process (World Bank, 2008) (the licensing system is discussed in 4.3). When a project is approved, the civil engineering phase takes in the region of three to five years. The subsequent installation of the turbines (the mechanical and electrical phase) takes years more, depending on the number required (for a large project such as Belo Monte, up to ten years overall). This is followed by the first period of operation during which electricity sales are applied to pay off project loans (typically 10-20 years). The thinking behind these investments is that, despite the high upfront cost, hydropower plants, once operational, are cheaper and easier to switch on and off than other sources (called in the industry fast 'despatch'). The ONS, which operates the national grid, will despatch as much hydro-generated electricity as possible at any given time. Whether, or how far, hydropower continues to be the 'obvious' choice is discussed in Section 4.3, while the extent of the evolution in design and management of individual large hydropower projects is considered in Section 3.4.

3.1.3 The use of liquid ethanol as a fuel

The development of liquid ethanol – both in its anhydrous form as a blending agent ('gasohol') and in its refined form as a fuel itself (hydrous ethanol) – is the outstanding example of a long-term energy policy consensus in Brazil. The country's natural geography is favourable to sugarcane production, and it remains the world's leading producer. That said, the cultivation of cane for sugar *and* biofuel was not an obvious choice, especially looking back at the origins of the ethanol development policy. According to the literature and the interviews conducted during this research, government policy to stimulate and

³³ The BNDES figure relates to its own support for energy investment, and therefore excludes investment projects that are funded through other channels. Similarly, the World Bank excludes investment in energy infrastructure that is entirely publicly funded with no private-sector involvement. As a result, both figures are likely to be underestimates of the total investment in the generation, transmission and distribution of energy.

expand the ethanol industry is clearly linked to the 1970s oil shocks as discussed above (Potter, 2008), although some interviewees noted that government regulation to promote the use of ethanol as a blending agent had already begun in the 1920s. In response to the oil shocks, the then military government decided to pursue energy independence through development of alternatives to oil imports, culminating in the PRO-ALCOOL policy of the 1970s. This matched the broader policy at that time which focused on a relatively closed economy involving import-substitution industrialisation and a high degree of 'self-sufficiency'. That decision, and the subsequent public policy support for the industry, has proved effective in making it possible for liquid ethanol to compete in terms of cost and energy value per unit of fuel with traditional fossil fuels (Goldemberg et al., 2004).

The political power of the sugarcane industry has also been noted as contributing to these policies (Shikida, 2012). Sugarcane production in Brazil has a 500-year-long history, with sugar producers' interests intertwined with those of the colonial and post-colonial state. At the time of the PRO-ALCOOL policies, a low world price for sugar had depressed the industry in Brazil and threatened some producers with bankruptcy (Dias de Oliveira et al., 2005). Consequently, the goal of achieving energy (particularly oil) independence through ethanol from the 1970s can be seen as combining with a tradition of state support for a strong sugar industry that long predates the modern period.

While many countries mandate a certain percentage of fuel blending for their national fleet, Brazil has gone further and developed a domestic market that has for many years supported both ethanol and petrol/gasoline vehicles. The development of flex-fuel cars from the early 2000s has made it even easier for the market to support both fuels. Interestingly, relatively few of the interviewees in this study referred to the liquid ethanol fuel policies and the development of a predominantly flex-fuel national fleet as a success story. To Brazilians, ethanol has perhaps become a feature of everyday life and, as such, unremarkable. As other countries move to reduce their GHG emissions, and the future price trajectory of oil remains uncertain, the advantage Brazil has created for itself in developing, over many decades, ethanol as a viable liquid fuel, with a market capable of supplying it, is an almost unparalleled achievement for a major economy.

3.1.4 Expansion of household electricity access

Despite the commitment to universal energy access expressed in the 1988 Constitution (Article 21 XII (b)), it was not until the second term of President Fernando Henrique Cardoso and his social democratic administration (the *Partido da Social Democracia Brasileira*) that the government established in 1999 a national initiative, *Luz*

no Campo ('Light in the Countryside'). Prior to that, there were some requirements for electricity distribution companies to expand network connections, but without substantial regulatory oversight and enforcement, or public funding, behind it. The Workers' Party administrations of Lula and Rousseff subsequently created *Luz para Todos* ('Light for All'). As described in Box 2, overleaf, these two programmes have taken different approaches to bringing electricity to poorer households.

The benefits of electricity to connected households have been shown in a government survey on the results of LpT. Of the 3,892 respondents in 26 states, 90% said there had been benefits in terms of way of life and well-being. Forty per cent noted the ability to undertake their educational studies after dark and 30% said that they had been able to offer 'new products and services'. Of the total number of households assisted by LpT, 79.3% said they had been able to acquire a television, 73.3% a refrigerator, 39% a blender and 24.1% a water pump. Moreover, 24% talked about the improved activities in agriculture and livestock³⁴ supported by the arrival of electric power (MME, 2009).

These achievements were due to the continuity of support to expansion of access across four government administrations, a further example of the benefits of consistency in energy policy. LpT has been extended to 2015 and interviewees anticipate that it will probably be continued after 2015 until all households are connected, albeit at an increasing cost for reaching the most remote communities.

Interviewees – from both within and outside government – were, however, keen to stress a number of important issues concerning the two programmes. First, that, as noted in Section 2.2, the progress in expansion of access between 1990 and 2010 started from a strong base. About 92% of Brazilian households were already served in 1990, according to government sources. Second, a more systematic evaluation of results of the expansion programmes would be useful, given the lack of clear data. Based on ANEEL's figures, according to which the target was to connect 3.031 million households, the 2.5 million households reached falls somewhat short at 80.6%. This is an example of inconsistent data on the results of LpT. Third, the expansion programmes have not operated in a vacuum, and should more accurately be seen as parts of wider government strategy to reduce poverty and promote social inclusion working alongside the beneficial impact of general economic growth and associated rise in incomes. Under the Rousseff administration, public programmes aimed at reducing poverty and increasing social inclusion are encapsulated in the 'Brazil Without Poverty/Misery' strategy, of which *Bolsa Familia* is the best-known component (Government of Brazil, 2013). Access to electricity is part of this mix of policies designed to improve the social position of poorer households. Similarly, under the FHC administration, LnC

34 The survey report does not elaborate on which sorts of agricultural activities.



Construction of the hydroelectric power plant in Batalha, Goiás. Photo: © Divulgação Furnas

Box 2: Government programmes to expand electricity access

Luz no Campo (LnC) concentrated principally on providing electricity to unconnected households located close to the grid (the ‘low-hanging fruit’ in terms of additional connections). The funding of LnC was modest, R\$2.68 billion (\$1.48bn in 1999), equivalent to around 0.25% of GDP in 1999 (World Development Indicators, 2013), enabling 419,000 households to be connected over a period of three years. LnC required households to contribute to the cost of connection. While this may have reduced the cost to the public purse (reflecting the fact that electricity connection offers private as well as public benefits), the effect of the connection charge was to place it beyond the reach of many low-income households.

Luz para Todos (LpT) – a more ambitious initiative – is designed to build on the progress made through LnC and reach those households who live further away from the grid. LpT has invested, in two phases, substantial federal funds in the effort to provide greater access for unconnected rural households, particularly in the north and north-east, where access rates are lowest. LpT has supported that effort with significantly more public funding and more assertive use of regulatory instruments, although asking for a lower contribution from its target population. The total investment to October 2010 was R\$15.7 billion (\$8.9bn in 2010) representing 0.37% of GDP in 2010 (World Development Indicators, 2013) – a near 50% increase compared to LnC. According to the figures published by MME, LpT has reached 2.5 million households (86% of the goal).

This funding has come from general public revenue, in part through some of the surcharge levied on all electricity bills by the Energy Development Account (CDE). This funding has substantially reduced the real cost of the programme to the distribution companies that are expected to provide the connections. In addition, these companies had to commit to a certain number of new connections each year as part of their concession, with the threat of fines if they did not meet these targets. This ‘carrot and stick’ approach to subsidising connections and regulating providers has proved successful in substantially increasing the number of remote rural connections.

In contrast with LnC, LpT has provided the initial connection free of charge for eligible people alongside a ‘starter pack’ of basic electrical equipment, allowing for much stronger uptake.

operated alongside the forerunner of the *Bolsa Familia* programme (known as *Bolsa Escola*). Fourth, there are clear political benefits to governments in expanding electricity access, and in promoting wider pro-poor social policies. Increasing the access to electricity for low-income households is beneficial for a number of economic and social reasons, and also pays off for the party and/or government associated with the policy.

Finally, the formula applied by LpT of a public subsidy matched with strict regulation to provide additional connections is likely to face increasing challenges as the programme moves to connect the remaining remote communities. The recent abolition of the CDE component of the tariff in order to reduce electricity costs to the consumer has meant that the federal government treasury has stepped in to fill the gap. The continuation of public financing will now be subject to general spending priorities without its own dedicated financing generated by the electricity tariff. This could potentially make it more vulnerable to cuts if other public spending priorities take precedence. When asked about the increasing marginal cost of connecting the very last households, programme managers and other specialists interviewed said that the physical constraints on electricity connection now constituted the main problem, not cost, and they seemed to assume that additional public money would be forthcoming for further connections.

3.2 Financing environment for promotion of key aspects of sustainable energy

Progress in installing the capacity to generate electricity and expanding access to it depends, crucially, on finance. Brazil’s progress in both respects has been largely due to its development of a supportive financing environment.

3.2.1 Finance for energy – public and private

Government intervention to secure the significant financing required for energy generation and access has taken a number of forms. The government has, since the 1950s,³⁵ used BNDES to provide subsidised financing for the construction of new electricity-generation and transmission facilities. Subsidies are provided through a number of channels, including leveraging BNDES’ implicit state guarantee to allow it to provide lower-interest and/or longer-term loans than the market would provide for high-risk infrastructure. In examples reviewed in this research, this form of subsidised loan can be provided directly to private companies responsible for installation, and also channelled through private banks that make the loans. This has reduced risk to investors and created positive incentives for the private sector to finance new energy-generation projects.

Further, the 1990s reform of the Brazilian energy sector, by unbundling utilities and selling off many of the resulting companies to private investors, encouraged

35 The BNDES was originally called ‘BNDE’. The ‘S’ was added in 1980 when the social mission of the bank was included (after the ‘E’ of economic).

new sector assets to be privately built and operated. Interviewees familiar with large hydropower projects were clear, however, that private finance would not have been available without the complementary concessional funding provided by BNDES, providing a strong incentive for governments to use BNDES to support expansion of electricity supply in these cases. They added that the level of public financing needed to meet current energy-generation capacity-expansion requirements would have been beyond what the government alone could provide. This mix of public and private investment has been used in the Madeira hydropower plants – Jirau and Santo Antônio – discussed in Section 3.4. These have majority holdings by private companies, supported by BNDES concessionary finance, while the private companies manage the construction and operations. In the case of the (very large) Belo Monte project, due to its risks and the social and political controversy it has aroused, the government is the majority shareholder.

3.2.2 Finance from domestic sources

BNDES' role has become more important since the 1990s when multilateral financial institutions such as the World Bank and the Inter-American Development Bank stopped supporting large hydropower plants in the Amazon.³⁶ It is important, however, to place withdrawal of this support in context. Brazil was not a major recipient of official development assistance (ODA) over the 1990-2010 period, receiving less than 1% of its GNI as ODA for all sectors, including energy (World Development Indicators, 2013). All respondents in this research agreed that the involvement of international development institutions, such as development banks and bilateral donors, may have had some importance in the initial post-war development of Brazil's energy infrastructure, but was negligible over the 1990-2010 period. Except for international assistance in the 1950s and 1960s, almost all financing for Brazil's energy progress has been raised from domestic sources. This points to the progress (and setbacks) of Brazil's energy development trajectory being the result of domestic policy and provision, rather than influenced by external development agencies.

3.2.3 Support for renewables

Government interventions have been used to achieve other energy policy goals in terms of renewable energy. For example, the policies of PRODEEM (providing funding of R\$60m (\$25m) from 2001) and PROINFA (involving a much more significant credit line of up to R\$5.5bn (\$1.83bn) from 2002) have provided subsidies to stimulate the production of renewable energy. This has been

complemented by more generous prices paid at government electricity auctions for wind and other renewable power. These auction prices, guaranteed by government, support the development of renewable technology that may be uncompetitive in the early stages. The intention is that these technologies will eventually become cost-competitive with hydropower. As noted above, the PRO-ALCOOL programme represented the start of substantial government intervention in the sugarcane market in order to promote the use of ethanol as a liquid fuel. After this initial involvement, government intervention in the ethanol and sugar markets through regulation (including of prices) continued for over 20 years.

3.2.4 Government funding for increased electricity access

In relation to increasing access to electricity, the government has played a key role in that much of the substantial financing to achieve this has come from the federal budget. For LnC, R\$2.68bn (\$1.48bn) was provided, and most notably under the LpT programme, public spending totalling R\$15.7bn (\$8.9bn) in 2010 was made available, from both federal and state governments, to support expansion of access. Under the most recent phase of LpT, the combined government support has provided around 84% of the finance for the programme with the remainder coming from distribution companies (Zeriffi, 2007). Regarding regulation of the distribution companies, LpT has, compared with LnC, seen an increase in government intervention to secure connections. Overall, the active use of government policy measures (in this case direct public subsidy combined with market regulation) has driven a significant rise in the number of poor rural households that receive electricity. It should, however, be noted that this expansion has also entailed rising costs. As the LpT programme has expanded coverage to increasingly distant communities – and used more off-grid solutions such as solar PV panels and diesel generators – the cost per connection has risen from R\$4,366 (around \$1,521) per household in 2004 to R\$8,219 (around \$4,834) in 2010 (Viera, 2011).

3.2.5 Assessing the policy mix

While the financing environment for expanding electricity generation and access has clearly resulted in progress, there are different views on whether government has yet achieved the correct policy mix. Some interviewees believed that the electricity-generation market remains too fragmented and market-led, with costs met by the government while private companies reap the profits. One commentator argues that the benefits of the reforms of the 1990s, designed to open up the market to private funds,

36 The joint initiative of the World Bank and the International Union for the Conservation of Nature to promote the World Commission on Dams (WCD) and the subsequent WCD report allowed for lessons and recommendations to be drawn from the case studies on the impacts of existing large dams. Nevertheless, since the publication of the WCD strategic priorities and guidelines over a decade ago (WCD, 2000), financial support from multilateral financial institutions to green-field hydropower projects in Brazil remains negligible.

could have been provided by public financing (de Oliveira, 2003). Others consider there have been positive benefits in terms of greater competition and opportunities for private enterprise (Lock, 2005). The escalating cost of the LpT programme, as it aims to connect the most marginal households, was seen by some interviewees as representing too much of a drain on public resources while LpT is seen by other actors in Brazil as a key contribution to reducing poverty and inequality. What is clear is that Brazil's current energy situation would not have been possible without the deployment of a range of government policies – such as taxation, subsidies and regulation – in order to provide a conducive environment for financing substantial growth in energy generation and access.

3.3 Improvements in electricity-sector regulation

As regards regulation, over the last 20 years the energy sector in Brazil has been engaged in a process of 'learning from mistakes' rather than following a straight and smooth road.

3.3.1 The 1990s reforms: too far, too fast

The literature and interviews identify the electricity-sector reforms of the early 1990s under the FHC administration as a turning point (e.g. World Bank, 2010). These reforms took place against a backdrop of broad international trends for state-owned utilities to be privatised, deregulated and placed, where possible, in market or quasi-market competition. Several interviewees noted that the UK experience of unbundling and selling off state-owned electricity generation, transmission and distribution companies, and establishing technical bodies to regulate the sector at arm's length³⁷ from government, directly inspired the Brazilian reforms along the same lines. The overall orientation of the Brazilian economy was changing at the same time, with the FHC administration promoting greater openness to foreign trade and capital, and reducing policies aimed at economic 'self-sufficiency' (Fishlow, 2011) – part of its ideological preference for market-led solutions. Interviewees noted that, pre-reform, the major public electricity companies were seen as inefficient and poorly managed.

For reasons of space, it is not possible to set out the detailed history of Brazil's energy reforms of the early 1990s.³⁸ Broadly, before the reforms, the generation and distribution companies were publicly owned (often by state governments) and often vertically integrated. Finance for the construction of new assets was predominantly public and the government determined the expansion of the network and the establishment of new generation plants. By the 1980s, however, the

sector was facing increasing shortfalls in the necessary investment, and tariffs were too low to sustain expansion. As noted above, the 1990s reforms of the Brazilian energy sector unbundled utilities and opened the way to private investment in the resulting energy companies, thereby allowing the market to influence decisions on where and how to build new capacity. The planning role of central government was reduced. Several key technical agencies, notably the national electricity regulator, ANEEL, were created to build and enforce the regulatory framework for the sector. The reform process was very fast. Some interviewees commented that the Brazilian government attempted to achieve in three to five years of regulatory reform what the UK government had spent more than 15 years trying to do.

3.3.2 The 'reform of the reforms'

This 1990s market-driven system produced imbalances that most commentators consider were partly (or even largely) responsible for the mismatch in supply and demand that led to the rolling blackouts and electricity rationing of 2000-2001 – the *apagão* in Portuguese – alongside weather patterns that substantially affected hydropower output. Combined with a period of drought that reduced the river flows and water storage on which hydropower depends, lack of investment led to a 'capacity crunch' whereby demand significantly outstripped supply. The FHC government introduced rationing to restore the balance between supply and demand, with the aim of reducing consumption by 20% nationwide. The deep unpopularity of the blackouts and rationing was seen by many interviewees as directly contributing to the defeat of the government at the 2002 presidential elections. As a result, the regulation of the sector underwent further change – the 'reform of the reforms'. These further changes in 2004-2005 left some of the existing principles in place, notably the idea of independent technical regulators for the sector and a leading role for private finance in investing in new infrastructure, while re-introducing a greater role for state planning. The EPE was created in 2004 as the research and planning arm of the ministry responsible for energy (the MME), with a much more directive role. For example, whereas previously private companies were expected to propose the means and location for generating electricity (designed to maximise return on private investment), after 2004 it was the EPE that determined the overall electricity mix through auctions for different kinds of supply (to meet pre-determined government policy objectives based on forecasts of demand) and decided on the key sites that could be developed for electricity generation. Other reforms strengthened the role of ANEEL in setting

37 See Victor and Heller, 2007 for a comparative review.

38 The issue of the independence of Brazil's energy regulators is discussed in section 4.2.

conditions for holders of electricity concessions, notably in requiring a specified number of new electricity connections as part of the LpT programme.

3.3.3 Assessing the reforms overall

Brazil's experience of regulating the energy sector is, therefore, an example of adaptive policy learning and the impact of ideological shifts. International regulatory trends for managing public utilities were translated to the Brazilian context alongside complementary changes in the broader economy. When key elements of this model resulted in policy failure (e.g. the imbalances referred to above), new reforms were made to re-introduce elements of the previous regime in order to reduce the risks of repeated policy failure. The result has been no recurrence of the rolling blackouts of the kind that occurred in 2000-2001. Well-placed interviewees reported that there is significant pressure from highest political levels to ensure that the system is resilient to such shocks.

3.4 Improvements in the design and management of large hydropower plants

Sustained high-level policy support for development of technical capacity in hydraulic engineering and associated disciplines, noted in Section 3.1, was a major factor in Brazil's exploitation of large hydropower from 1990 to 2010. A further key driver was improvements in the design and management of (individual) hydropower plants.

3.4.1 Project management of hydropower – in the 1980s

In the 1970s and 1980s, two major hydropower plants were constructed with public financing: Itaipu, on the border with Paraguay,³⁹ and Tucuruí, the first major project in the Amazon, completed in 1984.⁴⁰ Tucuruí was the subject of the Brazilian case study for the World Commission on Dams (WCD, 2000), and the resulting report (La Rovere and Mendes, 2000) noted that the project had failed to take account of the 'profound socioeconomic transformation' caused by the dam and reservoir (see Box 3).

Among the negative impacts caused by Tucuruí noted in Box 3, a local grievance was that the plant was principally aimed at supplying electricity to other users, including intensive energy-using industries.

Box 3: Tucuruí hydropower plant – 1980s

The Tucuruí hydroelectric plant required retrospective measures to remedy – as far as possible – problems caused by lack of foresight and care by project developers, and by failures of regulation and oversight by government authorities.* The 2000 case study report for the WCD, carried out by a Brazilian and international interdisciplinary team, noted poor water quality in the reservoir behind the Tucuruí dam, which flooded 2,850 km² instead of the planned 1,630 km². The downstream impacts were also underestimated prior to construction and there was a need to reassess them. Operation of the plant gave rise to drastically reduced river flows in the dry season. Meanwhile, failure to take account of the 'profound socioeconomic transformation' caused by Tucuruí (translating from page xv of the report) resulted in a legacy of dissatisfaction among significant segments of the directly and indirectly affected population. Those stakeholders were largely ignored in the decision-making process. For the planners of Tucuruí, the overriding priority was to supply energy to the mining and metals industries as well as the populations of the big cities further north. This lack of recognition of the impacts on local people was, noted the report (2000: xv), a consequence of the approach during the 1980s, of 'denying existence of conflicts of interest' in the name of the 'general interest' as defined by the 'superior authorities'.

Source: La Rovere and Mendes, 2000.

* Prior to creation of IBAMA, the national environmental regulator.

3.4.2 Project management of hydropower – current practice

An example of current project practice is the Jirau hydropower plant (3,750 MW) in Rondônia state, being built on a tributary of the 'right' bank of the Amazon, the Madeira River. Two decades after Tucuruí, Jirau illustrates the extent to which leading practice in the manner of design and construction of large hydropower plants, when viewed as individual projects,⁴¹ has evolved since the 1980s, or at least the capacity to deliver improved projects.⁴² The Jirau project is managed by *Energia Sustentável do Brasil* ('Sustainable Energy of

39 At 14,000 MW, Itaipu is currently the world's second most powerful hydropower plant.

40 Tucuruí was initially 4,000 MW and is now 8,370 MW.

41 The practice of individual projects as compared with broader strategic planning, as discussed in section 4.3.

42 Jirau is not here presented as 'typical' or 'representative' of all large hydropower projects in Brazil.

Brazil' – ESBR).⁴³ Also, on the Madeira River, the Santo Antônio hydropower plant (3,150 MW) has recently been constructed by another company⁴⁴ and is operating.

The Jirau project was evaluated in 2012 by an international team of assessors in accordance with the Hydropower Sustainability Assessment Protocol (HSAP), an assessment tool designed by an international multi-stakeholder group to score the performance of hydropower projects against a wide range of criteria based on international principles and practices.⁴⁵ To reduce and compensate (as far as possible) for local impacts, the Jirau project design includes specific technical features and the budget includes provision for socioeconomic and environmental activities. The horizontal 'bulb' turbine design has allowed a lower dam and reduced reservoir size for operation of this 'run-of-river' plant. Some 500 families have been displaced, with compensation in cash, a letter of credit or the offer of collective re-settlement in a new town called Novo Mutum Paraná. The town has good services (including electricity) and facilities (shops, community centre, etc). A budget of R\$1.2 billion (\$500m), equivalent to 12% of the total initial project budget,⁴⁶ is allocated to a range of socioeconomic and environmental activities.

When all the turbines become functional in 2016, the Jirau plant will be able to deliver its electricity to the sub-station at Porto Velho (94 km from the dam site), at which point the power will be available to the national grid including, presumably, supply for that city. One resident of Porto Velho observed that the benefit of the electricity from the Santo Antônio plant had not yet been reflected in electricity prices. This seems to be consistent with the data given in Table 4, whereby the price of electricity supplied by CERON (*Centrais Elétricas de Rondônia*) is higher than four of the five other utilities listed. In the new town of Nova Mutum Paraná, the cost of electricity was referred to in the international assessors' report (Locher et al., 2013: 72) as an issue for some households that 'have chosen to [rent out their property in the town], or even to sell their property, because they felt they could not afford high water and electricity

prices' (the amount charged to the consumer not being within the remit of, or controlled by, ESBR).

3.4.3 Assessment of the Jirau project – 'winners' and 'losers'

Overall, based on a critical reading of the international assessors' report, it appears that ESBR, as the company managing the Jirau site, has done its job well.⁴⁷ In contrast to the Tucuruí plant in the 1980s, the negative impacts of the Jirau project have been recognised and considerable efforts made to mitigate and compensate for them.

Despite that, there are 'losers' from the two Madeira dams. These include indigenous fisher people who (according to FUNAI, interviewed in Porto Velho) tell of reduced fish stocks upstream of the Santo Antônio dam, while the riverside properties downstream are said to be suffering from erosion of the riverbank. In terms of impact on the biological diversity of the Amazon, it remains to be seen whether the fish-transposition scheme at Jirau is able to maintain the species diversity of the River Madeira (459 species, according to Furnas and Odebrecht, 2005).⁴⁸

As for the effectiveness of the measures designed to mitigate or compensate for impacts on local people, the assessors highlighted the issue of whether the living standards of those resettled will improve in the medium and long term. There are, they said, 'significant questions on economic sustainability of the new settlement' (Locher et al., 2013: 72). During the construction phase of Jirau plant, the workforce was nearly 25,000 at its peak and 'approximately 40%' of jobs went to local people (Locher et al., 2013: 57). The next operational phase of Jirau will require only a handful of employees, so the challenge will be to maintain local jobs/livelihoods. One person interviewed in Porto Velho commented, pessimistically: 'Nova Mutum Paraná is a long way from the city. In ten years' time, I expect it'll be abandoned'. By comparison, Santo Antônio is located very close to Porto Velho.

There seems to be a tendency by the Jirau project leaders to 'talk up' the project's local benefits. An example

43 ESBR is a private-public company, majority owned (60%) by the multinational, GDF Suez, and 40% owned by public-sector companies, part of the Eletrobras group. Mitsui will take a 20% equity interest in the project.

44 Santo Antônio Energia is a consortium of Brazilian private companies – Odebrecht and Andrade Gutierrez – and Furnas and Cemig, public companies.

45 The multi-stakeholder group (or 'Forum') included representatives of industry, non-governmental organisations and independent specialists, as well as participation by international financing institutions. The HSAP 'Background Document' (IHA, 2010), noted a substantial level of 'convergence amongst the diverse views of Forum member organisations on how to best incorporate into this assessment tool the issues relevant to hydropower sustainability', with, it adds, either unanimous or majority support for the wording of the final text. The document adds that some 'areas of non-consensus' were identified in relation to the topics of 'Project Affected Communities & Livelihoods', 'Resettlement' and 'Indigenous Peoples' – where the minority of the Forum felt strongly that those areas required 'further analysis and dialogue'. As for the Jirau project in Brazil, the report (Locher et al., 2013) has formed part of the first set of HSAP assessments to be made publicly available.

46 At the time of the auction for Jirau, the total project budget was about R\$10 billion of which the socioeconomic and environmental activities represented 12%. Subsequently, the project cost increased due to the addition of six extra turbines and to delay in the works on site as described in the assessment report.

47 The assessors concluded the Jirau project was being managed to a good standard (Locher et al., 2013).

48 ESBR states, that it is 'fully focused on monitoring and optimising the [transposition] solution to provide not just genetic exchange of specific target species, but also to maintain population levels of fish communities on natural pre-project levels. Definite success can only be demonstrated after a few years of monitoring of the fish passage system and the population levels'.



Working on the Santo Antônio hydroelectric plant on the Madeira River at Porto Velho, Rondônia. Photo: © Divulgação Furnas

noted by the international assessors is that the project had set a target (under the ‘Social Compensation’ programme) for local recruitment during the construction phase at 70% of the workforce (Locher et al., 2013: 50). The actual figure was ‘approximately 40%’ in 2012 when the assessors visited (Locher et al., 2013: 57), at which time ESBR said that the target was ‘not yet met, but believed to be on track’ (Locher et al., 2013: 50). It is difficult to see how the civil engineering contractor could, four years after start of construction, with most of the ‘civil’ work already carried out, expect to make up the 30% difference.⁴⁹

As for the implications of the Jirau project on regional development, ESBR has ventured the prediction that the plant will be a ‘vector of social, environmental and economic development beyond energy generation’. Regarding hydropower projects in the North generally, the MME/EPE states these will be a ‘dynamic impulse for the regional economy’ (MME, 2007a: 198). But how exactly? ‘Electricity does not of itself bring rural development’, commented one person interviewed, noting also ‘the lack of advance planning for regional development around large hydropower projects, especially in the ‘frontier’ areas of the Amazon’ (such as Rondônia). ‘Projects are decided upon’, he added, ‘based on exogenous criteria; decisions are then made on the measures required for mitigation of impacts; finally, the implications for the region are considered’.

3.4.4 Benefit-sharing: the Brazilian system of royalties

In that connection, one important issue will be whether the royalties paid to Rondônia State and Porto Velho municipality on electricity sales from the Jirau and Santo Antônio plants are used to support the state and local economy. In Brazil, the system of royalties provided for in the Constitution⁵⁰ requires payment of ‘financial compensation for the utilisation of water resources for electrical energy generation’: 3% of the revenue from electricity sales goes to each of the municipality and the state. In the case of Jirau and Santo Antônio, the combined royalties may be expected to add a further 9% to the budget of Porto Velho municipality – a useful boost⁵¹ that will supplement general municipal funds, to be applied to a standard set of categories and percentages of expenditure as prescribed by federal law for all municipalities in Brazil. There are questions about the capacity of the municipality to manage these funds, not least after former municipal officials recently served prison sentences for corruption. Without a change to existing legislation, those who are displaced and otherwise affected by Jirau and Santo

Antônio will have no special claim to benefit from the royalties. An alternative mechanism could be to set up a special development fund. The fund could target the ‘losers’ from the two Madeira dams, in line with the concept of ‘compensation for the utilisation of water resources’.

3.4.5 Local interests – national interests

A key point is that, in the decision-making process that approved the Jirau and Santo Antônio projects, one fundamental thing has not changed from the time of Tucuruí. Local people were consulted *not* on whether the projects should go ahead (i.e. not on whether or not local water resources should be used to generate electricity), but on how they would be compensated and supported once the government decided that the projects should go ahead – in the name of the ‘general interest’ (as at the time of Tucuruí). Successive Brazilian leaders have, in other words, resisted the former interpretation of ‘consultation’ on the grounds that it would constitute a right of veto, which would not be compatible with the needs of the country as a whole. In weighing up local considerations against the national interest, the project-level design and management improvements, exemplified at Jirau, contrast with a major flaw in national-level strategic planning. In contrast to the Brazilian government’s current mode of national decision-making, a more transparent and inclusive process should be developed in relation to future decisions on investments in large energy infrastructure projects, as discussed in Section 4.3.

3.5 Long-term public and private investment in ethanol-related R&D

A further driver of Brazil’s progress in developing energy has come from sustained investment in the development of new technologies for ethanol production.

3.5.1 Sustained public investment and support

A significant proportion of this technology development has come from public action, either direct public investment in research, or interventions to incentivise the market. From the beginning of the PRO-ALCOOL programme in the 1970s, there has been public funding for research into better sugarcane yields and improved ethanol extraction. The CTC (*Centro de Tecnologia Canavieira*) – a private research facility built by a cooperative of São Paulo cane producers with the help of public soft loans – alongside publicly funded university research centres, developed new technologies for sugarcane and ethanol production.

49 The company explains this as being the consequence, essentially, of the presence of two large construction sites, Jirau and Santo Antônio, drawing on local labour at (in part) the same time – in which case why did ESBR not revise the target downwards?

50 In accordance with Article 20 of the Constitution and the law no. 8.001 of March 1990 establishing the royalty system, as modified by laws in 1997 and 2000.

51 This 9% figure is calculated as follows. In 2012, the revenue of Porto Velho was R\$991 million, projected to rise to R\$1.04 billion in 2013. The estimated annual royalties from Santo Antônio are forecast by the company operating the plant to be R\$44.3 million in 2013, i.e. 4.441% of the municipal budget. The combined figure (from 2015, with Jirau’s somewhat greater installed capacity) is likely to be upwards of 8.8% of the municipal budget.

This resulted in consistent, long-term improvements in sugarcane yields and ethanol extraction. The total amount of energy recoverable from sugarcane has grown at roughly 1.5% a year from 1977 to 2005, with more land under cultivation (Goldemberg, 2008). Some authors believe these technological improvements mean that ethanol can now be considered broadly cost-competitive with fossil fuels (Goldemberg et al., 2004). Interviewees agreed that public investment in research was instrumental to improving yields in the early stages of the ethanol's development, while suggesting that the market has developed to a degree whereby government-supported investment is of declining importance compared to private-led R&D.

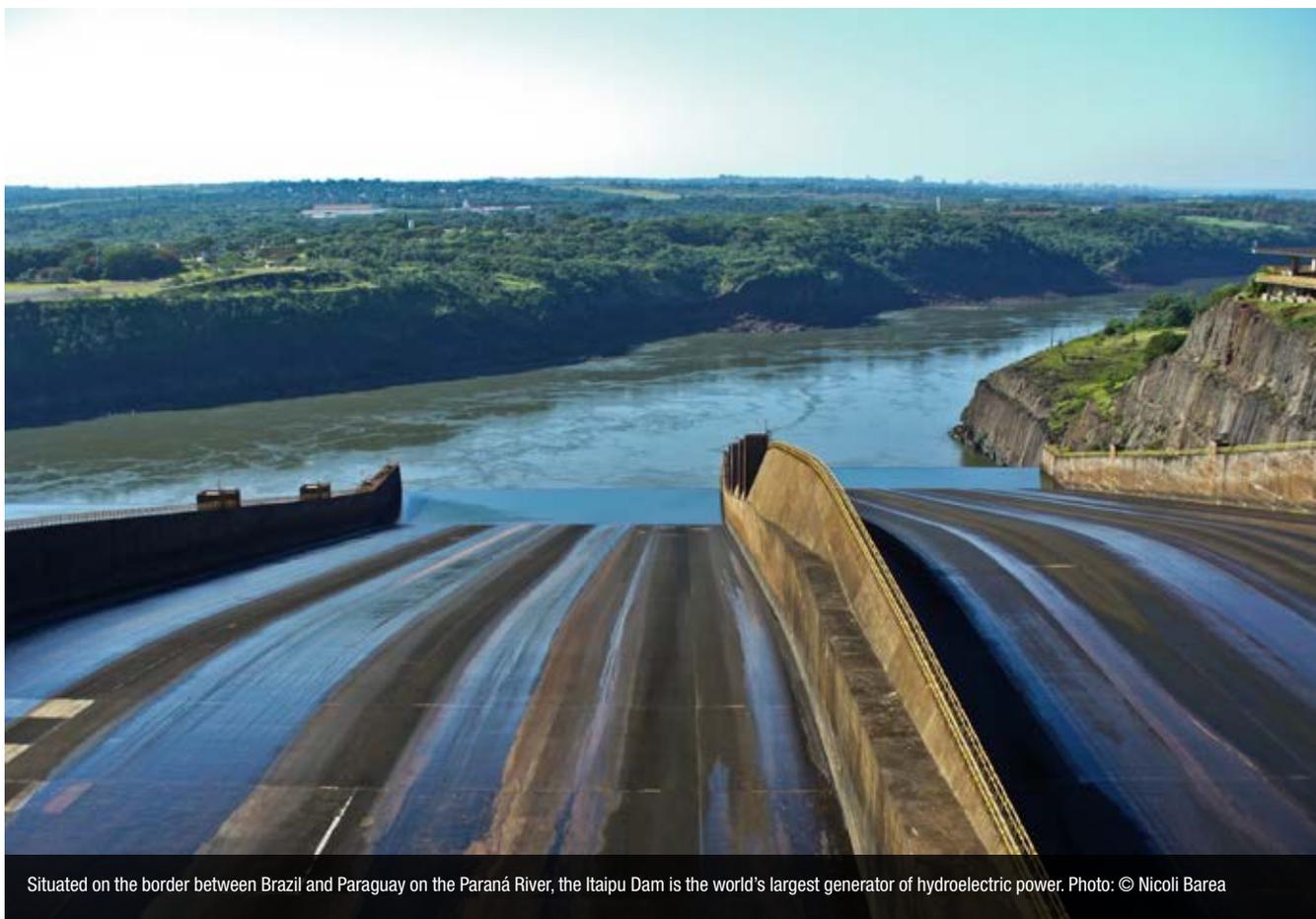
The existence of a sustained and robust market for ethanol products as a result of government intervention also provided clear incentives for private-sector investment in development of new ethanol-based technologies. The structuring of the market by government to subsidise ethanol production has spurred ethanol producers and car manufacturers to develop technologies that can take advantage of the fuel. Car engines have, for example, been developed to run on petrol fuels blended with high levels of ethanol (up to 25%); the ethanol-only car engine was developed for the Brazilian market in 1979, followed in 2003 by the development of flex-fuel cars, capable of running on either blending gasoline or ethanol fuel. The great majority of new cars sold in Brazil today are flex-fuel vehicles, capable of using fuels interchangeably (UNICA, 2009), and, as noted above, ethanol is estimated to have replaced almost 40% of Brazil's requirement for petrol. The success of Brazil's investment in sugarcane R&D has also led to it being used as an instrument of

aid and international diplomacy with other developing nations. The Brazilian Enterprise for Agricultural Research (EMBRAPA) has shared technology with several African countries with climates suitable for cultivating sugarcane (Cabral and Shankland, 2013). Overall, Brazil's approach to development cooperation includes a significant amount of this kind of 'South-South' technology transfer (AfDB, 2011).

3.5.2 Ethanol and petrol: balancing act

The ethanol policy is not, however, without difficulty. It requires a careful balancing act to sustain a market for ethanol-related fuels that remains competitive with traditional petrol. Some of the factors involved, such as the price of sugar on the global market, are beyond the direct control of Brazilian policy makers. Over the 30-40 years since the PRO-ALCOOL programme began, there have been times when liquid ethanol fuels faced real problems of competitiveness and viability. For example, in the late 1980s, falling prices for oil and a decline in the production of ethanol fuel left ethanol-only cars with fuel shortages. The nation began to import ethanol fuel in the early 1990s and consumer confidence in ethanol-fuelled vehicles reduced sharply (IDB, 2007). Many well-informed interviewees expressed concern that the government's recent policy interventions in the price of petrol were becoming less informed by technical advice, and driven more by short-term political expediency. In line with the conclusions drawn elsewhere in this report, the development of new and better ethanol-related technologies as a result of a stable and profitable market has been one of overall development progress, but not always of uninterrupted achievement.

4. What are the challenges?



Situated on the border between Brazil and Paraguay on the Paraná River, the Itaipu Dam is the world's largest generator of hydroelectric power. Photo: © Nicoli Barea

‘Sector regulation still needs some fine-tuning’ – Energy sector specialist

This section highlights some of the major challenges that the Brazilian energy sector faces:

- managing oil and gas exploitation
- maintaining the independence of sector regulators
- improving strategic planning for large hydropower
- managing demand while balancing supply from variable and intermittent sources.

Addressing these challenges will be a key part of ensuring Brazil's continued progress in sustainable energy.

4.1 Managing exploitation of the significant oil and gas reserves

The discovery of offshore oil and gas deposits from 2007 onwards represents a potential ‘game-changer’ for Brazilian energy policy.

Some forecasts see Brazil joining the top five oil-producing nations in less than a decade, with the Brazilian government indicating total offshore reserves of around 50bn barrels –which, at current rates of consumption, would supply Brazil's oil needs for around 50 years (EIA, 2013a; EIA, 2013b).

The development of oil resources offers substantial opportunities for the Brazilian economy. Brazil could become a major energy exporter with a growing and internationally competitive oil and gas industry. Additional government revenue would improve prospects for public investment in physical and human infrastructure, resulting in faster economic and social development and the potential to improve living standards. Oil exports could substantially reduce overall trade imbalances and dependency on external sources of energy.

Managing such a ‘windfall’, however, brings significant risks. There are macroeconomic risks arising from a rising

exchange rate, often associated with sudden increases in natural resource exports (the so-called ‘Dutch disease’). Investment in oil and gas development may displace productive investment in other areas of the economy (‘crowding out’). There are also political risks: oil revenues might be used to simply strengthen dysfunctional patronage politics; it may entrench a disproportionately politically influential natural resources lobby, and/or be used to ‘paper over the cracks’ of persistent social and economic problems rather than investing in long-term solutions (a form of the ‘resource curse’).

Importantly, the development of offshore fossil-fuel resources could jeopardise Brazil’s long-term record in delivering relatively clean energy. As has been discussed, Brazil’s GHG emissions compare favourably with other LAC countries and UMICs, and, if these resources are used for domestic energy production, they could reduce this relatively clean and green energy mix. It may also risk destabilising the ethanol/petrol balance that promotes the use of flex-fuel engines and ethanol consumption by the national vehicle fleet, although interviewees were generally of the view that most oil is intended for export rather than domestic consumption, and even domestically produced oil will be priced in alignment with the international market. As noted in previous sections, the share of hydropower in Brazil’s energy mix is due to decline a little, relative to other sources, and thermal power generation using natural gas to increase. There is lively commentary on the impact that the oil and gas deposits have had on the quality of regulatory policy making within the Brazilian government. Several commentators have proposed that the prospect of major natural resource revenues have led, since 2010, to decisions that indicate policy dysfunction, and therefore increase the chances of Brazil ending up with many of the negative outcomes discussed above. Other writers suggest that the risks of this are overstated or merely part of a passing electoral cycle.⁵² In any case, the challenge remains for Brazil to develop the deposits in a way that supports macroeconomic stability, does not destabilise Brazil’s social and political development and maintains the country’s relatively clean and non-polluting energy mix.

4.2 Maintaining long-term policy coherence and the independence of sector regulators

Since the reforms of the early 1990s and the ‘re-reforms’ of the early 2000s, technical regulators – such as ANEEL, the national petroleum regulator (ANP), ONS and others – have played a leading role in achieving the overall energy policy objectives set by government.

Given the progress Brazil has made, as described in this report, it can be suggested that these regulators have been

broadly successful in contributing to the development of sustainable energy in Brazil.

Many interviewees, however, raised concerns regarding recent government policy decisions since 2010 that might undermine the impact of regulators’ technical advice, reducing their ability to independently regulate their respective areas. This suggests that the energy and electricity sector regulation may be increasingly subject to wider political economy factors, particularly in an election year.

Respondents cited numerous examples of regulatory decisions they viewed as not having been informed by technical advice. For example, the unexpected decision to abolish the system of charges levied on electricity bills to fund various accounts that promote electricity development, universal service objectives and support access for unconnected rural households (the CDE) or to provide funding for the fuel necessary for isolated off-grid diesel plants (the Global Reversions Reserve – RGR). These funds, according to interviewees, will now be met from general treasury resources. The decision was widely seen as part of the government’s response to the social protests in 2013 (referred to in Section 2.2) where mass demonstrations demanded a lower cost of living, better public services and less corruption.

In the oil and gas sector, interviewees raised concerns over the government’s decisions to amend the legal framework so as to mandate a role for Petrobras in exploitation of all oil fields, and to require Petrobras to import and sell gasoline and diesel at a loss in order to keep fuel prices low for consumers and therefore restrain inflation in the short term. Such a move has made ethanol uncompetitive for consumers, and, if continued, risks a long-term reduction in investment in ethanol development that could jeopardise the successful mixed-fuel market that Brazil has created. The subsidy is also regressive in that the consumers who will benefit the most will be those who consume the largest volumes of fuel – the least poor.

Interviewees suggested that future expansion of ethanol production is currently ‘on hold’ while investors wait to see what direction government policy will now take. Several saw significant risks to longer-term sustainability in the government’s use of state-controlled institutions, such as BNDES and Petrobras, as instruments to implement policy directly, rather than as arm’s length entities with operational independence, but acting in accordance with a broad government-defined mandate.

4.3 Improving strategic planning for further expansion of large hydropower

The energy plan of the MME/EPE for the period up to 2030 forecasts that hydropower will continue to play a major role in meeting growth in the national demand for

⁵² See conflicting views of the nature of Brazil’s energy policy in financial newspapers and magazines such as Reuters (2013), The Economist (2011), Brazil Works (2013), and Brazil Confidential (2013).

electricity, which it estimates (as noted in Section 2.1) as increasing by 4.1% per annum.

Up to 2030, the MME/EPE plans for 164 GW of hydropower ‘potential’ that is, it says, ‘exploitable’, but as yet unrealised,⁵³ of which a great part will be in the Amazon. At the above 90% figure, that would be roughly 147 GW⁵⁴ in the Amazon. Of new hydropower capacity planned before 2020, 90% will come from projects in the Amazon (La Rovere, 2010).

The 164 gigawatt figure would have the effect of more than doubling the total installed electricity-generation capacity in Brazil which, in 2012, was 121 GW (all sources), with hydropower capacity at 84.29 GW (70%) (EPE, 2013). While the growth in demand for electricity will require *some* large hydropower projects, the task for the Brazilian government will be to determine *how many* plants, and where to site them, as well as clearly articulate which types of users are to benefit (to avoid the grievances caused by the Tucuruí project). Answering these questions equitably entails modifying the decision-making process to make it more transparent and inclusive.

In the management of the current system, the MME/EPE is currently dominant, while other interests within government are inadequately represented. The development of hydropower in Brazil depends, of course, on using its water resources⁵⁵ and yet, ANA, the national water regulator, is weakly represented in the planning process. ‘The MME has clearly been reluctant’, observed one energy sector specialist, ‘to share decisions with other ministries and agencies and consult more widely’. Another Brazilian energy specialist interviewed commented that the MME/EPE was starting to open up to collect views from industry and other energy sector stakeholders, but that, once it had decided something, consultation was a ‘pure formality’ – for information only. On environmental issues, in particular, the EPE, as the planning and research arm of the MME, is supposed to undertake energy planning in an ‘integrated’ manner, but interviewees expressed doubts about its declared intention to take fuller account

of environmental issues in assessing prospective sites for hydropower plants.⁵⁶ One energy specialist commented that time pressure faced by EPE staff when preparing for a round of auctions means that the environment is the first aspect of projects to be de-prioritised.⁵⁷

Currently, the key checks and balances in the process are represented by the environmental licensing procedure managed by the federal environmental regulator, IBAMA (described in Box 4, overleaf).

The environmental licensing process described in Box 4 is operated on a project-by-project basis (WWF, 2013) and is essentially reactive. The ‘big picture’ strategy is currently left to the MME. To provide the answer to the ‘164 gigawatt question’, the challenge in Brazil is to develop a strategic planning process operating both *within* government, so that all relevant government agencies are involved in approving major investment decisions, and *beyond* government, so that other stakeholders are actively consulted. In the past, one energy sector specialist commented that Brazilians had been passive and very accepting of government thinking, with officials and elected representatives adopting the paternalist view that: ‘We know what is best for you’. How people see themselves and their relationship with government has since changed (Cornwall et al., 2008). Improved levels of education have gradually facilitated wider public engagement in politics. So, while decision-making still tends to be characterised by the ‘lack of a culture of negotiation’ (e.g. typically, little or no consultation with non-government experts), said another person interviewed during this study, ‘things are changing – people are learning to question’. The evolving social and political context conditions are changing the arena in which energy policy is prepared and needs to be implemented. More open dialogue is needed (WWF, 2013) between federal government ministries, and between federal and state governments – and other stakeholders. That driving through energy policy by wilful imposition cannot continue has recently been acknowledged by the chair of the EPE who is noted as saying that ‘hydropower

53 Major hydropower projects proposed in the plans of the MME for the next four years are as follows: São Manuel (700 MW) in 2013; São Luiz Tapajós (6,133 MW) in 2014; Jatoba (2.3 MW) in 2015; Bem Querer (708.4 MW) and São Simão do Alto (3,509 MW) in 2016 (source: EPE).

54 Alongside 6 GW of small hydropower (MME, 2007a). One GW is equivalent to 1,000 megawatts (MW), and a megawatt is equivalent to 1,000 kilowatts (kW).

55 Commenting on the Amazon as a region, the MME/EPE, in its energy plan to 2030, says that there is ‘less competition in the Amazon for water than in other countries’. Viewed at the local level, however, it is clear that large hydropower plants in the Amazon will often compete with other water uses. In the case of the Santo Antônio hydropower plant on the Madeira River, for example, fishing upstream of the dam has been affected (as seen above in section 3.4), despite the fish-transposition scheme.

56 The creation by inter-ministerial decree no. 494 in 2010 (Ministry of Environment and MME) of the ‘Strategic Group for Accompanying Infrastructure Ventures’ (Acompanhamento de Empreendimentos Energéticos Estruturais) may prove to be a positive step.

57 As for the role of the Public Prosecutor’s Office (Ministerio Público), there are contrasting perceptions. The Public Prosecutor is sometimes called the ‘fourth branch’ of the state, alongside the legislature, executive and judiciary. Acting independently of the other three, it is authorised by the Constitution (Articles 127-130) to bring legal actions against the government (at federal, state and municipal levels) as well as commercial companies and private individuals. Its role is ‘to uphold the rule of law, the democratic system’, including in the defence of minorities, the environment, consumers and the civil society in general. One view is that the Public Prosecutor, with its autonomy, is an institutional peculiarity of Brazil that plays an important part in causing delays and unpredictability (World Bank, 2008). An opposing view is that it acts as the critical last-resort defender of citizens in the face of unacceptable executive action. The Public Prosecutor has, for example, taken to courts or tribunals the argument that the government failed to consult local populations adequately over the Belo Monte project.

Box 4: The environmental licensing system in Brazil

The origin of Brazil's licensing system was the 1981 National Environmental Law, although it did not come into effect until 1986, following the election of a democratic government in the previous year. The subsequent 2000 legislation that declared illegal the flooding of national parks and other conservation areas was another milestone. The 1988 Constitution, meanwhile, provided the legal foundation for protection of indigenous lands, under Article 231.

According to Brazil's licensing system, IBAMA may accept a project proposal, attaching to the licence conditions for mitigation of impacts, or it may reject it, in which case the impacts are averted.

Social issues tend to be insufficiently taken into account in the licensing process, because IBAMA lacks sufficient technical capacity (La Rovere, 2010; World Bank, 2008).

Views are polarised on the question of whether the environmental licensing procedure helps or hinders the establishment of large hydropower projects in line with government policy objectives. The power sector (project planners and developers) sees the assessment and approval procedure for hydropower plants as causing unreasonable delays and uncertainty. Other commentators, on the other hand, would like to see the licensing process further strengthened, with more strategic environmental assessments ('SEAs', known in Portuguese as 'AAEs').

cannot be constructed by steel and fire' (*Valor Econômico*, 2013). More discussion between government departments, and open public debate, on, for example, the MME's proposals for further expansion of hydropower in the Amazon, would help to determine the middle path to which the EPE chair has referred, between the extremes of a 'totally conservationist vision' on the one hand and an 'ultra-pro-development attitude' on the other (*Valor Econômico*, 2013). Without more consultative decision-making, the future expansion of large hydropower projects in the Amazon is unlikely to gain public acceptance. The Belo Monte project has, for example, been met with major resistance. In the evolving social and political climate in Brazil, referred to in Section 2.2., whereby Brazilians are more readily questioning the actions of government and politicians, the MME/EPE's plans for hydropower in the Amazon will surely have to win an increasingly broad social and political 'licence' for its policy.

The separate Discussion Paper on *Advancing Sustainable Hydropower* that accompanies this report reviews the current mode of decision-making for major energy infrastructure projects in Brazil and considers what an *alternative* approach could look like.

It was striking during this research project that only one of the interviewees volunteered a view on climate change and its potential impacts on river flows and on hydropower generation. One energy specialist commented that the power sector in Brazil is beginning to be concerned with the potential risks of climate change. As yet, however, the information produced by climate models has produced contradictory forecasts of future precipitation levels in, for example, the Amazon: the results of two of the six models suggest that the region will become wetter, while the other four predict that it will be dryer. The low river levels that contributed to the rationing of power in 2001-2002 (noted in Section 3.3) and the drought that occurred in the Amazon in 2005 (INPE, 2005) were perhaps foretastes of future increased variability in river flows. Developing better information about, and policy responses to, climate

change will be an increasingly urgent challenge for Brazil's energy policy makers.

The hydropower model relies on conveying electricity over great distances, from the North of Brazil to the South and South-East and Central-West. This raises the question of transmission losses – the volume of energy that is lost in conveyance of electricity from where it is generated to where it will be used. The sources offer markedly different accounts of this issue. Rey (2012) refers to a workshop held in Curitiba in 2004 that cites 'technical' energy losses in Brazil at a level (12.7%) higher than in other countries in South America (e.g. Argentina at 6.8% and Colombia at 8.3%). The author then compares the figures with lower levels in Europe (averaging 6.5%). As for government figures, MME/EPE's Ten-Year Energy Plan to 2021 states that total losses in the transmission lines in the North will be 18.1% in 2021 (MME, 2006: 40). Meanwhile, the MME/EPE states that transmission losses in high-level tension cables in Brazil are at 4% of volume of energy transmitted (MME, 2007b: 26). Whatever the exact figures, strategically siting the development of electricity infrastructure and taking advantage of better technologies in order to reduce losses over the long transmission distances will remain a challenge for energy-sector managers.

In the search for ways to reduce the negative effects of hydropower plants in sensitive areas, a new concept has been proposed for them to be built as 'platforms' to minimise impacts on the landscape. According to this model, no road would be built to the construction site, and all construction and operational staff would be flown in by helicopter for weekly rather than daily shifts, thereby reducing by two-thirds the need for on-site accommodation, and the area allocated to it. Once the hydropower plant is in operation, the construction area would then be dismantled and the area largely re-forested or returned to other use for the duration of the plant (Melo, et al., 2012). Following the offshore oil and gas analogy, all access would be by air or river, avoiding the need to build access roads that risk 'opening' the area

to other environmental damage. Maintaining isolated hydropower platforms would appear to offer significant environmental benefits, but at greatly increased cost. Policy makers in the energy sector will face a continued challenge in managing this kind of environmental and cost trade-off as hydropower expands.

4.4 Managing demand while balancing supply from variable and intermittent sources

In managing supply and demand, Brazil's energy policy makers face two related and ongoing challenges.

First, Brazil faces a challenge – but also an opportunity – to manage energy demand more actively (i.e. to reduce it), rather than simply building more supply to meet it. Second, the grid managers face challenges in ensuring continuity of electricity supply as the system moves towards increasing use of renewable energy sources that are seasonal and/or intermittent in nature.

Regarding the management of energy demand, the second of three global objectives set by Sustainable Energy for All, to be accomplished by 2030, is the doubling of the rate of improvement in energy efficiency (SE4ALL, 2013). The proxy indicator is doubling of the rate of improvement in energy intensity (from a starting point of –1.3% in 2010 to –2.6% in 2030 (SE4ALL, 2013). As noted in Section 2.4, in Brazil energy intensity is forecast to move in the other direction. The MME/EPE acknowledges this in its energy plan to 2030: for the greater part of its 25-year planning horizon (2005-2030), energy intensity will increase before it starts to decline (MME, 2007a: 196, Figure 8.1). Government and industry sources in Brazil acknowledge that there are major energy savings that are yet to be realised. Although electricity concessionaires are obliged (by Law 9991/2000) to pay 0.5% of the Net Operating Income to energy efficiency R&D programmes,⁵⁸ all the interviewees agreed the effectiveness of this spending so far was doubtful. The impression is that the MME/EPE is focusing on supply-side measures without to date making a corresponding emphasis on managing demand. Yet, as one Brazilian energy specialist emphasised: 'Increasing intensity of energy use is avoidable – efficiency is the remedy'. By increasing investment in energy efficiency, the sector could meet demand through slowing down the growth in supply.

While 'managing down' demand is a relatively under-explored area in Brazil's energy policy, it will remain a priority to ensure that supply can meet demand. As noted above, there is a strong political imperative in Brazil's electricity system to avoid a repeat of the 2001-2002 rolling blackouts. Brazil faces challenges, however, in ensuring that electricity supply continuously matches

demand (however that demand is managed) as it moves towards increasing use of renewable energy sources that are seasonal and/or intermittent in nature.

Currently, in their determination to avoid any repetitions of the rationing of power in 2001-2002, Brazil's energy planners risk overplaying the supply side. Supply-side forecasts will tend to become self-fulfilling prophecies. That is because once generation capacity has been installed, at considerable cost, power companies will want to work to capacity in order to boost their revenues. Power distribution companies, along with department stores and other retailers, will aim to encourage households to purchase electricity-consuming goods. Similarly, projections of industrial demand, including in heavy energy-using sectors, may become a reality without the costs and benefits – in economic, social and environmental terms – having been fully considered.

As noted earlier, the EPE is forecasting a continuing major role for hydropower generation. However, the drive to improve the environmental and social impact of individual hydropower plants, for example through run-of-river design, increases the variability of supply from such plants because of having smaller reservoirs for 'storage' of energy supply. Similarly, the desire to expand wind and solar power output would improve the country's overall renewable mix, but leave supply more vulnerable to seasonal variation and intermittency of output. Bagasse electricity production – also expected to increase in the future – is also to some extent seasonal, following the timing of sugarcane harvesting. As discussed above, Brazil has the good fortune that wind and hydropower seasonality in the north-east and bagasse and hydropower in the south-east are broadly countercyclical, allowing for some balance. But the avoidance of power cuts requires sufficient redundancy to protect against these variables. This redundancy is often in the form of 'reserve' thermal plants that are not subject to intermittency or seasonality. This redundant capacity must then also be paid for, via the consumer tariff and other sources, even if it is not regularly used – which will push up costs. Using thermal plants to balance renewable sources also to some extent undermines the positive environmental benefits of using renewables.

The role of ONS in matching output from all the potential sources of electricity from across the country against fluctuating daily and seasonal demand is an ongoing balancing act. Policy makers face a challenge in getting serious about demand management over the long term, at the same time as playing a day-to-day balancing role that may become increasingly difficult as more variable and intermittent sources of power are used in the national electricity mix.

58 The cost of these programmes is not charged to the utility companies but passed on to consumers, via tariffs, as part of their electricity bills.

5. What lessons can we learn?



View of Recife by night. Photo: © Filipe Oliveira

Brazil has made impressive progress in the area of sustainable energy. Its policy makers have succeeded in planning and providing additional electricity-generation capacity and energy supplies to serve the country's growing economy and population. Nine out of every ten Brazilian households now have access to electricity and enjoy the benefits and opportunities that brings.

These advances have been made possible by sustained government leadership, with support to public programmes to expand access, as well as energy sector reforms to create a favourable financing environment for both private and public investment. Brazil has emerged as a world leader in the use of ethanol, with most cars in Brazil adapted to take conventional and bio-fuel.

Compared to other Latin American countries and UMICs, Brazil has succeeded in connecting more of its population, particularly in rural areas, to electricity,

uses a significantly 'greener' total energy mix and emits significantly less GHG per capita.

Brazil's energy story has not been all good, however. The frequent blackouts of the early 2000s represented a clear policy failure. The history of ethanol development also features reversals and setbacks, for example, the knock to consumer confidence from supply shortages in the early 1990s. Large hydropower is no longer the 'easy' option it was, because of the social, political and other trends described in this report. Growing demand requires *some* large hydropower projects, but the issue of how many new plants, and where – and to supply electricity to whom – needs to be further discussed within government and debated in public. More democracy entails more open and transparent consultation on major investment choices, including energy infrastructure.

The design of the latest generation of large hydropower projects in Brazil, with smaller reservoirs to reduce

displacement and environmental impact, means less water and energy is stored as a 'buffer' against uncertain weather and climate change. Faced with that risk, energy planners are hedging their bets by building thermal plants as a reserve. The question arises whether this approach risks leading the country's energy policy into a corner. Instead of increasingly overlapping investments on thermal and large hydropower, ensuring redundancy, energy planners could usefully look to other complementary options, for example, a broad mix of renewables with counterbalancing seasonality and variability aspects. The share of renewables in Brazil's overall national energy portfolio has been decreasing, and there is unrealised potential in other renewables. Prioritising (as past policy has done) one renewable energy source that is 'sustainable' does not make for a sustainable energy policy for the future.

Meanwhile, the big increase in the availability of energy in Brazil contrasts with little progress made in energy savings. Brazil still has a poor record on energy efficiency. This, one Brazilian energy specialist commented, is a 'serious aspect of energy policy requiring urgent change'. More efficient use of energy would allow for reductions in demand, which in turn would mean that fewer (or smaller) power plants would be needed, meaning less impact on local people and environments.

New oil and gas fields will significantly affect Brazil's energy development, offering both possibilities for greater energy security but also the risk of adopting a less sustainable energy mix. Ultimately, the path taken will depend on what kind of development the country seeks.

'Despite its particular features, there are lessons for other countries in Brazil's experience' – International energy specialist

There are clear limits to how far Brazil's experience can be transferred to other countries, many of which do not possess Brazil's natural resource endowment. Neither do they necessarily start with Brazil's relatively capable policy-making and regulatory institutions. There are, however, certain lessons and examples from Brazil's experience that could be applicable to other countries:

- **Establishing and maintaining a high-level political consensus on policy goals.** The governments of other countries could take active steps to generate a long-term policy consensus on energy, as far as national politics permit. Sustained high-level consensus on the goal of universal energy access, for example, allows for linking of potentially disparate social programmes for reduction of poverty and inequality. This means establishing and maintaining cooperation among key government ministries and major political parties and other stakeholders on the broad outlines of energy

policy. *How* this can be achieved will depend on the specificities of the political system, but may include the following elements: cross-party and inter-ministerial consultation and dialogue on major energy policy decisions; the creation of high-level advisory bodies and well-resourced technical planning units that command the respect of the political system; and the establishment of independently led 'long-term policy reviews' with representation from all sides of the political spectrum, as well as independent experts. These approaches can help to ensure that the overall aims of energy policy rise above party politics, even if the mode of delivery and balance between particular objectives are more contested.

- **Development of a system for open and transparent dialogue on major infrastructure development.** Governments could consider developing an open and transparent system of strategic planning for major energy investment infrastructure, particularly for large projects such as hydropower dams. That would increase the political legitimacy of decisions taken. This system should incorporate a process of dialogue both within government, so that relevant government agencies are involved in approving major investment decisions, and beyond government, for active consultation of broader stakeholder interests. To date, the focus in Brazil has been on the evolution of procedures for planning and licensing individual projects, without open dialogue on alternative project options or the wider strategic direction of infrastructure development. Other countries can look at the Brazilian experience and acknowledge the need to design decision-making systems that provide for consultation on alternative options as a means to generate greater consensus.
- **Building an independent regulatory system that strikes a balance between government- and market-based regulation.** There are lessons for other countries to draw from Brazil's experience of energy regulation in relation to striking the right balance between the state and the market in designing 'the rules of the game' for the energy sector. Brazil's energy and electricity regulatory environment moved over the 20 years on which this study has focused from a state-led to a much more market-driven system, and then back to a kind of 'middle way' involving greater state-led planning, but a mixed economy of provision. As a result, Brazil can be a useful case study for the governments of other countries that are considering regulatory reform on how to 'strike the right balance'.

Brazil's system of energy market regulation aims to give expert independent technical regulators significant autonomy within the sector to make operational decisions that will achieve the high-level policy objectives set by government. In each country, maintaining the impartial and non-partisan nature of energy regulators is crucial

to ensuring they can make decisions that will ensure sustainable long-term positive outcomes. Maintaining the technical expertise of regulators in such a system requires commitment to their independence for regulation of markets without day-to-day political interference. The institutional tools to do this will vary in each context, depending on national politics, but might include appointment rules to favour long-term tenure of widely respected non-political technical experts, clear administrative and financial separation from the relevant ministry, and funding from industry levies rather than general public revenue. Such measures may be unpopular among some political interests in the short term, but they are likely to produce a better technical system in the longer term.

Brazil's experience of government intervention in, and regulation of, energy and electricity markets also

offers lessons regarding the range of policy measures that can help to provide access to electricity as part of wider poverty-reduction programmes. Brazil has used a number of policies to ensure more household electricity connections. These have included regulatory instruments to require households and private companies to undertake certain activities; subsidy financing to reduce the cost to individuals, households and companies of engaging in socially beneficial activities; and taxes, in the form of contributions from all consumers via cross-subsidy elements of the common tariff, in order to finance wider social goals. Other countries could consider how these various regulatory levers have been used to provide access to unconnected households, and how they are embedded into a wider set of anti-poverty programmes.

References

- AfDB (2011) 'Brazil's economic engagement with Africa', *Africa Economic Brief* 2(5).
- ANEEL (2013) 'Matriz de Energia Elétrica', Banco de Informações da Geração (www.aneel.gov.br/aplicacoes/capacidadebrasil/OperacaoCapacidadeBrasil.asp).
- ANEEL (2014) 'Capacidade de Geração do Brasil', Banco de Informações de Geração-BIG (updated Jan 2014) (www.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm).
- BNDES (2012) 'Apoio do BNDES à Infraestrutura'. BNDES: Rio de Janeiro.
- Brazil Confidential (2013) 'The start of Dilma's 2014 campaign?' 31 January (www.latamconfidential.com/Report-Archive/2013-01-31-Report/The-start-of-Dilma-s-2014-campaign).
- Brazil Works (2013) 'Energy anxiety in Brazil' 9 January (<http://brazil-works.com/?p=628>).
- Cabral, L. and Shankland, A. (2013) *Narratives of Brazil-Africa cooperation for agricultural development: New paradigms?* Future Agricultures Working Paper 051. Brighton: Future Agricultures Consortium.
- Cornwall, A., Romano, J. and Shankland, A. (2008) *Brazilian experiences of participation of citizenship: A critical look*. Discussion Paper 389. Brighton: Institute of Development Studies.
- de Araujo, J.L.R.H and de Oliveira, A (2003) 'Brazilian energy policy: Changing course?', paper presented at Coloquio Internacional 'Energia, Reformas Institucionales y Desarrollo en América Latina', Universidad Nacional Autónoma de México – Université PMF de Grenoble, Mexico, DF, 5-7 November.
- de Oliveira, A. (2003) 'The political economy of Brazilian power industry reform', Working Paper 2, Political Economy of Power Market Reform conference, PESD, Stanford University, 19-20 February.
- Dias de Moraes, M.A.F (2007) 'O mercado de trabalho da agroindústria canavieira: desafios e oportunidades', *Economia Aplicada* 11(4): 605-619.
- Dias de Oliveira, M, E., Vaughan, B. E. and Rykiel Jr., E.J (2005) 'Ethanol as fuel: Energy, carbon dioxide balances, and ecological footprint', *Bioscience* 55(7): 593.
- The Economist* (2011) 'Filling up the future' 5 November (www.economist.com/node/21536570).
- EIA (2013) 'Brazil Overview'. Washington, DC: US Energy Administration Information (www.eia.gov/countries/cab.cfm?fips=BR).
- EIA (2013a) 'Recent production growth from pre-salt resources increases Brazil's total crude output'. Washington, DC: US Energy Administration Information (www.eia.gov/todayinenergy/detail.cfm?id=13771).
- EIA (2013b) 'Brazil: Country Analysis Brief Overview'. Washington, DC: US Energy Administration Information (www.eia.gov/countries/country-data.cfm?fips=BR).
- EPE (2001) 'Balanço Energético Nacional 2001' Rio de Janeiro: Empresa de Pesquisa Energética (www.dca.ufrn.br/~ricardo/files/ben_p20012.pdf).
- EPE (2011) 'Balanço Energético Nacional 2011'. Rio de Janeiro: Empresa de Pesquisa Energética (https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2011.pdf).
- EPE (2012) 'Brazilian Energy Balance 2012 – Year 2011'. Rio de Janeiro: Empresa de Pesquisa Energética.
- EPE (2013) 'Balanço Energético Nacional'. Rio de Janeiro: Empresa de Pesquisa Energética (www.mme.gov.br/mme/galerias/arquivos/publicacoes/BEN/2_-_BEN_-_Ano_Base/1_-_BEN_Portugues_-_Ingls_-_Completo.pdf).
- EPE (2013a) Anuário Estatístico de Energia Elétrica 2013. Rio de Janeiro: Empresa de Pesquisa Energética (www.epe.gov.br/AnuarioEstatisticodeEnergiaEletrica/20130909_1.pdf).
- Fishlow, A. (2011) *Starting over: Brazil since 1985*. Washington, DC: Brookings Institution Press.
- Furtado, A.T., Scandiffio, M.I.G., and Cortez, L.A.B (2011) 'The Brazilian sugarcane innovation system', *Energy Policy* 39: 156-166.
- Furnas and Odebrecht (2005) 'Estudo de Impacto Ambiental e Relatório de Impacto Ambiental das Usinas Hidrelétricas de Santo Antônio e Jirau'. FURNAS and ODEBRECHT.
- Gaye, A. (2007) *Access to energy and human development*. Human Development Report Office Occasional Paper 2007/25. New York: UNDP Human Development Report Office.
- Goldemberg, J. Coelho, S.T. and Guardabassi, P. (2008) 'The sustainability of ethanol production from sugarcane', *Energy Policy* 36(6): 2086-2097.
- Goldemberg, J., Coelho, S.T., Nastari, P.M. and Lucon, O. (2004) 'Ethanol Learning Curve – The Brazilian Experience', *Biomass and Bioenergy* 26: 301-304.
- Goldemberg, J. (2008) 'The Brazilian biofuels industry', *Biotechnology for Biofuels* 1: 6.
- Government of Brazil (2013) 'Brazil without Extreme Poverty – One Year of Results'. Brasilia (www.brasilsemisera.gov.br).
- GVEP (2011) 'The history of mini-grid development in developing countries', Global Village Energy Partnership, Policy briefing, September.
- Horta Nogueira, L.A. (2008) 'Eficiência energética: um imperativo para a sustentabilidade', paper delivered at 'Colóquio 2010-2020: uma década promissora para o Brasil', São Paulo University, June.
- IBGE (2013) 'Brasil em Síntese: população'. Rio de Janeiro: Instituto Brasileiro do Geografia e Estatística

- (<http://brasilemsintese.ibge.gov.br/populacao/populacao-total-1980-2010>).
- IBGE (2010a), '2010 Census – Atlas of the Population'. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística (<http://censo2010.ibge.gov.br/en/noticias-censo?view=noticia&cid=3&cidnoticia=2417&busca=1&t=atlas-censo-demografico-ibge-mapeia-mudancas-sociedade-brasileira>).
- IBGE (2010b) 'Pesquisa de Orçamentos familiares 2008-2009'. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística (http://www.ibge.gov.br/home/estatistica/populacao/condicaoodevida/pof/2008_2009/POFpublicacao.pdf).
- IHA (2010) 'Background document', Hydropower Sustainability Assessment Protocol, November (www.hydrosustainability.org/getattachment/4c0b52b7-7744-47c1-b6a7-692e2b7dfb03/Background-Document.aspx).
- INPE (2005) 'Seca na Amazônia em 2005', Ministério da Ciência, Tecnologia e Inovação, Instituto Nacional de Pesquisas Espaciais (www.inpe.br/noticias/noticia.php?Cod_Noticia=492).
- IDB (2007) 'A blueprint for green energy in the Americas'. Washington, DC: Inter-American Development Bank.
- Ipeadata (2013) 'Macroeconomic data/historical series/national accounts'. Institute of Applied Economic Research (www.ipea.gov.br/portal/index.php?option=com_content&view=frontpage&Itemid=346).
- Khatiwada, D., Seabra, J., Silveira, S. and Walter, A. (2012) 'Power generation from sugarcane biomass – A complementary option to hydroelectricity in Nepal and Brazil', *Energy* 48: 241-254.
- Lapola, D.M., Martinelli, L.A., Peres, C.A., et al. (2014) 'Pervasive transition of the Brazilian land-use system', *Nature Climate Change* 4: 27-35
- La Rovere, E.L. and Mendes, F.E. (2000) 'Tucuruí Hydropower Complex, Brazil'. Case study for the World Commission on Dams, Final report, November 2000. World Commission on Dams Secretariat.
- La Rovere, E. L. (2010) 'Estudo 58: Energia Elétrica', Perspectivas dos Investimentos Sociais no Brasil, PIS. Rio de Janeiro: Centro de Desenvolvimento e Planejamento Regional, Universidade Federal de Minas Gerais; Laboratório Interdisciplinar de Meio Ambiente, UFRJ (<http://web.cedeplar.ufmg.br/cedeplar/site/pesquisas/pis/Estudo%2058.pdf>).
- La Rovere, E.L. (2011) 'Projeto 'A Carta do Sol', Relatório Técnico – Subsídios para o Planejamento da Promoção da Energia Solar Fotovoltaico no Brasil'. Rio de Janeiro: LIMA/PPE, COPPE/UFRJ.
- Locher, H., Hartmann, J., Khalil, A., Rydgren B. and Smith, D. (2013) 'Jirau Hydropower project – official assessment, in accordance with the Hydropower Sustainability Assessment Protocol, of the Jirau HPP (www.hydrosustainability.org/IHAHydro4Life/media/ProtocolAssessments/PDF%20Reports/Jirau-Official-Assessment-Final-Report-170513.pdf?ext=.pdf).
- Lock, R. (2005) 'The new electricity model in Brazil: An institutional framework in transition', *The Electricity Journal* 18(1): 52-61.
- Marques, P.V. (2009) 'Custos de produção agrícola e industrial de açúcar e álcool no Brasil e na safra 2007/2008'. Piracicaba: Universidade de São Paulo – ESALQ/USP.
- Maroun, C., Rathmann, R. and Schaeffer, R. (2011) 'Brazilian Bio-fuels Programmes from the WEL Nexus Perspective'. Background paper to the *European Report on Development 2011/2012* (http://erd-report.eu/erd/report_2011/documents/dev-11-001-11researchpapers_maroune-rathmann-schaeffer.pdf).
- Massarente, M., Serrano, A., Machado, L., Hara, L. and Frazão, V. (2013) 'Aluminium in Brazil: Major changes in the past 15 years', São Paulo: Bain & Company.
- McKinsey & Company (n.d.) 'Pathways to a Low-Carbon Economy for Brazil. São Paulo: McKinsey & Company.
- Melo, A.C.G., Maceira, M.E.P., Zimmerman, M.P., Wojcicki, F.R. (2012) 'Sustainable Development of Hydropower in Brazil: Technical and Institutional Aspects'. International Council on Large Electrical Systems (CIGRE), Paris: CIGRE.
- MME (2006) 'Plano Decenal de Expansão de Energia Elétrica 2006-2015'. Brasília: Ministério de Minas e Energia & Empresa de Pesquisa Energética.
- MME (2007a) 'Plano Nacional de Energia 2030'. Brasília: Ministério de Minas e Energia & Empresa de Pesquisa Energética.
- MME (2007b) 'Análise Retrospectiva, Plano Nacional de Energia 2030'. Brasília: Ministério de Minas e Energia & Empresa de Pesquisa Energética.
- MME (2008) 'Tecnologias de Energias Renováveis – Soluções Energéticas para a Amazônia'. Brasília: Ministério de Minas e Energia.
- MME (2009) 'Programa Luz para Todos – Pesquisa Quantitativa Domiciliar de Avaliação da Satisfação de Impacto – Principais Resultados'. Brasília: Ministério de Minas e Energia.
- Pereira, M.G., Vasconcelos Freitas, M.A. and da Silva, N.F. (2010) 'Rural Electrification and energy poverty: Empirical evidences from Brazil', *Renewable and Sustainable Energy Reviews* 14: 1229-1240.
- Plovnick, A. (2010) 'Renewable Energy in Rural Amazônia: a case study of its advantages and limitations in Santo Antônio', Independent Study Project (ISP) Collection, Paper 932 (http://digitalcollections.sit.edu/isp_collection/932).
- Potter, N. (2008) 'How Brazil achieved energy independence and the lessons the United States should learn from Brazil's experience'. St Louis: Washington University School of Law.
- Reuters (2013) 'Analysis: Brazil's once envied energy matrix a victim of 'hubris' 7 January (www.reuters.com/assets/print?aid=USBRE9060MS20130107).
- Rey, O. (2012) 'Um olhar para as grandes perdas de energia no sistema de transmissão elétrico brasileiro', 'O Setor

-
- Elétrico Brasileiro e A Sustentabilidade no Século 21', International Rivers.
(www.internationalrivers.org/files/attached-files/o_setor_eletrico_brasileiro_e_a_sustentabilidade_no_sec_21-opportunidades_e_desafios_-pdf_leve.pdf).
- Shikida, P.F.A. and Perosa, B.B (2012) 'Álcool Combustível no Brasil e Path Dependence', *Revista de Economia e Sociologia Rural* 50(1): 243-262.
- Soares, L.H.B. (2009) 'Mitigação das emissões de gases de efeito estufa pelo uso de etanol da cana de açúcar produzido no Brasil', *Circular Técnica* 27: EMBRAPA.
- Silva, N. F. da (2008) 'Fontes de energia renováveis complementares na expansão do setor elétrico brasileiro: o caso da energia eólica'. Doctoral thesis, COPPE/UFRJ, Rio de Janeiro.
- SE4ALL (2013) 'Sustainable Energy for All: Global Tracking Framework', Washington, DC: World Bank.
- UNICA (2009) 'Participação de carros flex nas vendas volta a bater 94%', 8 September (www.unica.com.br/noticia/5363604920331483908/participacao-de-carros-flex-nas-vendas-volta-a-bater-94-por-cento).
- UNICA (2012) 'Bioeletricidade de cana no Brasil completa 25 anos com tres Belo Monte adormecidas nos canaviais' (www.unica.com.br/noticia/14531440920334804993/bioeletricidade-de-cana-no-brasil-completa-25-anos-com-tres-belo-monte-adormecidas-nos-canaviais).
- UNICA/Apex-Brasil (2013) Information on the impact of sugarcane production on Brazil's economy (<http://sugarcane.org/the-brazilian-experience/impact-on-brazils-economy>).
- UNICA/Apex-Brasil (2014) 'Brazil: A leader in ethanol production and use' (<http://sugarcane.org/sugarcane-products/ethanol>).
- Victor, D. and Heller, T. (eds) (2007) *The political economy of power sector reform: The experiences of five major developing countries*. Cambridge: Cambridge University Press.
- Viera, D.M. (2011) 'Obstáculos à universalização do acesso ao serviço público de distribuição de energia elétrica no meio rural Brasileiro'. Brasília: TCU.
- Valor Econômico (2013) "'Não se pode construir a ferro e fogo", diz Tolmasquim'. *Valor Econômico* 14(3256) 16 May. (Also reported by the *Instituto Humanitas Unisinos*: www.ihu.unisinos.br/noticias/520194-qnao-se-pode-construir-a-ferro-e-fogo-q-diz-tolmasquim).
- WWF (2013) 'Hydroelectric power plants in the Amazon; is dialogue possible? The case of Tapajos'. Brasília: WWF Living Amazon Initiative.
- World Bank (2008) 'Environmental Licensing for Hydroelectric Projects in Brazil – a Contribution to the Debate', Summary Report (Vol. 1 of 3). Washington, DC: World Bank.
- World Bank (2010) 'Low Carbon Emissions Scenarios in Brazil – Synthesis Report', Washington, DC: World Bank.
- World Bank (2013) 'Brazil – Country Snapshot' in 'Private Infrastructure Projects' (http://ppi.worldbank.org/explore/ppi_exploreCountry.aspx?countryID=104#).
- WCD (2000) 'Dams and Development: A New Framework for Decision-Making'. Berkeley, CA: World Commission on Dams.
- Zeriffi, H. (2007) 'Making Small Work: Business Models for Electrifying the World', Working Paper 63, Program on Energy and Sustainable Development. Stanford: Stanford University.
- Zeriffi, H. (2008) 'From Acai to Access: distributed electrification in rural Brazil'. *International Journal of Energy Sector* 2(1): 90-117.

This is one of a series of Development Progress case studies. There is a summary of this research report available at developmentprogress.org.

Development Progress is a four-year research project which aims to better understand, measure and communicate progress in development. Building on an initial phase of research across 24 case studies, this second phase continues to examine progress across countries and within sectors, to provide evidence for what's worked and why over the past two decades.

This publication is based on research funded by the Bill & Melinda Gates Foundation. The findings and conclusions contained within are those of the authors and do not necessarily reflect positions or policies of the Bill & Melinda Gates Foundation.

ODI is the UK's leading independent think tank on international development and humanitarian issues. Further ODI materials are available at odi.org.uk



**Development
Progress**

Overseas Development Institute
203 Blackfriars Road
London SE1 8NJ

Tel: +44 (0)20 7922 0300

Email: developmentprogress@odi.org.uk

facebook.com/developmentprogressproject

twitter.com/dev_progress

Designed by Soapbox, www.soapbox.co.uk

Infographics by Infogr8

developmentprogress.org