SWITCH

Sustainable Water Management *in the City of the Future*

Findings from
the SWITCH Project
2006-2011

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Contents

Executive Summary

Managing Water for the City of the Future

Increasing global change pressures, escalating costs and other risks inherent to conventional urban water management are causing cities to face ever-increasing difficulties in efficiently managing scarcer and less reliable water resources. In order to meet these challenges, SWITCH (Sustainable Water Management Improves Tomorrow's Cities' Health) is attempted to facilitate a paradigm shift in urban water management. SWITCH was an action research programme funded by the European Union that was implemented and co-funded by a cross-disciplinary team of 33 partners from across the globe, including 17 from Europe and 12 from South America, Asia and Africa. The consortium represented academia, urban planning, water utilities and consulting interests. This network of researchers and practitioners worked directly with stakeholders in cities around the globe. The overall goal behind this global consortium was to catalyse change towards more sustainable urban water management in the 'City of the Future'.

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Demonstrating research and sharing knowledge across a range of different geographic, climatic and socio-cultural settings has led to global adoption and acceleration of more sustainable solutions.

Two of the key challenges that the SWITCH approach addressed were developing relevant new science and accelerating the uptake of this new science within cities.

In order to address these challenges, the SWITCH approach was guided by two main principles:

- Demand-led research – Implementation of the SWITCH approach, and its subsequent successful uptake, required the approach to be placed within a holistic framework embracing all aspects of the water system in a city; it was initiated through the learning alliance via a demand-led process.
- Sustainable, robust and flexible technologies – Central to all the new research undertaken within SWITCH was that it dealt with two key aspects of sustainability: the challenge of doing more with less (while having a small resource footprint in terms of energy and materials) and adaptability in the face of uncertain future conditions.

Key SWITCH Objectives

SWITCH set out nine key objectives that it sought to achieve.

1 Improve the scientific basis for long-term strategies for sustainable urban water management, equipped to resist negative effects of global change.

2 Achieve a switch in urban water management practices, towards sustainability in the SWITCH demonstration cities.

3 Develop an overall strategic approach to achieve sustainable urban water management in the city of the future.

4 Increase impact and visibility by dissemination to stakeholders through a learning alliance approach, wide dissemination and teaming up with other international initiatives.

5 Develop effective stormwater management options in the context of the hydrological cycle at urban and river basin level.

6 Provide effective water supply services for all at minimum impact on water resources and the environment at large.

7 Develop effective sanitation and waste management options based on the principles of 'Cleaner Production'.

8 Integrate urban water systems into the ecological and other productive functions of water at city and river basin level.

9 Develop innovative, effective and interactive institutional arrangements covering the entire urban water cycle in the urban and broader river basin setting.

SWITCH Approach

One of the major outcomes of the SWITCH project was the development of a 'SWITCH approach'. It was envisaged that the implementation of this approach would achieve a 'switch' towards sustainability in urban water management practices. The key features of the SWITCH approach included:

Learning Alliances – Limited uptake of research, fragmentation of institutions and the complexity of urban water management prompted SWITCH to develop a multi-stakeholder process to its research. An ambitious aspect of the project was the development of stakeholder platforms, called Learning Alliances, to guide and support the implementation of research and demonstration activities in the demonstration cities. These platforms were designed to take account of local problems and needs, leading to effective integration of activities at the city level and scaled-up implementation of findings within cities. The Learning Alliances were a central concept in the original plan for the SWITCH programme. They represented a practical means of bringing key stakeholders (people and organisations) into a forum where they could discuss problems that they had previously wrestled with in isolation. The Learning Alliances were the key mechanism for integration within the project, focusing on the city scale where integration was most vital and appropriate.

A key Learning Alliance activity was to monitor and evaluate the process of change as it was happening in individual cities. Process documentation enabled stakeholders to reflect on, analyse and disseminate why changes happened. Periodic review, such as independent assessments that were undertaken twice in the SWITCH cities, ensured that the desired direction continued to reflect changing circumstances. In several cases, the quest for sustainable outcomes generated the need for the learning alliances to include new knowledge areas, resulting in an adjustment of research activities, budgets and outputs.

Belo Horizonte 2008 – Scientific and Learning Alliance Meeting. Photo courtesy Carol Howe.

The main limitations to delivering on this activity were time constraints of the project with research and demonstrations needing to begin before the Learning Alliances and researchers had time to understand the complete water picture in the city including the institutional situation, competing priorities for Learning Alliances members and researchers and lack of local skills and resources. A synopsis of each city's learning alliance activities can be found in the SWITCH book entitled SWITCH in the City – Putting urban water management to the test. *http://www.irc.nl/page/66812*

City-Level Strategic Planning – SWITCH worked with the learning alliances in the SWITCH cities to implement a strategic planning process for all aspects of urban water management. The process involved visioning, scenario identification and development of strategic directions or strategies. Planning was supported by SWITCH partners through targeted research activities. Three primary models (CITY WATER Balance, CITY WATER Drain, and CITY WATER Economics) were developed to help cities explore the environmental, economic and physical implications of water management options. Strategic planning moved forward in the SWITCH cities of Accra, Alexandria, Bogota, Cali, Tel Aviv and Lodz. Sustainability indicators were discussed and selected in order to monitor the progress towards the vision. *http://www.switchurbanwater.eu/research/21.php*

Lodz vision 2038
The city's resources management is based on an efficient and integrated system ensuring access to information for all. Investors and authorities respect ecological properties of land and waters. Infrastructure serves the functions and requirements of an environmentally secure city, is reliable, meets the needs of all the city's population and assures good status of aquatic ecosystems. Green areas – river valleys along open corridors – provide space for recreation and are the 'green lungs' of Lodz. The application of ecological biotechnologies and the population's common and in-depth ecological awareness contributes to exceptional quality of life. Our city is a leading centre for innovation, education and implementation in Poland.

Some lessons from the learning alliance and strategic planning processes in SWITCH included:

- The large number of organisations involved in the urban water sector, leading to ambiguity in responsibilities, complicated by a lack of incentives for particular areas or institutions to work together;
- A lack of expertise in integrated urban water management in planning organisations (both at city and national level), which limited their ability to engage with the technical organisations and provide leadership or co-ordination;
- Difficulty in agreeing on indicators for integrated urban water management, rather than a collection of indicators for various technical areas;
- The short- to medium-term focus of water management organisations, in accordance with political and funding cycles and priorities, which made it difficult for them to plan for a 30-50 year timescale;

- The stronger expertise at some organisations in design and construction using conventional technologies, rather than in more holistic water management and planning disciplines and in unfamiliar technologies such as sustainable urban drainage, natural treatment systems and demand management;
- The difficulty in getting groups like energy providers, developers, and architects involved in the process – these issues were generally represented by planning organisations.

Transitioning Framework – The SWITCH approach had to be applicable on long timescales and deal with the very real problems of transitioning from the present conditions of often well-developed (but to varying degrees unsustainable) water systems to a future sustainable city. SWITCH designed a transition framework to help cities to move from their current situation to a more sustainable platform. The SWITCH Transition Framework offers a road map that is simple and easy to use and facilitates a knowledge leap. The Framework communicates the pathways and tools available for encouraging the uptake of innovative practices and techniques that can guide or influence a transition towards the goal of more sustainable urban water systems. It can be used for more effective planning of processes focused on stakeholder engagement, such as those attempted by the SWITCH project. *http://www.switchurbanwater.eu/research/21.php*

Action Research – One of the key objectives of SWITCH was to cover the entire urban water cycle. When developing research agendas, most cities had clear drivers for improving their water systems. Cities focused on the problematic areas of the urban water cycle in their own city whilst maximising the potential gains that could be made in other areas where possible. For example, development of soil aquifer treatment technologies for treatment of wastewater effluent in Tel Aviv also created additional water supplies reducing the need for potable water.

Water Supply

Research focused on the areas of demand management, soil aquifer treatment and capture/use of rainwater. There were a number of projects in this context, including the following:

Managing Water Demand considered how cities in industrialised and developing countries could use water demand management to meet the challenge of increasing demands. Research considered end-use and options analysis and various strategies and tools at both customer and utility level to maximise the benefits of water services while minimising water usage and water losses. Water Demand Management in the City of the Future is a book that summarises this research.

Water Security through Re-use reviewed the effectiveness of Soil Aquifer Treatment (SAT) and Engineered Environmental Buffer technologies (*http://www.switchurbanwater.eu/research/23.php*) to enable safe water reuse so that wastewaters treated could be used multiple times through return to the supply side of the infrastructure. Analysis was done of the removal of contaminants by different combinations of SAT, membrane systems and conventional pre-treatment and post-treatment systems. Guidelines for design, operation and maintenance of SAT and hybrid SAT systems were produced. *http://www.switchurbanwater.eu/research/23.php*

Water Quality improvement was explored by modelling viral lifespans and transport in aquifers. The removal of pharmaceutically active compounds and endocrine-disrupting compounds was researched for bank filtration and artificial recharge. A spreadsheet-based tool was developed for prediction or preliminary assessment of removal of these compounds. *http://www.switchurbanwater.eu/research/23.php*

Water Supply demonstrations in Beijing and Belo Horizonte showed the viability of collecting rainwater as a water supply source for horticulture. The Beijing demonstration included an economic analysis. *http://www.switchurbanwater.eu/demos/2.php*

Wastewater

Research focused on natural treatment and decentralised wastewater systems. Situational analysis was done in Lima, Beijing, Accra and Hamburg.

Source Separation using "Ecosan" systems was explored. Adoption and operational performance reports were produced on practical experiences in applying 'ecosan' source-separating sanitation systems, including a comprehensive overview of drivers and barriers for ecosan implementation, operational experience and user perception based on over 100 case studies. Performance improvements to the tannery industry with a focus on Colombia were also developed. *http://www.switchurbanwater.eu/research/25.php*

Pharmaceuticals in wastewater were extensively researched. Biological and physico-chemical removal of pharmaceutical compounds from concentrated wastewater flows, including the potential uptake by plants was completed with a number of publications, including an inventory and assessment of the biodegradability of these compounds from ecosan and natural treatment systems such as bank filtration and artificial recharge and recovery. *http://www.switchurbanwater.eu/research/25.php*

Agricultural Use of Nutrients explored strategies, guidelines, market value and transport logistics associated with the use of sewage-based nutrients. Demonstrations in Chongqing, Lima, Accra and Beijing provided experience and data and linked action research to demonstrations. Guidelines and standards for ecological sanitation and reports on the value of ecosan fertilisers and urine reuse were produced. *http://www.switchurbanwater.eu/research/25.php*

Urban agriculture contributes to a wide variety of urban issues, provides multiple benefits for urban inhabitants and can have many different functions. An assessment was conducted to determine which institutions should be involved in the working group on urban agriculture, what need there is for a particular demonstration, and what research should be undertaken. *http://www.switchurbanwater.eu/research/25.php*

Best Practice and Decision Support Systems outlined approaches for sanitation technology selection under various conditions. Institutional Change explored the arrangements between government and stakeholders with a focus on resolution of conflicts and regulatory change. A conflict resolution manual and policy guidelines for promoting water reuse systems for irrigation of urban and peri-urban areas were produced. *http://www.switchurbanwater.eu/research/25.php*

Stormwater

Research explored Sustainable Urban Drainage Systems (SUDS), addressing stormwater not just as a hazard but as a potentially valuable resource, while Water-Sensitive Urban Design (WSUD) focused on integrating rivers, lakes, banks, and their landscape systems to achieve sustainable ecosystems and to enhance a city's landscape and environment.

Stormwater Control Technologies were reviewed in terms of risks and the adaptability of stormwater best management practices (BMPs) to a range of environmental and socio-economic conditions. The research supported SWITCH learning alliances in identifying city-specific threats and impacts on stormwater control strategies over both short-term and longer-term timescales. Major outputs included a review of the adaptability and sensitivity of stormwater technologies and a database showing threats and uncertainties in stormwater management.

Design and Urban Integration of Stormwater BMPs (*http://www.switchurbanwater.eu/research/24.php*) reviewed the guidelines for stormwater best management practices, assessed their potential for integration with existing infrastructure and evaluated the performance of brown roofs and ecohydrology approaches in selected SWITCH cities. Outputs included a design manual incorporating best practice guidelines for stormwater management options and treatment under extreme conditions. *http://www.switchurbanwater.eu/research/24.php*

Decision Support Tools for Modelling of Stormwater Best Management Practices looked at this topic from a range of perspectives. Models for best management, site selection, water quality and quantity were provided by SUDSloc, which takes a GIS-based approach to management selection. Analysis of life-cycle costs was explored by LCCCA and a relative risk-modelling approach to managing uncertainty was provided by COFAS. *http://www.switchurbanwater.eu/res_software.php#24*

Institutional Analysis documents the current institutional arrangements for stormwater management in selected SWITCH cities and sets out guidelines for the development of institutional maps of stormwater management. *http://www.switchurbanwater.eu/research/24.php*

Stormwater as a Resource in Integrated Urban Water Management provides a deeper analysis of decision-making processes involved in managing urban stormwater, with a particular focus on the identification of opportunities for reusing stormwater and its potential to contribute to meeting the needs of other sectors of the urban water cycle. *http://www.switchurbanwater.eu/research/24.php*

Stormwater Best Management Practice Principles facilitates the integration of stormwater within a sustainable urban water management approach and its inclusion as a resource within the wider urban landscape, providing inspiration for a creative, artful and healthy handling of stormwater within urban areas. The book Water Sensitive Urban Design: Principles and Inspiration is one of the outputs of this research. *http://www.switchurbanwater.eu/research/24.php*

Demonstrations – Early action demonstrations representing different aspects of the water cycle were designed and implemented for up-scaling at both the local and global level. The demos were successful to varying degrees. In Lima, activities resulted in national guidelines for reuse being prepared. In Lodz, the eco-hydrology demonstration resulted in a change to city planning around the concept of a blue-green spatial network for the city. In order for demonstrations to be demand-led, local stakeholders needed time to collaborate and decide on priorities. Demonstrations were often dependent on timescales that were not controllable by the utility or research community. In Hamburg, the demonstration was a part of the International Building Exhibition which experienced delays, while construction delays in Chongqing resulted in monitoring not being possible within the SWITCH timescale. Arranging co-funding for demonstrations also proved to be difficult and time-consuming. Details on the demonstrations in SWITCH cities can be found in the "Summary of city-level processes and outcomes" section of this report and at *http://www.switchurbanwater.eu/demos/index.php*

Training toolkit – SWITCH developed a training toolkit to maximise the utility and impact of the SWITCH approach. The toolkit includes 6 modules to help practitioners including city staff and utilities to work through a strategic planning process and to increase their knowledge and capacity in different aspects of urban water management.

Module 1: Strategic Planning – Preparing for the future
Module 2: Stakeholders – Involving all the players
Module 3: Water Supply – Exploring the options
Module 4: Stormwater – Exploring the options
Module 5: Wastewater – Exploring the options
Module 6: Decision-Support Tools – Choosing a sustainable path
All available on: http://www.switchtraining.eu/

A module on Climate Adaptation was also produced to help link this current topical issue to the wider strategic planning process. *http://www.switchtraining.eu/switch-resources/*

The toolkit (available in English, Spanish and Portuguese) was launched at World Water Day 2010 in Capetown, South Africa and has been incorporated into ICLEI and UNESCO-IHE training courses.
It is available electronically at www.switchtraining.eu.

Global Learning Alliance – SWITCH 3rd Scientific Meeting, Belo Horizonte 2008. Photo courtesy Carol Howe.

Summary of city-level processes and outcomes

The SWITCH project was a short-term, global experiment in socio-technical transition. It has attempted to guide and even accelerate the co-evolutionary and participatory processes required to move the cities towards transitioning their urban water planning and operational practices in a timescale that is very short in transitioning terms. There are very positive results from the cities, which have embraced the learning alliance approach: this stands as testimony that the potential to influence a change towards more sustainable outcomes through transitioning principles is possible and that the learning alliance is a successful vehicle for facilitating an urban water paradigm shift.

In **Accra**, SWITCH played an important role in bringing together information and people across the different municipalities in the city. As well as municipalities, the project engaged different national government departments, research institutes, public utilities, and representatives from peri-urban and slum communities, and worked hard to promote urban water and sanitation issues and solutions with the media. Outcomes that have had a significant impact included a presidential debate in 2008 that was organised for the candidates to present their visions on water and sanitation, and a strategic planning process that led to findings being utilised in other major and more 'official' planning processes, such as the development of a new project supported by the World Bank, as well as the Metropolitan Assemblies' development plan.

In **Alexandria**, activities focused on developing an integrated urban water management plan and demonstrating how urban slum communities could be served with the existing water supply and be given capacity to manage their sanitation system. Key actors included the city government, water and sanitation utilities, an urban slum community and a research institute. Although finalisation of the plan was delayed and it was therefore not possible to identify its short-term outcomes, the project actively engaged the main city water institutions in the plan's development. The demonstration project pushed the boundaries in showing that the water utility can engage with and supply the most marginalised informal communities in the city.

In **Beijing**, the project focused on means for peri-urban farmers to cope with the pressures put on them by the city in response to increasing water shortages. The learning alliance meetings brought together research institutes, government officials and farming cooperatives. A demonstration project showed how innovative rainwater harvesting from greenhouses can provide a useful source of water for urban farmers and support a shift to higher-value crops. The rainwater collection innovation is being patented and deployed widely throughout China.

In **Belo Horizonte**, SWITCH focused on the development and uptake of more natural and environmentally sympathetic approaches to urban drainage to minimise flooding risks while also improving river corridor habitats. A partnership between the municipality and the university was at the heart of the project. Learning alliances at the local level engaged schools and communities in several demonstration projects, as well as institutions such as other municipal departments, the utility and metropolitan and river basin committees at the city scale and beyond. Outcomes included commitment by the Municipal Parks Foundation to scale up rainwater harvesting and a start by participatory budgeting committees on implementation of alternative and more sustainable solutions.

In **Birmingham**, activities concentrated on future risks, such as climate change, but also the implications of rising groundwater levels as industrial consumption falls. Some of the partners in the learning alliance included the city council, the water company, the Environment Agency, the regulatory authority, consumer bodies and a professional association. Some specific outcomes of engagement with development agencies were influencing the plans for redevelopment of a major site within the city through the extensive use of green and brown roofs.

In **Bogota**, pollution from small- scale, unofficial tanners on the Rio Bogota resulted in a focus on cleaner production. Key players engaged throughout the project were a tanners' association, the environmental regulator, local government, an NGO, a university and the Chamber of Commerce. The project had a number of positive outcomes. Unofficial small enterprises, which produce almost half of the pollution, have now implemented cleaner production principles, removing 90% of their contribution to pollution through improved treatment processes and recycling. These improvements also led to additional productivity gains for these enterprises. The project demonstrated the feasibility of alternatives to a solely punitive and legalistic approach based on fining polluters (which was failing with the informal sector), offering such options as conflict resolution, capacity building, and dialogue; the regulator is now pursuing and supporting such approaches. The research supported local action, and now the approach is being expanded across a wider catchment area as part of a follow-up project.

In **Cali**, the project focused on research, creating dialogue and promoting more sustainable alternatives (although there were no demonstration activities) in relation to pollution of the Cauca River, urban drainage and city expansion. Creating a shared vision proved essential to counter-balance prevailing short-term planning and construction in most of the institutions. Outcomes beyond the research reports and training were a reduction in the emphasis on end-of-pipe solutions in wastewater management and growing consideration of alternative technologies in new housing developments. Even more importantly, planning processes at the level of municipal and national policy consultations on the future of the Cauca River are building on the foundation laid by dialogue amongst SWITCH members, utilising SWITCH outputs and advice.

In **Hamburg**, SWITCH worked on improving planning, with the river island of Wilhelmsburg as the focus area. Learning alliance activities brought together a broad range of stakeholders from the island in the development of a water management plan that raised the level of discussion on the islands future development. Unfortunately, because of delays in activities outside the scope of SWITCH, it proved impossible to realise the intended demonstration activities.

In **Lima**, the focus selected was scaling up the reuse of wastewater in green productive areas in an extremely water-scarce environment (only 13 mm of rainfall per year). Key players included national ministries, the national water authority, local governments, and an NGO. The project developed learning alliances both at the national level, focusing on policy issues, and at the local level, linked to a demonstration project and related research. The main outcomes were a successful demonstration project showing how water could be safely reused for multiple purposes, and the development and official approval by the government of new national policy guidelines that promote safe re-use of wastewater in Peru.

In **Lodz**, the focus was on restoring rivers that have become polluted, degraded and even buried as the city developed. Key actors were the local government, utilities, the university and a specialist research institute. A successful demonstration project has partially revitalised one river corridor, providing a more attractive environment for residents and future development. Through the learning alliance, activities are firmly embedded in the city institutions that will be responsible for continuing and scaling up river restoration across the city. The idea of linking restored river corridors and other open green spaces in a 'blue-green network' is now recognised as part of the city's planning strategy.

In **Tel Aviv**, research focused on reducing the area required by soil aquifer treatment technologies to treat wastewater for reuse purposes. At the city level, an important outcome achieved through engagement with the city planning authorities was the inclusion of water indicators in the strategic plan for the city, an aspect that had been previously overlooked.

In **Zaragoza**, the project focused on demonstrating zoning as a means to manage water demands in a city that takes pride in minimising its water consumption. Zoning has now been scaled up or is under study across almost half the urban area, and is included in draft municipal by-laws. The project used existing stakeholder platforms to communicate these activities, especially the Municipal Water Commission. The Expo Zaragoza in 2008 focused on sustainable water management and was an important venue for showcasing the activities of SWITCH.

Detailed descriptions of the activities and outcomes in the SWITCH cities can be found in the publication "SWITCH in the CIty - putting urban water management to the test" *http://www.irc.nl/page/66812*

Measures of Success – A key outcome for the SWITCH project was to move a city towards an IUWM paradigm using the model of stakeholder engagement that actively encouraged experimenting with new innovations and methodologies. Movement towards the new paradigm would happen more quickly if learning alliances made progress towards delivery of the key SWITCH objectives. The SWITCH approach of 'learning by doing and doing by learning' is an approach in which investigation and learning take place at the same time. The support of knowledge flows between key stakeholders and between the stages of a process are key factors to facilitating the uptake of sustainable practices. Table 1 below provides a synopsis of the degree of success that was achieved by applying the SWITCH approach in the cities to meet the nine project objectives.

table 1 **SWITCH Approach and meeting objectives**

City	Scientific Base	SWITCH to IUWM	Strategic Approach	Stormwater	Water Supply	Sanitation/ Waste Management	Urban Water Services	Institutional Arrangements	Exposure/ Dissemination
Accra	Meeting	Meeting	Met	Meeting	Meeting	Meeting	Meeting	Meeting	Met
Alexandria	Meeting	Meeting	Met		Met		Meeting	Meeting	Meeting
Beijing	Met	Meeting	Meeting	Met	Met	Met	Meeting	Met	Meeting
Belo Horizonte	Met	Met	Meeting	Met	Meeting	Meeting	Met	Met	Met
Birmingham	Met	Meeting	Meeting	Met	Meeting	Meeting	Meeting	Meeting	Met
Bogota	Met	Meeting			Meeting	Met	Meeting	Met	Met
Cali	Meeting	Meeting	Met	Meeting	Met	Met	Meeting	Meeting	Meeting
Hamburg	Meeting	Meeting	Meeting	Meeting			Meeting	Meeting	Meeting
Lima	Met	Meeting	Meeting	Met	Met	Met	Met	Met	Met
Lodz	Met	Meeting	Met	Met	Meeting	Met	Meeting	Met	Met
Tel Aviv	Met	Meeting	Met	Met	Met	Met	Meeting	Met	Met
Zaragoza	Met	Meeting	Meeting	Meeting	Met	Meeting	Meeting	Met	Met

Met the objective (blue) · Meeting the objective (yellow) · Objective not achieved (red) · Not a city objective and not met indirectly through other objectives (blank)

Table 1 provides a synopsis of the degree of success that was achieved by applying the SWITCH Approach in the cities to meet the nine project objectives.

- **Blue box** – Fully meeting the objective by demonstrating that an actual change had taken place. For example: strategic plans were actually being implemented at the city / river basin level).
- **Yellow box** – Meeting the objective indicates that a tangible impact was made. For example: several features of a strategic plan or agenda were implemented, or official approval of strategies developed during the SWITCH strategic planning process was pending. Although one of the key objectives of SWITCH was to cover the entire urban water cycle, when developing research agendas, most cities had clear drivers for improving their water systems. Cities focused on the problematic areas of the UWC in their own city whilst maximising the potential gains that could be made in other areas where possible. If a city was achieving objectives that resulted in secondary or indirect gains then this was also considered as meeting an objective. For example: Water demand management approaches such as stormwater reuse in Zaragoza results in decreased potable water use whilst also delivering stormwater drainage gains with the potential for an overall reduction in pollutant load to watercourses or sewers which also creates gains in combined sewer network in the form of reduced stormwater volumes.
- **Blank box** – Signifies that this particular objective was not a key city objective and the objective was not being achieved indirectly through successful implementation of another objective.
- **Red box** – The objective was not met. This was not a common outcome, but would have occured when communication links were broken and relationships that had been developed between the key players at all levels were suspended which effectively brought the strategic planning processes to an end.

SWITCH Known World-Wide – SWITCH has become widely known and well-respected as a major R&D project in relation to integrated urban water management. This is reflected by the high-profile position the project has been given at major scientific events (e.g. World Water Forum, IWA Development Congress, Singapore Water Week, Stockholm Water Week, ICLEI World Congress). SWITCH is a central part of several international initiatives in relation to urban water, including IWA Cities of the Future and the UNESCO 7th Urban Water Programme, which together with SWITCH established the International Research School for Urban Water Management in collaboration with the International Hydrological Programme (IHP). The IRS-UWM presents a platform for academic cooperation and information generation and exchange where researchers from both developed and developing countries can interact with each other and identify areas of commonalities and complementarities.

Five major SWITCH Scientific Meetings were held during the project period in Birmingham, Tel Aviv, Belo Horizonte, Delft and Lodz; all proceedings can be found on the SWITCH website. Following the 4th Scientific Meeting in October 2009, SWITCH organised a Global CityWater Futures Summit in Delft, with over 100 research and practitioners participating from 25 cities. SWITCH partners and other participants from a range of cities around the world discussed the presentations and thematic papers in a series of interactive workshops, and the proceedings were enlivened by journalists from India, Ghana and Yemen, who contributed to the discussion in the sessions and through the Summit blog.

Foreword

As the Scientific Director of SWITCH, it gives me great pleasure to present some of the major achievements of the project.

With increasing global change pressures like urbanisation, climate change, deterioration of urban infrastructure systems and more, cities all over the world experience difficulties in efficiently managing scarcer and less reliable water resources. Amidst these challenges, SWITCH has generated new thinking that has improved approaches, practices and technologies in urban water management of existing cities while also enabling them to adapt to global change and to transition to a future and more sustainable state. The SWITCH global consortium has catalysed change towards more sustainable urban water management in the 'City of the Future' by demonstrating its research and sharing knowledge across a range of different geographical, climatic and socio-cultural settings, promoting the global adoption and acceleration of more sustainable solutions.

The main goal of SWITCH was finding new solutions to increase the efficiency of urban water systems by rethinking old paradigms and developing new solutions. To achieve this goal, SWITCH improved the scientific basis and shared knowledge to ensure that future water systems are robust, flexible and adaptable to a range of global change pressures. A major outcome of the SWITCH project is the development of the 'SWITCH approach', which is envisaged to cause a transformation in urban water management practices, switching cities towards sustainability.

The key features of the SWITCH approach are:

- Establishment of platforms for city learning alliances – These multi-stakeholder learning alliances guided and supported SWITCH in the development and implementation of research and demonstration activities, by taking local problems and needs into account.
- Implementation of a strategic planning process – This encourages and enables all stakeholders in the city to view the urban water cycle in an integrated way and allows the development of new strategic directions for urban water management.
- Establishment of early-action demonstrations – Such demonstrations represent different aspects of the water cycle that are designed for up-scaling at both the local and global level.
- Development of a training toolkit – with the city learning alliances to maximize the utility and impact of the SWITCH approach.

By adopting a demand-led approach, SWITCH has been able to speed up the process of identification, development and uptake of solutions related to urban water management. Based on the 'SWITCH approach', new solutions have been developed in this field which are based on key concepts of urban water management, including: resilience of urban water systems to global change pressures; interventions over the entire urban water cycle; governance and financial management structures, covering the entire urban water cycle; reconsideration of the way water is used (and reused); and greater application of natural systems for water and wastewater treatment.

The challenge of servicing more people with scarcer water resources requires us to take a critical look at water use practices and to develop strategies that maximise the benefits of water services. SWITCH developed innovations that promote increased recycling of wastewater and ensure that water can be used many times, by cascading it from higher to lower-quality uses. Local water reuse approaches that permitted safe and productive re-use within domestic, industrial and (urban) agriculture systems have the potential both to increase the available water and to reduce the operational costs for treatment. Energy-efficient treatment has also been developed around natural systems that are capable of removing multiple contaminants in a single system. Innovations in this area include constructed wetlands, soil aquifer treatment and river/lake bank filtration. In addition, SWITCH has investigated the potential of small-scale, decentralised storm water measures such as green roofs, swales, rainwater harvesting, etc. These decentralised options provide internal degrees of freedom, allowing many different combinations of stormwater options to be considered so that they can be optimised over time.

SWITCH recognised the high-level relationships among water resources, energy and land use in an urbanising world. Besides improving the performance and efficiency of the component parts of the water system, solutions were also produced at a system-wide level. SWITCH developed an integrated modelling approach – CITYWATER – that enables analysis of the entire water cycle and allows us to simulate the impacts of future global change pressures on the performance of urban water systems. Optimal design configurations are then developed based on measurement against sustainability performance indicators. The result is that water and its interactions with other sectors can be the central focus in the development and redevelopment of urban areas.

SWITCH developed solutions that addressed how to design and manage systems in an uncertain world, since most external pressures involve hugely uncertain factors, such as urbanization and climate change. One of the proposed approaches is flexibility of systems through a framework that is used to generate urban water systems which are adaptable to new, different, or changing requirements. In addition, SWITCH has developed a framework for transitioning systems from their current unsustainable state to a more sustainable one, including the transition of institutions and governance frameworks which are better suited to manage our resources in more intelligent and sustainable ways.

SWITCH has redefined sustainable urban water management in the city of the future and is now sought by many other cities across the globe. SWITCH Asia and SWITCH LAC (Latin America and Caribbean) were recently launched to build on the outcomes of this project and to take it further. In addition, SWITCH thinking has been embedded into other major urban water programmes, including the International Water Associations' Cities of the Future program and the Urban Water Programme at UNESCO-IHP.

There is a need to recognise that global change pressures will affect our ability to manage urban water in the city of the future. At the same time, we need to find new ways of catering to more people, with more needs, while using the same quantity of water. All this has to be achieved while reducing our ecological footprints. Innovation can make existing technology more efficient and durable. By defining new design objectives, the same technologies can be combined to achieve new system solutions. When these solutions are integrated with behavioural, institutional, legal, regulatory, professional and academic innovations, sustainability becomes a feasible possibility. We hope that SWITCH has contributed in a small but significant way to the future of urban water management.

Kalanithy Vairavamoorthy
Scientific Director of SWITCH

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The SWITCH family included many, many individuals who gave their time, expertise and personalities to this project. They were all instrumental in bringing the pieces of the puzzle together.

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1.

Introduction

The idea of SWITCH began in 2004 when a consortium that included the International Water and Sanitation Centre (IRC) responded to a call from the European Union for integrated, decentralised and alternative solutions in urban water management. One of the core concepts was 'learning alliances's to promote the application of research to solve urban water problems.

The project development phase was an intense period that culminated in 32 partners from 15 countries in Europe, Asia, Africa and South America joining the project team. Partners were chosen for their expertise in various aspects of urban water management, covering the spectrum of water, sanitation and drainage, but were also selected to ensure representation of a cross-section of disciplinary areas including environmental science, engineering, hydrology, social science and economics.

From this partner base, cities were chosen that the project would focus on. The emphasis was on having a cross-section of cities that represented the climatic, institutional and economic situations displayed in other cities around the world and the various regions in Europe. Partners worked together to develop a five-year research, demonstration and training plan that would be a catalyst for change towards more sustainable water management in the City of the Future.

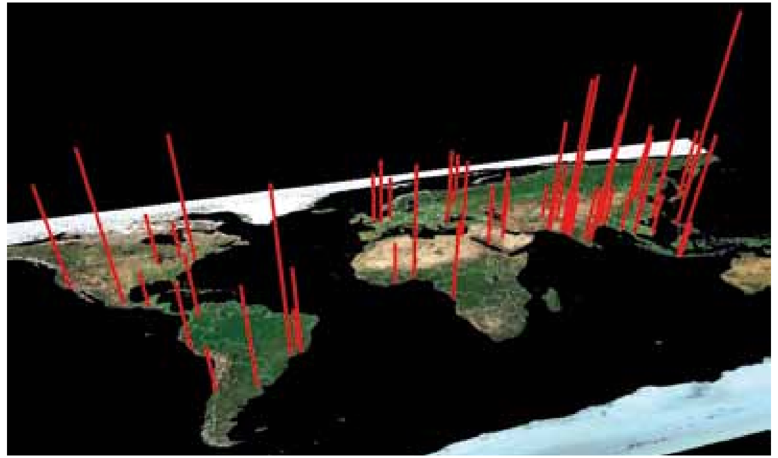
In 2005, an expanded Consortium, now led by UNESCO-IHE Institute for Water Education, submitted a final proposal. In 2006, the Consortium was awarded a five-year contract from the EU to pursue this goal. The project had its first kick-off meeting in Delft in April 2006. This report provides an overview of what SWITCH has achieved during this time.

Launch of SWITCH by Prof. Huub Gijzen at World Water Forum in Mexico City, 2006.

Rise of cities as an issue

During the period of the SWITCH project, from 2006 to 2011, the total urban population of the world grew to exceed the total rural population for the first time. The urban population is predicted to continue growing to about 60% of the total global population by 2030, with the increases taking place primarily in the cities of developing countries (UN-HABITAT 2009) where growth is occurring in an unplanned way, in informal settlements and slums.

figure 1 **2015 – World cities exceeding 5M residents**



Data source: UN Population Division

The increasing population of cities puts major demands on urban services, including the supply of water and the management of wastewater and stormwater. Population growth and urbanisation are leading to increased demand for water and wastewater services, increased pollution, changes in land use and many other pressures in cities around the world. Some of the challenges include:

- Climate change – increased intensity of rainfall, rising temperatures and sea level, increased floods and droughts, changing seasonality
- Population growth and urbanisation – migration from rural to urban, loss of greenspace and peri-urban agriculture
- Governance and policies – new institutional frameworks, political regimes, global policies
- Deterioration of infrastructure systems – pipe breakage with water losses and wastewater leakage, rising operational costs
- Changes in public priorities – basic economics versus environment protection
- Emerging technologies – membranes, natural systems, Information Technology (IT), modular small-scale units
- Energy costs – rising costs, intermittent supplies, Green House Gas (GHG) targets
- Increasing complexity – dependencies on IT systems, interlinkages between the water, energy and transport sectors

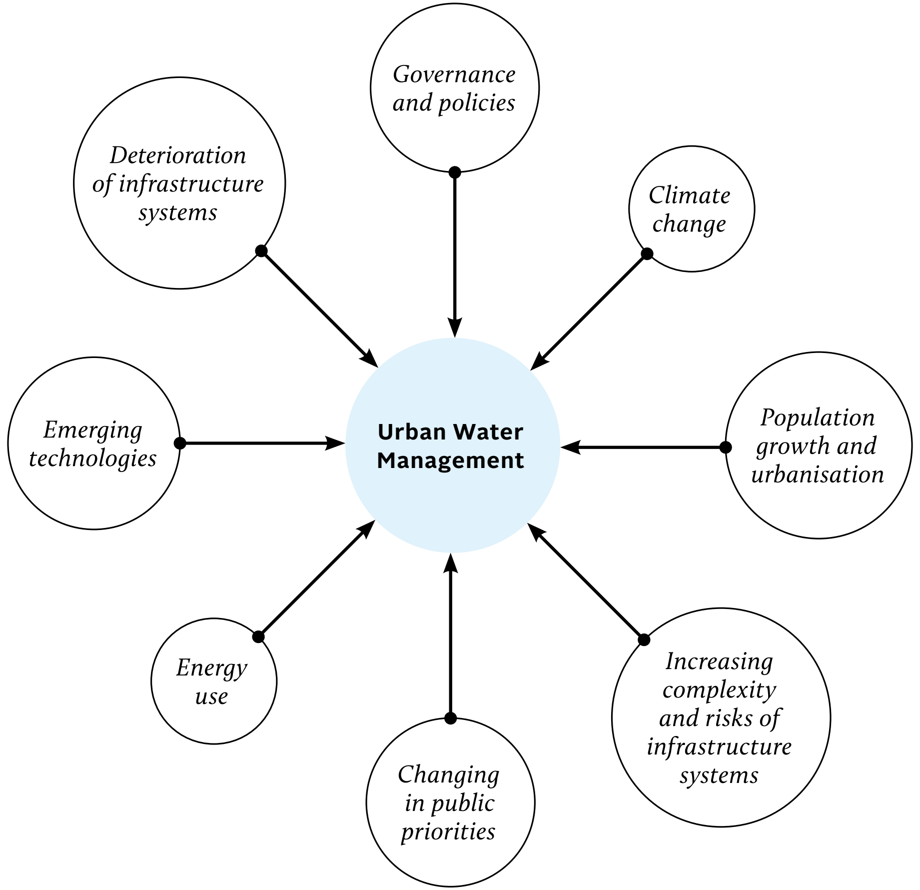


figure 2 **Issues and Future Challenges in Urban Water Management**

Water sector institutions need to prepare themselves to cope with the changes that are on-going, but also with future changes that are not known yet, or the extent of which is not yet known; they need to be more resilient. This uncertainty needs to be included in planning and decision-making processes. Uncertainty also requires strategic thinking, translated into strategic and flexible planning, rather than conventional blue-print planning.

(Van der Steen et al. 2011)

Scope of the project

SWITCH was an EU-funded action research project that was implemented and co-funded by a cross-disciplinary team of 33 partners from across the globe, including 19 from the EU and 12 from developing countries. The consortium represented the fields of academic research, urban planning, water utilities and consultancy. This network of researchers and practitioners worked directly with stakeholders in 13 diverse cities around the globe, including Accra, Alexandria, Beijing, Belo Horizonte, Birmingham, Bogotá, Chongqing, Cali, Hamburg, Lima, Lodz, Tel Aviv and Zaragoza.

SWITCH aimed to develop, apply and demonstrate a range of tested scientific, technological and socio-economic solutions and approaches that would contribute to achieving more sustainable water management in the "City of the Future", The activities were designed to take place at the city level but in the context of the river basin, with due recognition of global change factors.

The EU Water Framework Directive provided a basic reference point, with its emphasis on interdisciplinary approaches, stakeholder participation and integrated planning for water resource management and environmental protection within the river basin. SWITCH has applied this integrated approach to cities to as a sub-set of river basins.

SWITCH was also framed in the context of the EU Water Initiative and its support for the internationally agreed Millennium Development Goals, particularly MDG 7 which aims to ensure environmental sustainability, in accordance with the following associated targets:

Target 7a: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources

Target 7b: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss

Target 7c: Reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation, in the period 1990-2015

Target 7d: Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020

The SWITCH approach

The SWITCH approach to integrated urban water management (IUWM) covers:

- Cities in four continents and at various stages of development;
- All aspects of the water cycle – water, wastewater, stormwater and natural systems;
- A wide range of climatic, socio-economic and institutional situations;
- Social, economic and environmental perspectives;
- Scales ranging from household to city levels;
- Water as part of urban planning and the built environment;
- From the present time to the 'City of the Future'.

The SWITCH project adopted a 'grey to green' approach, recognising that green infrastructure, like parks and clean rivers, is not only "nice to have", but also provides "the environmental foundation that underpins the function, health and character of urban communities" (CABE, 2009). SWITCH's research on stormwater, for example, studied how sustainable urban drainage systems could be used to provide both effective drainage and green environments, compared to conventional 'grey' pipe systems.

Sustainability is key to SWITCH thinking, with its emphasis on interdisciplinary research, bringing together social, economic and environmental aspects from a long-term perspective. SWITCH also promotes a systems approach to urban water management, considering interactions between different elements of the urban water system (water supply, wastewater, stormwater, natural systems) and both structural and human dimensions.

Two of the key challenges that the SWITCH approach addressed were the development of relevant new science and the uptake of this new science within cities. In order to address these challenges, the SWITCH approach was guided by two principles:

Demand-led research: Implementation of the SWITCH approach and its subsequent successful uptake require that the approach be placed within a holistic framework embracing all aspects of the water systems in a city and initiated through the learning alliances via a demand-led process.

Sustainable, robust and flexible technologies: A central focus of all the new research undertaken within SWITCH was that it dealt with two key aspects of sustainability: the challenge of doing more with less (while having a small resource footprint in terms of energy and materials) and adaptability in the face of uncertain future conditions.

Within each city, this approach was taken forward by establishing a learning alliance, bringing together a range of key stakeholders in the water sector. The next step was to develop a vision for the city that extended 30 to 50 years into the future, studying appropriate strategies to achieve this vision under various scenarios, and then formulating a long-term strategic plan. Concurrent with development of the strategic plans, short-term demonstrations of innovations took place. Finally, a phase of monitoring and learning began, in which the findings were disseminated within the city and beyond. This approach will be explained in more detail in the following chapters.

Key SWITCH Objectives
SWITCH set out to achieve a number of key objectives. This report will explore how successful SWITCH was in meeting those objectives.

1 Improve the scientific basis for long-term strategies for sustainable urban water management, equipped to resist negative effects of global change.

2 Achieve a switch in urban water management practices, towards sustainability in the SWITCH demonstration cities.

3 Develop an overall strategic approach to achieve sustainable urban water management in the city of the future.

4 Increase impact and visibility by dissemination to stakeholders through a learning alliance approach, wide dissemination and teaming up with other international initiatives.

5 Develop effective stormwater management options in the context of the hydrological cycle at urban and river basin level.

6 Provide effective water supply services for all at minimum impact on water resources and the environment at large.

7 Develop effective sanitation and waste management options based on the principles of 'Cleaner Production'.

8 Integrate urban water systems into the ecological and other productive functions of water at city and river basin level.

9 Develop innovative, effective and interactive institutional arrangements covering the entire urban water cycle in the urban and broader river basin setting.

Structure of the research

To confront the challenges facing SWITCH the SWITCH project was designed around six key theme areas.

Urban Water Problem/Challenge	SWITCH Theme Area
Ineffective 19th century "once-through" concepts of the urban water cycle	Urban water paradigm shift
Water quantity issues – floods and droughts	Stormwater – water-sensitive urban design and sustainable drainage
Urbanisation and inequality	Water – efficent supply and water use for all
Low wastewater and sanitation coverage accompanied by ecological and health issues	Wastewater – access, treatment and recycling, including decentralisation
Degraded natural water systems	Natural systems for improvement in ecological quality and urban amenities
Poor governance, fragmented institutions and conservative financial systems	Governance and institutional change

To ensure that the themes integrated their activities most research activities were focussed on issues that SWITCH cities were facing. Themes worked together to look at the connections between areas and develop solutions that were optimal for all aspects of the water cycle and sustainability

Upper Cauca River, Cali, Colombia. Photo courtesy Carol Howe.

Moving forward - a transitioning framework

Towards the end of the SWITCH project, the SWITCH transitioning framework was developed, following empirical investigations into the change processes that were taking place in the cities. The framework provides a re-conceptualisation of ways to promote change in urban water management, drawing upon the project's Learning Alliance model of stakeholder engagement, practical experiences in cities and new scientific thinking in the field of transition knowledge. The primary contribution from that field was the concept of the transition management cycle and associated activity clusters: arena, agenda, experiment and evaluation.

The transition management cycle consists of several steps that are aimed at influencing, organising and coordinating processes at different levels of governance or management: strategic, tactical and operational (Loorbach, 2007). At the strategic level, visioning processes are developed, strategic discussions take place, long-term goals are formulated, collective goal-setting and cultural norm-setting are debated, and long-term anticipation of innovative outcomes takes place. Societal sub-systems (the different elements of the entire urban water system) are the focus at the tactical level, which is where we see implementation of short-term strategic goals based on a vision, capacity building activities, and development of the transition agenda (or strategic plans). Short-term actions, experiments and innovation projects take place at the operational level. Different types of actors participate at each management level. A diverse set of competencies and skills required across all levels.

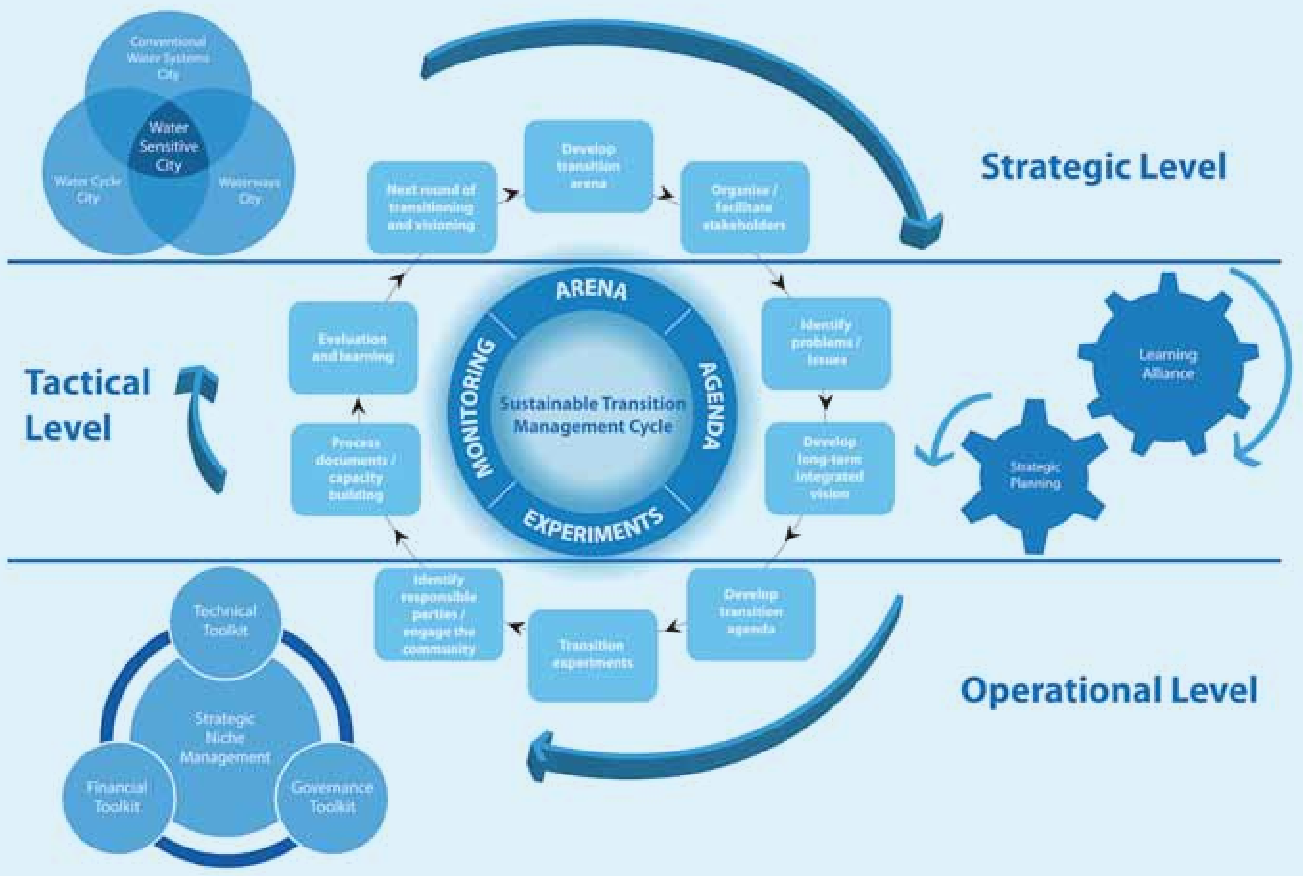
The learning alliances were encouraged to apply a systemic approach that took the entire water system into account (natural systems, water supply, sanitation and stormwater); sustainable and integrated design and operation of all water networks was the ultimate goal or vision. It became very clear that the learning alliances were the motor driving a transition management process in which the learning alliances represent the arena, strategic planning processes represent the activities that develop an agenda, and the science and demonstrations represent the experiments.

table 2 **The SWITCH Approach as Phases in a Transition Management Cycle**

Transition Clusters[1]	SWITCH Approach
Establish the transition arena	Establish a learning alliance
Develop a transition agenda	Develop a strategic plan
Execute transition experiments	Execute research and demonstration projects
Evaluate, monitor and learn	Monitor, evaluate and learn

1. Loorbach and Rotmans, 2006

figure 3 **Transition Framework**



Structure of this Report

The information in this report is directed primarily at water managers, urban planners and engineers from local governments and water, wastewater and drainage utilities, as well as researchers in the field of urban water management.

This report is structured in the same manner that one would undertake implementation of the SWITCH approach in a city.

Forming Alliances (Chapter 2) discusses how to engage with stakeholders and form a Learning Alliance. It also addresses ways to improve communications amongst water sector institutions and increase the transparency of decision-making processes and presents lessons learned from the SWITCH cities. Institutional and governance arrangements are explored.

Planning for the Future (Chapter 3) looks at methods and tools for strategic planning, including visioning, scenario planning, use of sustainability indicators, decisionsupport tools and transitioning.

Exploring the Options (Chapter 4) goes in-depth into the various options and new technologies that might be used for water, wastewater and stormwater management in a city. Demonstrations are explained and research results are presented.

Monitoring and Learning (Chapter 5) reviews the changes that occurred as a result of SWITCH and the monitoring and learning process that supported this analysis.

And finally, **Measures of Success** (Chapter 6) explores how successful SWITCH was in meeting its objectives and facilitating transitions towards more sustainable water management in cities.

The report is linked to the transition phases through colour coding of the sections around the transition cluster concepts noted in Table 2.

*More detailed information on the research can be found on the SWITCH website at **www.switchurbanwater.eu***

Freeze coring on the River Tame, Birmingham. Courtesy © M. Cuthbert.

2.

Forming Alliances

Establish the Transition Arena

Background

At the outset of the project, poor uptake of available research findings was identified as a major constraint to achieving significant impact in cities through a research-focused initiative. Different perspectives included researchers who were frustrated by the limited uptake of their work, with good ideas too often remaining on the shelf, and potential research users who were not satisfied with the way that innovations were sold to them by researchers. This was reflected at an early meeting with the Governor in Alexandria whose experience had mainly been that academics provided information in forms that were not structured for practical application: "We need solutions, but we don't want research." In the cities, SWITCH tried to bridge this gap between research providers and research users in the field of urban water management.

The challenges this entailed were reflected in the project design. The structure of SWITCH recognised the fragmentation of institutional arrangements for the rather broad subject of water. In most cities, water-related issues (including sanitation and many aspects of development and environmental management) are often handled by perhaps 15-20 organisations dealing with different aspects. It is normal to find relatively weak links and limited functional cooperation amongst these organisations.

Urban water management was also viewed as a complex or 'wicked' problem (the WITCH in SWITCH) requiring integrated solutions. It was recognised that the problems are often so complex that they cannot be solved by individual stakeholders acting alone, that working on only a part of the jigsaw may be pointless or even harmful, as solutions in one area may only create problems elsewhere. Moreover, such problems are difficult to solve relying exclusively on technological approaches, as socio-intensive approaches are also required.

These three issues (limited uptake, fragmentation and complexity) prompted SWITCH to develop a multi-stakeholder process approach in its research. An ambitious aspect of the project was to develop stakeholder platforms, called Learning Alliances, "to guide and support the implementation of research and demonstration activities in the demonstration cities, taking into account local problems and needs, and leading to effective integration of activities at the city level and scaled-up implementation of findings within these cities".

The Learning Alliances were a central idea in the original plan for the SWITCH programme. They represented a practical means of bringing key stakeholders (people and organisations) into the same forum to discuss problems that they had previously wrestled with in isolation. The development of these learning alliances has been a tortuous journey, with setbacks and successes. Over time, work on stakeholder engagement was allocated significant resources, both human and financial, within the consortium, picking up considerable momentum and developing a growing suite of activities. The Learning Alliances were the key mechanism for integration within the project, focusing on the city scale where integration of SWITCH activities was most vital and appropriate.

SWITCH approach: learning alliances

The stakeholder engagement model envisioned by SWITCH was the development of Learning Alliances, nested and linked platforms at various levels: neighbourhood, city, national (for policy influencing) and global (for learning across cities). In practice, the focus of most cities was at the city scale, with neighbourhood and national platforms only being developed in a couple of cases (Belo Horizonte at the local level, and Lima at the national level). Although all these platforms were project-driven and externally guided, it was always the intention to build on and link to existing platforms when present. In Zaragoza, where multi-stakeholder platforms already existed at different levels (including the city and the autonomous region) no new alliances were developed.

The Global Learning Alliance was progressed through project initiatives including the Annual Scientific Meetings which were held annually in the different SWITCH cities and the Global CityWater Summit held in Delft in 2010 where 25 cities (both SWITCH and other cities) were brought together to share learnings and experiences. SWITCH learnings were also disseminated through ICLEI, UN Decade of Water, Habitat and UNESCO activities and the International Water Association City of the Future programme.

The learning alliances were developed in a number of phases. These included start-up or design phase activities, operational activities, and capacity building and backstopping activities.

Start-up activities included:

· recruitment of learning alliance facilitators;
· training;
· scoping studies and stakeholder analysis to identify key issues and priorities of stakeholders;
· identifying the most relevant levels at which to work;
· building links to existing platforms.

City learning alliances held a start-up workshop or series of workshops to launch the project activities. A series of training activities was held during the first two years of the project and focused on process and event facilitation skills, communications, action research, visioning etc. The guidelines presented in the SWITCH in the City book (Butterworth et al, 2011) were originally developed to support those training courses.

Operational activities of the learning alliances included:

· workshops of different types;
· competitions and World Water Day events to raise wider awareness;
· visioning and planning processes;
· experiments or demonstrations;
· field visits;
· a multitude of communications, from websites and email groups to working the phone and visiting people in their offices.

Backstopping support was provided to the city teams on methodologies for stakeholder engagement, focusing in particular on support for monitoring and evaluation. This support was provided by consortium partners with a particular interest in stakeholder engagement processes, including the IRC International Water and Sanitation Centre (The Hague, Netherlands) and the Natural Resources Institute (Chatham, UK).

To support ongoing monitoring of and reporting from the city teams, 'city assessments' were led by a peer from another city or partner within the project consortium. This was done twice: in 2008 at the mid-point of the project, and in 2010 towards the end. In 2008, the focus was on helping to make the intervention logic in each of the cities more explicit, mapping the initial outcomes of the project, and making recommendations for possible changes in the intervention logic and activities. In 2010, with the end of the project approaching, the objectives and scope for the assessment were different. This assessment aimed to identify lessons learned about the effectiveness of the intervention logic, to look at whether the approach had produced the expected results, and to see what worked and what did not. The reports made recommendations for actions to be taken during the final months of the project to help achieve its goals (see Box 1), and identified mechanisms for scaling up and sustaining impact. The results of the assessments are presented fully in the SWITCH in the City book, but key highlights are summarised in this chapter (Butterworth et al, 2011; also add link to full papers online). These assessments mainly used qualitative methods, seeking feedback from a range of stakeholders in the SWITCH cities. They also included a review of documents such as plans and progress reports, interviews, questionnaires and correspondence with learning alliance members, focus group discussions with learning alliance members and reflection meetings with the city teams on the intervention logic and on the findings of the assessment..

SWITCH objectives

The 2008 and 2010 city assessments were guided by the following general objectives of SWITCH:

· To improve the scientific basis for integrated urban water management within focus cities through fundamental research that fills key gaps across all aspects of the urban water cycle;
· To test and demonstrate the feasibility and potential of innovative and better technologies through demonstrations and other activities, as set out in the SWITCH approach;
· To support cross-institutional platforms and better links between urban water stakeholders in a city, and between research providers and users, both to support an integrated approach to urban water management, and to maximise the uptake and impact of innovative and demand-led science;
· To improve decision support processes within focus cities (e.g. using more effective and accessible tools like City Water, SWITCH sustainability indicators) and the realisation of IUWM through evidence-based and far-sighted strategic plans and better policies

The amount invested in learning alliances at the city level by the SWITCH project was typically about €25,000 per city per year, not including the costs of physical demonstration activities. These investments were used mainly to fund the cost of a facilitator and operating costs such as organizing meetings and other events, managing communications and producing publications.

While the SWITCH project had a consistent approach overall, the intervention in each city sought to link activities to desired outcomes according to local contexts and interests. SWITCH's approach at the city level was therefore different in every case. Some cities focused on the whole city, approaching urban water management from a more holistic or institutional perspective, while other cities decided to focus on one key part of the urban water cycle, such as wastewater reuse or urban agriculture. With the exception of water and sanitation in Accra and sanitation in Alexandria, access to basic services was not the main focus. The focus was generally on the environmental side of water management, such as Sustainable Urban Drainage (SUDs), ecohydrology and river restoration, and wastewater reuse. The choices made by SWITCH were linked to where cities were in their development process (link to transitioning framework), but also the interests of the consortium partners and their existing contacts in the city. SWITCH often gained entry to a city through a technical department at a university, sometimes also working with the municipality as a key initial partner.

Examples and insights

Levels of engagement

The intention at the outset was that stakeholder engagement would need to span national, regional, city level and local (i.e. neighbourhood) stakeholders amongst others in order to promote the scaling up of innovations in urban water management. Despite this initial intention, most cities focused on the city level in their learning alliances. One important lesson learned was the need to intervene at the right scale in different cities. We saw widely varying degrees of influence amongst national, regional, city and local stakeholders; the city scale was not always the best scale or entry point for a research and learning initiative. For example, in Birmingham, which has a regionally focused private water company that operates in a strongly centralised government context, the institutions at the city level have much weaker powers in urban water management than was the case e.g. in the city of Lodz, where the most important institutions can be coordinated more easily at the city level. There was frequently a need to engage at multiple levels and to link learning platforms together, although limited resources made this difficult. However, Lima and Belo Horizonte successfully illustrate such a multi-level, integrated approach. For example, a learning alliance platform in Lima at the local, sub-city level focused on a demonstration project to pilot the re-use of wastewater for urban agriculture. The lessons learned in that pilot project were fed into a national platform that brought together different institutions and people with a focus on achieving improvements in policy at the national level.

Project and partner history

At the outset of the project, especially at the city level, partners were not selected on the basis of their experience, competencies or interests in stakeholder engagement, but rather for their profile in urban water management. We learned that project and partner history ultimately had a major impact on the nature of the stakeholder engagement process. In most cities, the lead partner was a university, usually working through a more technical or engineering-oriented department. There were exceptions, such as the Cinara Institute at the University of del Valle in Cali, which has a long history of action research in water management issues. However, in order to deliver on learning alliances, these organizations generally had to develop new competencies, recruit staff as facilitators or establish new partnerships. Some cities were able to do this more successfully than others, with responses ranging from the recruitment of full-time professionals with networking, communications and stakeholder engagement experience to the appointment of junior recent graduates who were enthusiastic but had little previous experience or support within their organization. Sometimes, providing adequate management for relatively junior participants was just one more task placed on top of an already full workload.

The limited seniority of learning alliance facilitators in many cases contributed to their relative weakness in terms of being able to influence the research agenda, with researchers generally remaining firmly in charge. Often the city coordinator who ultimately directed the learning alliance facilitator, and employed that person on a short-term contract, was also the project leader at the main research organization involved in the project. This could have led to conflicts of interest in which directions of interest within the learning alliances would have led to money being spent in other ways than the research provider had intended.

Progress was faster in situations where partners could adapt the easiest because they were working within more flexible institutions and could access higher levels of facilitation, communication and social science skills. Regular participation in training events intended to build the required capacities also proved its worth as the project unfolded. Where the municipality was a formal partner with a sizeable budget, it provided an advantage, bringing more convening power and greater potential to influence official policy and practice, such as in Belo Horizonte and Lodz. In conclusion, the initial approach used to launch a process and the partners that are involved in that launch are critical factors in the rate of progress and outcomes. The importance of investing sufficient time in getting these things right in the pre-project and inception phases cannot be over-emphasised; this lesson was only learned with the benefit of hindsight.

A role for outsiders

In several cities, the positive role of international collaboration in contributing new perspectives and supporting learning was highlighted. This may not be very surprising in the context of a multi-country project in which the partners had presumably signed up to make use of the network and gain access to knowledge it provided. During the evaluation of how participants experienced the project, one factor that stood out was the usefulness of being able to reflect on the cases of other cities rather than only one's own. The Learning Alliances aspect of the project meant also looking at new ways of *doing things, rather than just considering new things (i.e. new technologies). Within these processes, there were also occasions when the presence of outsiders could be used to garner attention from other people, including the media, and to help make the case for change.*

Demand-led research

A significant percentage of the work done at the city level involved conducting fundamental research to fill knowledge gaps across aspects of the urban water cycle, as well as collating and synthesizing existing information as an input to support Learning Alliance activities, especially strategic planning processes. The project aimed to undertake demand-led research, which can drive stakeholder engagement. Demand-led research is empowering and generates interest when cities have the chance to access the new knowledge that they believe they need. However, the idea of demand-led research is a problematic concept and proved difficult to realize within SWITCH. Researchers often operate within environments (including within the project) that pose serious obstacles to demand-responsiveness.

It was down to the flexibility and creativity of the teams (both individuals and their institutions) in SWITCH cities to create such responses and for all teams to negotiate changes with various managers. This was undoubtably much harder than just following the plans that had been set out at the start of the project, at a stage when cities had not been consulted and demands were not yet known. It involved moving budgets between activities and partners, and some people and organisations lost out in this process. Commendably, there was an increase in the willingness of many of the consortium partners to modify activities in line with the needs of the cities as they became clearer and better voiced during the course of the project. For example, several partners supported the City of Lodz in responding to needs in the area of storm water management, which had not been a part of the original plans. Where such changes were made, demand-led research strongly supported stakeholder engagement.

Demonstrating new approaches

Several of the city assessments reported that demonstrations were especially useful in engaging stakeholders. People are convinced by seeing things. The power of something visible is undeniable and provided a useful focus for targeted research, visits and training activities. Because 65% of funds for demonstrations had to be provided from non-SWITCH sources, their development always involved partnerships, e.g. with a municipality or utility company. Demonstrations also proved useful in bringing in other stakeholders, such as consultants and contractors, who were not effectively engaged in some of the other activities.

Risk management is an important part of experiments; municipalities, for example, often tend to be averse to taking risks, but the reasons for resistance need to be identified before they can be overcome. Experiments revealed areas where stakeholders were resistant, in some cases then making it possible for the barriers to be overcome. For example, in Tel Aviv, the plans for pilot grey water reuse as part of a sustainable building project encountered resistance from the regulatory authorities, bringing the underlying health concerns into clear focus. Unless those concerns could be overcome, there would be no scaling up. In this case, the compromise was to allow further development of the demonstration within the more controlled conditions of the university campus. Something similar happened in Belo Horizonte, where a trial infiltration gallery taking stormwater from a busy road was sited on university land where permissions could be obtained fast enough to allow completion and monitoring during the course of the project. Universities may not be the strongest partners in practical realization of infrastructure projects, such as e.g. procurement procedures, but it is nevertheless important for researchers to gain experience with constraints that may be encountered in taking innovations to scale.

Despite these positive experiences, some opportunities were missed. As we saw in research planning, demonstration planning was often not effectively linked to the Learning Alliances, so not all the interested and relevant stakeholders for scaling up were involved in every situation. SWITCH also focused primarily on physical demonstrations. In some cases, demonstrations of 'soft solutions' such as new financing mechanisms might have had more impact in the long term. Some smaller demonstrations could also been productively started much earlier in the SWITCH project.

Different types of learning alliances

One key lesson learned was that history, context, the approach taken (including both the partners), and the entry point of the project were key determinants in the success of learning alliances. Looking across the 12 cities, we can identify alliances of the 'old' and the 'new'. Some of the alliances, such as the water club in Tel Aviv, mainly brought together professionals who were already connected, although perhaps introducing some new tasks and objectives. It is also possible to distinguish between alliances with more controlled, formal and occasional interactions – an example would be Birmingham – and the more organic, multi-channel and even 'out of control' processes that developed in some cities. An example would be in Lodz, where groups within the learning alliance began to take on new activities and to communicate with each other directly rather than always interacting through the facilitator.

Facilitating, facilitating, facilitating

Learning alliances create social capital, they are new networks of relations, and they make it easier to find each other. They should make it easier for individuals to connect across departments, institutions and – critically – across cultures. A key lesson learned was that facilitation is all-important in order to connect and translate between cultures and domains. Facilitation and related tasks, including documentation and communication, need a range of competencies that will rarely be found within a single individual. In cities where facilitators had a high level of experience and more time on the job, the results clearly reflected that expertise. Examples included Lodz, Accra and Belo Horizonte.

Facilitation is not only about good events, although the meetings and workshops are key moments. Processes also need facilitation, which means a different set of skills, and may often require a lot of laborious communications, e.g. extensive mobile phone calls as works best in Accra, or running a Google group in Cali. One single person may not always possess all the necessary writing and communication skills; given the business at hand and the urgency of their tasks, the SWITCH learning alliance facilitators certainly found it difficult to document and reflect on their progress. Training sessions and the city assessments were therefore important. In hindsight, the documentation role should have been allocated to another person, although scarce resources meant that the learning alliance facilitators had to perform several functions.

SWITCH showed that successful learning alliances can be led by a university, a municipality or an NGO, but each type of institution involves its own unique challenges. Ideally, and perhaps most vitally, the organisation hosting and convening the learning alliance should not be implicated in local politics. The host organisation should be seen to be independent and impartial.

Besides the good facilitators that worked on the project, SWITCH benefited from a number of enthusiastic and well-connected advocates to champion the cause. Advocates are as important as good facilitators in getting the key people around the table.

Influencing plans and policies

Although it was not originally planned as an activity in all the cities, as learning alliance developed, it was decided to support all the cities in developing some form of visioning and strategy development process; this turned out to be a good decision. Scenario-based planning methodologies proved to be very popular with the learning alliances and the participatory development of visions, scenarios and strategies was one of the more effective integrating activities that helped to give the learning alliances coherence and purpose. These activities helped cities to broaden their focus in several cases, such as in Alexandria where planning became the main focus of the project, and to take on new key issues as their importance to stakeholders emerged, such as stormwater in Lodz. The methodology used proved to be relatively non-threatening, since it was focused on mutually agreed desired futures. In addition, it was a new and innovative approach from the perspective of the individuals involved, and it seemed relevant and effective in engaging many stakeholders in a joint activity. Almost all city learning alliances developed a shared vision; several developed 'unofficial' strategic planning processes, and some were able to build on this and influence official planning policies and documents. This process is discussed in detail in Chapter 3.

Summary of city-level processes and outcomes

ACCRA

In Accra, SWITCH played an important role in bringing together information and people across the different municipalities in the city. As well as municipalities, the project engaged different national government departments, research institutes, the utility, and representatives of peri-urban and slum communities, and worked hard to promote urban water and sanitation issues and solutions with the media. Outcomes that have had a significant impact included a presidential debate in 2008 that was organised for the candidates to present their visions on water and sanitation, and a strategic planning process that led to findings being utilised in other major and more 'official' planning processes, such as the development of a new project supported by the World Bank, as well as the Metropolitan Assemblies' development plan.

ALEXANDRIA

Alexandria, the most downstream city along the longest river in the world, focused on developing an integrated urban water management plan and demonstrating how urban slum communities could be served with the existing water supply. Key actors included the city government, water and sanitation utilities, an urban slum community and a research focused institute. Although it was not possible to complete the plan in time to identify its short-term outcomes, the project actively engaged the main city water institutions in the plan's development. The demonstration project pushed the boundaries in showing that the water utility can engage with and supply the most marginalised informal communities in the city.

BEIJING

In Beijing, the project focused on ways that urban farmers can cope with the pressures put on them by the city in response to increasing water shortages as urban water consumption grows. The learning alliance meetings brought together research institutes, government officials and farming cooperatives. A demonstration project showed how innovative roofwater harvesting can provide a useful source of water for urban farmers and support a shift to higher-value crops.

BELO HORIZONTE

In Belo Horizonte, SWITCH focused on the development and uptake of more natural and environmentally sympathetic approaches to urban drainage to minimise flooding risks while also improving river corridor habitats. A partnership between the municipality and the university was at the heart of the project, whilst learning alliances at the local level engaged schools and communities in several demonstration projects, as well as institutions such as other municipal departments, the utility and metropolitan and river basin committees at the city scale and beyond. Outcomes included commitment by the Municipal Parks Foundation to scaling up rainwater harvesting and a start by participatory budgeting committees on implementation of alternative and more sustainable solutions as a result of the training and exposure received.

BIRMINGHAM

In Birmingham, activities concentrated on future risks, such as climate change, but also the implications of rising groundwater levels as industrial consumption falls. Some of the partners in the learning alliance included the city council, the water company, the Environment Agency, the regulatory authority, consumer bodies and a professional association. Some specific outcomes of engagement with development agencies were influencing the plans for redevelopment of a major site within the city through the extensive use of green and brown roofs, reducing costs and introducing more sustainable alternatives.

BOGOTA

The project in Bogota addressed the highly polluted Rio Bogota flowing through the city, focusing specifically on preventing pollution by small-scale and unofficial tanneries upstream. Key players engaged throughout the project were a tanners' association, the environmental regulator, local government, an NGO, a university and the Chamber of Commerce. The project had a number of positive outcomes. Unofficial small enterprises, which produce almost half of the pollution, have now implemented cleaner production principles, removing 90% of their contribution to pollution through improved treatment processes and recycling. These improvements also led to additional productivity gains for these enterprises. The project demonstrated the feasibility of alternatives to a solely punitive and legalistic approach based on fining polluters (which was failing with the informal sector), offering such options as conflict resolution, capacity building, and dialogue; the regulator is now pursuing and supporting such approaches. The research supported local action, and now the approach is being expanded across a wider catchment area as part of a follow-up project.

CALI

In Cali, the project focused on research, creating dialogue and promoting more sustainable alternatives (although there were no demonstration activities) in relation to pollution of the Cauca River, urban drainage and city expansion. Creating a shared vision proved essential to counter-balance prevailing short-term planning and construction in most of the institutions. Outcomes beyond the research reports and training were a reduction in the emphasis on end-of-pipe solutions in wastewater management and growing consideration of alternative technologies in new housing developments. Even more importantly, planning processes at the level of municipal and national policy consultations on the future of the Cauca River are building on the foundation laid by dialogue amongst SWITCH members, utilising SWITCH outputs and advice.

HAMBURG

In Hamburg, SWITCH worked on improving planning, with the river island of Wilhelmsburg as the focus area. Learning alliance activities brought together a broad range of stakeholders from the island in the development of a water management plan that raised the level of discussion on the islands future development. Unfortunately, because of delays in activities outside the scope of SWITCH it proved impossible to realise the intended demonstration activities.

LIMA

In Lima, the focus selected was scaling up the reuse of wastewater in green productive areas in an extremely water-scarce environment (only 13 mm rainfall per year). Key players included national ministries, the national water authority, local governments, and an NGO. The project developed learning alliances both at the national level, focusing on policy issues, and at the local level, linked to a demonstration project and related research. The main outcomes were a successful demonstration project showing how water could be safely reused for multiple purposes, and the development and official approval by the government of new national policy guidelines that promote safe re-use of wastewater in Peru.

LODZ

In Lodz, the focus was on restoring rivers that have become polluted, degraded and even buried as the city developed. Key actors were the local government, utilities, the university and a specialist research institute. A successful demonstration project has partially revitalised one river corridor, providing a more attractive environment for residents and future development. Through the learning alliance, activities are firmly embedded in the city institutions that will be responsible for continuing and scaling up river restoration across the city. The idea of linking restored river corridors and other open green spaces in a "blue-green network" is now recognised as part of the city's planning strategy.

TEL AVIV

In Tel Aviv, research focused on developing soil aquifer treatment technologies to facilitate the reuse of wastewater. At the city level, an important outcome achieved through engagement with the city planning authorities was the inclusion of water issues in the strategic plan for the city, an aspect that had been previously overlooked.

ZARAGOZA

In Zaragoza, the project focused on demonstrating sectionalisation as a means to manage water demands in a city that takes pride in minimising its water consumption. Sectionalisation has now been scaled up or is under study across almost half the urban area, and is included in draft municipal by-laws. The project used existing stakeholder platforms to communicate these activities, especially the Municipal Water Commission. The Expo Zaragoza in 2008 focused on sustainable water management and was an important venue for showcasing the activities.

3.

Planning for the Future

Develop a Transition Agenda

State of the Art

Strategic planning is a well-established activity in business and government. It involves taking the long view by deciding on an end point or vision to be achieved and identifying appropriate means to reach that goal. In the conventional transition management cycle, strategic planning corresponds to the second stage: "Developing a Strategic Agenda".

The EU has adopted this approach with the Water Framework Directive (WFD), which requires preparation of river basin management plans every six years, based on a long-term vision for the river basin districts, stakeholder participation, and an integrated approach. The vision includes achieving 'good' quality for all water bodies by 2015, including socio-economic and environmental benefits.

The SWITCH Approach to Strategic Planning

SWITCH built on the Water Framework Directive and urban water cycle approaches, with the city rather than the river basin as the planning unit. The SWITCH Integrated Urban Water Management (IUWM) approach combines water supply, wastewater and stormwater and integrates these three aspects into city planning. Integration is crucial, as a combination of measures which optimise individual aspects may result in harmful sub-optimisation for the system as a whole (Hellström et al., 2000).

The natural water cycle of rainfall, infiltration, runoff, and evaporation is radically changed by human interventions, including storage, abstraction, distribution, use, collection and discharge, together with changes to land use and drainage. Water resource management therefore requires study of the whole water cycle.

Strategic plans for the urban water system need to take a long-term perspective (15-40 years). Not only because the life span of the infrastructure can be 40 years or longer, but because the changes and pressures also develop over these long time spans. Some changes occur gradually, but others may be sudden step-changes. The plan needs to take into account the uncertainty surrounding the changes and must therefore be flexible, using technologies and governance methods that can be applied under different future scenarios.

The vulnerability of many cities to various 'system failures' has undoubtedly increased. The interlinkage between energy supply, the transport sector, IT systems and the water sector infrastructure is strong. For example, reliability of flood protection in the Netherlands is not only determined by the physical infrastructure, but also by the reliability of the IT system that controls the flood barriers. Similarly, a disruption of power can cause sewer overflows as pumps fail to operate. Low flows in rivers may limit the cooling capacity of power plants and therefore reduce power production.

Water sector institutions need to prepare themselves to cope with the changes that are on-going, but also be prepared to meet with future changes that are not known yet, or the extent of which is not yet known (i.e. they need to be more resilient). This uncertainty needs to be included in planning and decision- making processes. The uncertainty also requires strategic thinking, translated into strategic and flexible planning, rather than conventional blue-print planning.

A strategic plan for the urban water system spells out the long-term strategy that the public and private sector will take towards achieving the objectives or the vision for the city's water system. A strategic plan that is jointly developed and accepted by all stakeholders becomes a powerful tool to give direction to the annual plans of municipalities, utilities and water boards. It may also inspire and invite the private sector to participate in realising the vision. The SWITCH strategic planning process was developed to be used by the city learning alliance. It is seen as a participative process, to be undertaken by a group of informed stakeholders working together from a range of perspectives, rather than by any one organisation, discipline or individual. The strategic analysis should result in the identification of the true priorities of the whole city, rather than personal interests, and the detailed application of professional resources to examine ways to meet those priorities.

The general SWITCH approach to strategic planning incorporates the following elements (van der Steen et al, 2011)

- An inventory of the major global change pressures that affect the state of urban water systems;
- An overview of the strategic issues that urban water managers are confronted with now and in the next decades; and the concrete strategic questions that need an answer;
- A description of the potential that strategic planning can provide for urban water management under changing conditions and uncertain developments;
- A strategic planning approach based on a learning alliance process and directed at creative visioning, scenario identification and strategy development;
- A method to implement strategic urban water management plans via the government and non-government sectors;
- Recommendations to use a monitoring system of sustainability indicators to measure the state of the urban water system, producing results to be used in a next cycle of strategic planning;
- Recommendations to use a decision support tool (SWITCH City Water) to evaluate the effect of various strategies and options on overall system sustainability before implementation;
- Recommendations on the application of a number of innovative (technological) options in future urban water management schemes.

A key issue is how to handle and combine the 'top-down' approach, which includes the strategic overview of the city as a whole, and the 'bottom-up' approach, which articulates citizens' demands.

Step 1

Analysis of major global change pressures that may affect urban water systems

SWITCH has advocated a strategic approach that includes analysis and sensitivity to global change pressures, including the following factors.

Climate change

Changes in precipitation patterns towards more intense storms lead to an increased risk of flooding. In the UK, annual damage due to flooding may increase from around 0.1% of GDP to 0.2-0.4% of GDP once global temperature increases reach 3 to 4 °C (Stern, 2006). This increase represents significant sea level elevation. At the same time, the fluctuations in river discharge are expected to increase. This may lead to extremely high water levels and disastrous flooding, or during low discharge periods to the invasion of saline water in Delta cities. Whilst storm events may become stronger, at the same time it is expected that dry periods will become longer, which could lead to increased water scarcity.

SWITCH, in collaboration with ICLEI and IWA, developed an Urban Water Systems Climate Adaptation Handbook to help cities understand the potential risks from climate change as well as potential adaptation studies, including case studies.

Governance and policies

Decisions and plans are no longer made from the top down; instead, joint decision-making processes involving citizens are likely to increase. Various forms of cooperation are emerging at the institutional level. No longer are government institutions the sole providers of water services to cities. In Europe 176 million people were estimated to be receiving water services in 2005 via some form of private sector participation, with this figure expected to increase to 75% by 2015. (Kelay et al., 2006). There is a landscape of different models of governance and institutional arrangements. In SWITCH, these governance and institutional arrangements were explored in the cities and the findings are as follows.

Key principles derived from the SWITCH project experience with institutional mapping.

Balanced information: Information gathering should use existing studies and official documentation as well as a range of other primary and secondary sources, supplemented and verified by empirical evidence.

Cultural understanding: Comprehensive institutional mapping is time intensive, requires proficiency in the local language and an awareness of local cultural and operating practices.

Stakeholder participation Institutional mapping should involve key local stakeholders, such as those involved in multi-stakeholder bodies (like the local Learning Alliances in SWITCH). Their involvement should ideally be more providing information and extend to participation in the analysis of information and commenting on any analysis by the main researcher.

Attention to informal rules: Because it is easier to identify the formal systems of rules, expressed in laws and regulations, than the informal systems of rules there is a risk that not enough attention will be given to informal rules. Social norms and informal rules of the game may be equally or more important than formal rules in terms of understanding power relations and decision-making.

Attention to timing: In the context of technical innovation, institutional mapping should be undertaken as part of planning or designing a technical intervention or identifying potential options for water related innovations, rather than as an afterthought or an add-on activity.

Progressive focus: Depending on the direction of the innovation being considered, further information gathering will usually be needed as part of an ongoing planning and review process. This may require involving new stakeholders on board to assist with gathering and analysing information.

Managing information & confidentiality: It may be difficult to get access to some key information, particularly the informal rules, either because such information may be sensitive or because those holding the information are fearful how it might be used. Agreement with key stakeholders about confidentiality, and their participation in decisions about what information should be shared with whom is important in terms of developing trust and achieving a progressive focus in the analysis.

Developing trust: Particularly when there are sensitivities around sharing information, and a history of conflict or mistrust between institutions, gaining access to key information may hinge on developing the trust of key stakeholders. When trust is developed then this provides a basis for developing a platform for stakeholder engagement and achieving progressive focus.

Dynamic perspective: Analysis should incorporate the dynamic aspects - Policy and practice are constantly in a state of change so it is necessary to see what changes are being contemplated. For example the innovatory demonstrations undertaken in Cali, Lima, Beijing and Lodz were based on analysis of dynamics going on within and around these cities, which made it possible to promote the uptake of certain technologies.

History is important. Prevailing concerns and technologies from the past are reflected in definitions of terms, in laws, regulations and institutions. This underpins the importance not only of having clear definitions for local terms used in water management, but understanding the history behind how these terms came into use.

(Sutherland, 2011)

Population growth and urbanisation

Growth rates of up to 4% per year pose almost impossible challenges for cities in developing countries. Cities are in principle vulnerable because they rely heavily on external resources (water, food, energy, etc.) that need to be imported from outside the city. Some European cities are even facing a decrease in the number of their inhabitants or a significant change in the composition of the population (fewer 'productive' people). Cities that face an increased urban water demand will struggle to find water resources.Groundwater table lowering due to overabstraction is already a reality in many cities. Informal, unplanned areas generally lack a basic water supply and sanitation, and form an important target group for reaching the Millennium Development Goals on water and sanitation.

SWITCH City population trends

City	Country	Projected 2010 population in urban area (millions)	Population trend (2005-2010)	Average annual rainfall (mm)	Country Human Development Index rank, 2010
Accra	Ghana	3.7	Moderate growth	725	130
Alexandria	Egypt	4.3	Slow growth	178	101
Beijing	China	14.0	Slow growth	572	89
Belo Horizonte	Brazil	4.9	Moderate growth	1491	73
Birmingham	UK	2.3	Stable	662	26
Bogota	Colombia	7.8	Moderate growth	824	79
Cali	Colombia	2.3	Slow growth	908	79
Hamburg	Germany	2.0	Stable	773	10
Lima	Peru	8.0	Slow growth	13	63
Lodz	Poland	0.7	Slow decline	599	41
Tel Aviv	Israel	2.7	Slow growth	531	15
Zaragoza	Spain	0.7	Slow growth	318	20

Source: Butterworth et al (2011)

Deterioration of infrastructure systems

Urban water managers will increasingly be confronted with deteriorating infrastructure, especially pipe networks. In many parts of Europe, pipes are over 100 years old and the cost of rehabilitating the water infrastructure system is increasing. European cities are spending on the order of 5 billion euros every year for wastewater network rehabilitation (Vahala, 2004). The amount spent on asset rehabilitation programmes will continue to increase over the coming decades due to the synergetic effects of infrastructure ageing, urbanisation and climate change. Infrastructure deterioration will affect public health, the environment, and institutions in various ways.

Changes in public priorities

Increasingly, people in Europe express personal identity through the type of food they consume (e.g. organic) and the energy supply they use (e.g. green energy or private solar panels). This could also affect the priorities of citizens towards water. It could result in a favourable attitude towards decentralised (and therefore more personal and self-sufficient) ways of supplying and treating water.

Energy costs

Energy costs have recently surged to new heights, accompanied by subsequent recognition that the urban water system is a small, but significant energy consumer. Water supply and wastewater management consume energy to the equivalent of about 5-10 % of total domestic electricity consumption. The water sector can therefore not be ignored in initiatives to reduce overall energy consumption, such as the EU ambition to reduce energy consumption by 20% in 2020 as compared to its use in 1990 or the ambition of some cities to become 'carbon-neutral'.

Technological innovation

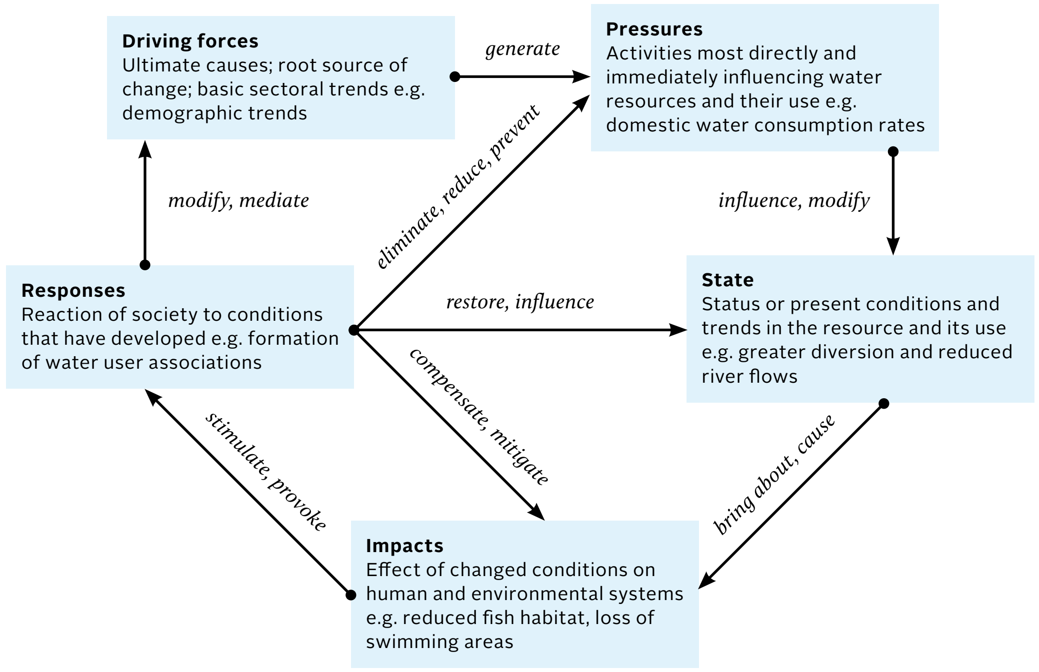
Technological innovation in the water sector is an on-going process; it has changed the range of options for urban water management and will continue to do so. The improvement of membrane technologies, use of natural systems and new leakage reduction techniques are changing the water and wastewater treatment industry. In Chapter 4 these innovations are discussed in more detail.

In order to take into account the challenges and changes whilst developing strategies for urban water management, one needs to understand the cause and effect relations that are part of today's realities. In Accra, the changes and the underlying cause-effect relations were analysed systematically using the DPSIR model (OECD, 2003). This model discerns the root sources of change (driving forces), the resulting pressures on the urban water system, the resulting conditions of the system (state), the effects of changes in conditions (impact) and finally the responses of society to mitigate the impact (see Figure 4). Global changes, such as climate change or population growth, can be interpreted in terms of driving forces and pressures, as well as in changes in state variables, impact and responses.

Step 2.

Visioning, scenarios and strategy development

figure 4 **The DPSIR framework (OECD, 2003)**



Visioning

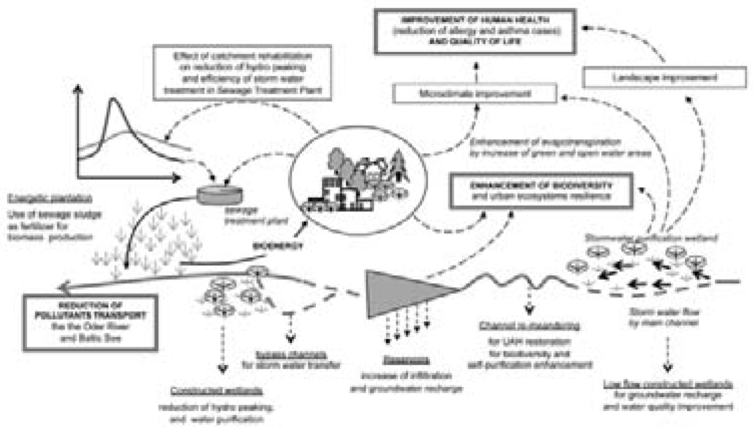
A strategic planning process includes creative visioning, scenario identification and strategy development (van der Steen et al. 2011). Having a shared vision may drive a society or a city to move forward. The absence of a shared vision may result in stagnation and deadlock. A vision gives direction to the overall planning and management of the city. The development and objective assessment of different urban water management strategies or plans is not possible unless decision-makers have a clear vision of what they would like to achieve. In the context of integrated urban water management, decision-makers are likely to be a diverse group of stakeholders with different visions of what future water services and the environment should be in all or parts of an urban area. The aim of a visioning process is to develop a consensus and a shared commitment to work towards the achievement of the vision. In SWITCH, visioning was used to promote stakeholder dialogue during the early stages of LA formation. Visioning provided stakeholders with an opportunity to exchange and debate opinions and aspirations for future water services and the urban environment. Well-facilitated visioning exercises proved to be empowering, inclusive, highly participatory and fun.

To be useful as part of a wider planning process, a vision must be realistic and achievable. Visions are invariably political. As a consequence, facilitation is needed to reconcile often very different views on the relative importance of, for example, environmental sustainability, economic growth and provision of water services to poorer social groups. That said, strategies and plans are often more politically contentious than visions. Facilitation is often needed to ensure that specialists present information in a form that can be understood by non-specialists. Ideally, community and city level visions should inform, and be informed by, national policies and strategies; it is important to have consistency across visions created at different spatial and temporal scales.

Visioning

- Encourages constructive discussion and understanding amongst a diverse group of stakeholders;
- Promotes active involvement of stakeholders in developing and implementing water management strategies and plans;
- Provides a target or benchmark against which the success or failure of the strategies and plans can be monitored;
- Allows stakeholders to look forward rather than to remain bogged down in current problems;
- Results in a statement of intent that can attract the attention and enthusiastic support of the media and the general public.

Lodz Learning Alliance (2011)



"Lodz Uses Its Water Wisely"
"In 2038, the city's resources management will be based on an efficient and integrated system, ensuring access to information for all. Investors and authorities respect ecological properties of land and waters. Infrastructure serves the functions and requirements of an environmentally secure city, is reliable, meets the needs of all the city's population and assures good status of aquatic ecosystems. Green areas – river valleys along open corridors – provide space for recreation and are the 'green lungs' of Lodz. The population's shared and in-depth ecological awareness contributes to exceptional quality of life. Our city is a leading centre for innovation, education and implementation in Poland."

Lodz Learning Alliance (2011)

"Wilhelmsburg 2030: Make Water Visible"
"Make Water Visible is the new image of Wilhelmsburg Island in 2030. The different types of water are visible, accessible and can be experienced by its citizens. Visible Water helps to build an attractive place to live, work and recreate along, on and with water. The new image of Wilhelmsburg will be realised not only through high-quality urban design, but also through improved chemical water quality, the ecological quality of the surface waters, as well as robust flood prevention. The inhabitants of Wilhelmsburg will be aware of the importance of the water system, will be informed about the sustainable management of water, and will identify themselves with their Elbe Island."

Hamburg Learning Alliance (HafenCity Universität, 2011)

"Nothing is more obvious than the unpredictability of the future"

Scenarios

In planning processes, we simply cannot escape from the dilemma that all our reliable knowledge is about the past, whilst all our decisions are about the future. Arguably, uncertainty in the water sector has now become so pronounced as to render futile the planning processes that are based on probabilities and extrapolation of current trends. In view of this dilemma, what can we do? One option is to use scenarios and scenario-building as an integral part of the strategic planning process. In the context of SWITCH, the main purpose of scenario-building was to enable a learning alliance to identify, evaluate and take explicit account of a whole range of uncertain factors that might either support or derail strategies and plans that are aimed at achieving the vision. Scenario-building is essentially a team exercise that can help a group of stakeholders to come to terms with uncertainty and risk in a planning process. In particular, scenarios can be used to identify the most uncertain and most important factors that are outside the direct control of the stakeholders. Experience has shown that it is these uncontrollable factors that are more likely to disrupt plans, rather than factors that, although very important, are predictable and under the control of stakeholders tasked with implementing strategies and plans. Scenario-building forces stakeholders to confront key beliefs, to challenge conventional wisdom and to really think outside the box. It also forces stakeholders to think imaginatively and systematically about the multitude of inter-sectoral issues and factors that will, in the future, have an increasingly important impact on the water sector (e.g. peak oil or climate change). Whilst scenario building is used routinely in other sectors, its use in the water sector is still relatively limited.

Scenario development starts with the identification of the most important factors that are also areas of major uncertainty. These factors are combined into narrative scenarios, which are then tested and evaluated for validity and internal consistency. Models and decision support systems (such as the City Water tool developed in SWITCH) can be used to predict the effect of various scenarios on the urban water system.

2037 Scenarios Alexandria, Egypt
A scenario is a plausible and internally consistent description of a possible future situation, a story about the way an area or domain of interest might turn out at some specified time in the future. The following three scenarios were developed in a workshop in Alexandria in July 2007.

Worst-case scenario
In 2037, Alexandria is a city characterised by:
- continued explosive population growth (summer population 12 million);
- A weak and stagnant economy;
- Low availability of Nile water which is 40% less than in 2007 (due to increased national water demand and/or climate change);
- increased risk of flooding (due to sea level rise);
- Poor availability of financial resources.

Best-case scenario
In 2037, Alexandria is a city which:
- Has a population which has largely stabilised (at 8 million);
- Is benefiting from a dynamic and fast-growing economy;
- Has a guaranteed allocation of Nile water similar to that of 2007;
- Has a positive scenario related to climate change (with minimal sea level rise and increased rainfall);
- Benefits from the new vitality of the Egyptian economy, which means that financial resources are readily available.

Business as usual
In 2037, Alexandria continues to be a city dealing with considerable uncertainty:
- Population is 10 million, and continues to grow;
- National allocation of Nile water is 20% less than in 2007;
- Economic growth has been steady but unspectacular;
- Rising sea levels are starting to threaten some parts of the city.

Alexandria Learning Alliance

Strategy development

After developing visions and plausible scenarios for the future, the learning alliance is ready to think about a response. Which strategies might be implemented to achieve the vision? The problem is that it is uncertain which scenario will become reality. Moreover, the outcome of a strategy is likely to be different under different scenarios. Regardless of the method used, flexibility remains an important consideration: strategic flexibility and the flexibility of the resulting measures (infrastructure or institutional "arrangements". An ideal strategy should be adaptable enough to achieve the vision under multiple scenarios.

A strategy is more about how to achieve the vision, what types of measures should be implemented and what strategic choices need to be made. The assessment of the various outcomes and strategies aims not at finding the optimal solution, but is rather intended to provide the stakeholders with information about all their options. The stakeholders can then use this information in the discussion and come to a decision.

Technological innovation in the water sector is an on-going process; it has changed the range of options for urban water management and will continue to do so. The improvement of membrane technologies, use of natural systems and new leakage reduction techniques are changing the water and wastewater treatment industry. Chapter 4 discusses these innovations in more detail.

Strategic planning in Hamburg
In July 2006, a scoping visit was conducted in Hamburg to identify and confirm the urban water management challenges that the city faces. It was agreed the overall aim of SWITCH in Hamburg would be the provision of a holistic and integrated approach to urban water management. The resulting approach would be based on the concept of sustainable development and decisions would be taken based on agreed indicators for sustainability and risk. The project activities in the city would be aimed at implementing research results in city planning, in order to make a difference in practice. The best way to achieve this was to link the SWITCH work to the IBA, the International Building Exhibition scheduled to take place on Wilhelmsburg Island from 2008-2013. The concept was to develop a plan for water management on the island. The plan would combine water management problems (e.g. flooding, stormwater, quality) and urban planning demands, i.e. using water to develop attractive residential areas and recreation.

Observations and lessons learned:
- In Hamburg, the municipality is one of the coordinators in the IUWM planning process; this means that authorisation of the process is clear. A good relationship with the university also created trust and built bridges between science and policy.
- The learning alliance in Hamburg is both 'horizontal' and 'vertical', i.e. it has members that cover all aspects of the urban water system (horizontal integration) and it has members from various government organisations, NGOs from Hamburg and from the island itself (vertical integration).
- The process in Hamburg achieved a nice balance between workshops and activities in between the workshops. The learning alliance facilitator prepared the workshops by collecting data and by conducting one-on-one interviews with learning alliance members. This approach allows each member to contribute and comment orally, thus speeding up the process.
- The emphasis of the research done in Hamburg was on WSUD, which easily combines water management and urban planning, building on the strengths of the learning alliance members.
- Good facilitators are critical to the process. In Hamburg, the loss of the facilitator mid-way through the project, as well as delays with the IBE, caused the strategic planning process to 'be delayed and change into a general stakeholder consultation.

Long-term indicators
SWITCH developed long-term indicators which serve as tools to measure and/or visualise progress towards project objectives that would assist in realising a vision. Targets are intended indicator values, usually expressed in specific and quantifiable figures (number of units, percentage, costs, etc). Objectives are a desired change of state (vision) to be achieved over time. In order to measure this achievement, indicators have to be defined that reflect progress towards the objective as shown in table 3.

An indicator that is used for purposes of urban water management indicates the state of the urban water system, or changes in the state of the urban water system. When a city selects a number of indicators, to be monitored during a long-term process of strategy implementation and strategy adjustments, careful consideration is required as to the number of indicators selected. The set of indicators should be in balance with the level of effort that a city (municipality, water utility etc.) is able and willing to invest in the monitoring programme. In addition, the indicators should be meaningful for a programme that will be implemented over a number of years (Van der Steen, 2011).

table 3 **Examples of indicators and targets**

Vision	Objectives	Indicators[2]	Targets	M&E
Vision 2050 (extract) …Water resources are protected through the actions of all of our citizens enabling a healthy environment where aquatic landscapes are ubiquitous and a reliable supply of water is available for all without environmental consequences.	To change behaviour among citizens that has negative impacts on water resources	Number of pollution incidents caused by public discharges to drains	Pollution incidents caused by public discharges to drains reduced to X by year X	Documentation of reported pollution incidents and evaluation of preventative activities
	To restore and revitalise the city's rivers and streams	Proportion of urban rivers and riparian zones restored to a near natural state	X kilometres of the city's rivers and riparian zones restored to a near natural state by year X	GIS mapping of river environments and an assessment of the natural ecosystems that have been established
	To replace environmentally damaging abstractions with alternative solutions for satisfying local water demand	Groundwater levels in environmentally sensitive aquifer	Groundwater levels maintained at natural recharge levels from year X	Groundwater measurements monitored and evaluated in conjunction with rainfall rates and abstraction programmes

Source: SWITCH Training Kit Module 1

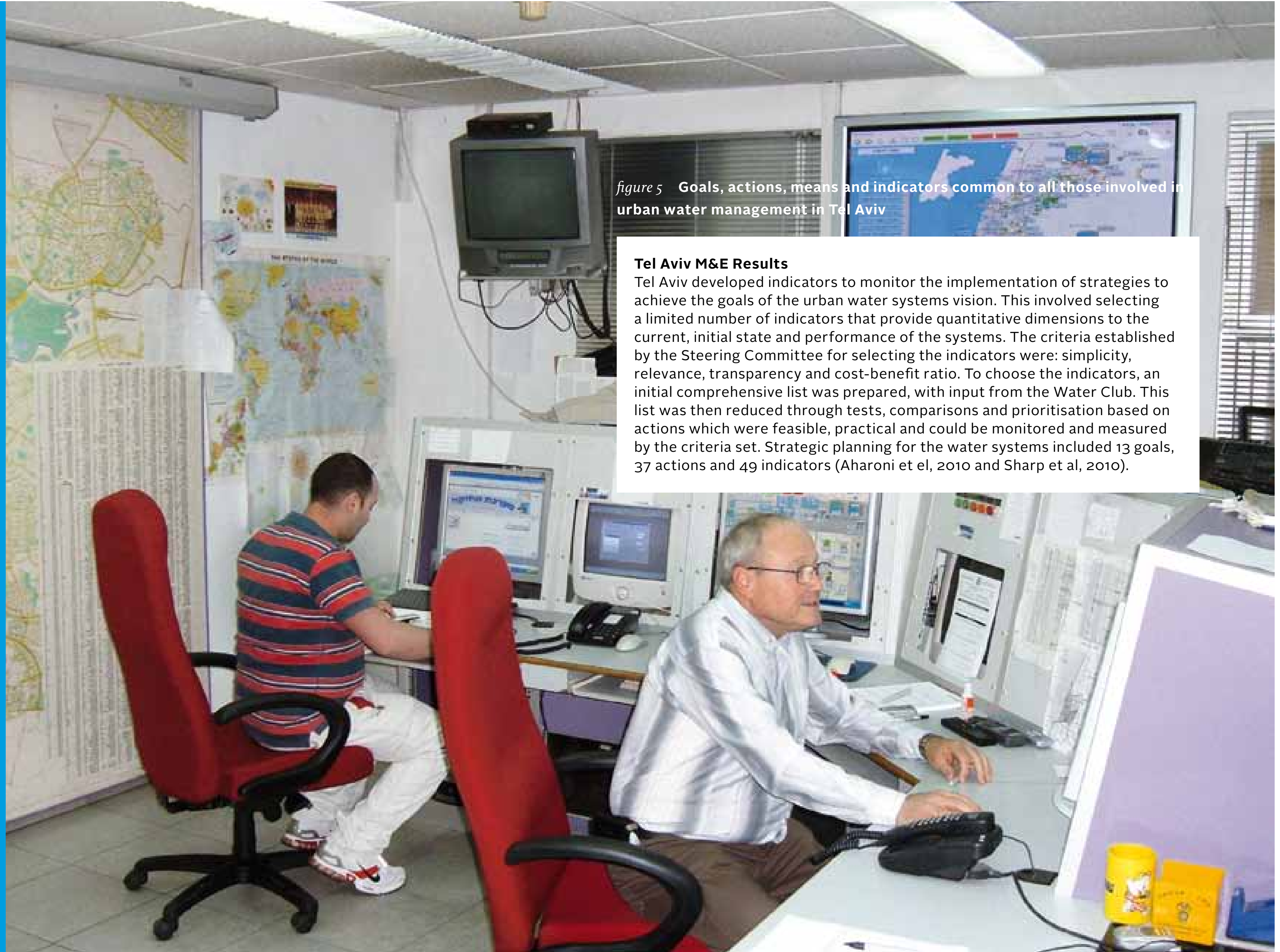


figure 5 **Goals, actions, means and indicators common to all those involved in urban water management in Tel Aviv**

Tel Aviv M&E Results
Tel Aviv developed indicators to monitor the implementation of strategies to achieve the goals of the urban water systems vision. This involved selecting a limited number of indicators that provide quantitative dimensions to the current, initial state and performance of the systems. The criteria established by the Steering Committee for selecting the indicators were: simplicity, relevance, transparency and cost-benefit ratio. To choose the indicators, an initial comprehensive list was prepared, with input from the Water Club. This list was then reduced through tests, comparisons and prioritisation based on actions which were feasible, practical and could be monitored and measured by the criteria set. Strategic planning for the water systems included 13 goals, 37 actions and 49 indicators (Aharoni et el, 2010 and Sharp et al, 2010).

table 4 **Goals, actions, means and indicators common to all municipal water systems**

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Improving consumer service	Formulating and adopting a Service Charter	Consumers' satisfaction	5*	No information currently	4*
	Improving the efficiencies of the organizations and procedures dealing with consumer needs and complaints	Faillure events' notifiers' satisfaction	5*	3.4*	4*
	Rapid and efficient responses to faillure events in any system				
Information transparency	Making all information relating to any system easily accessible to the public	Consumers satisfaction with the information's quality and transparency	5*	No information currently	4.5*
Faimess and affirmative action to the city's southern and eastern sections	Under equal conditions, giving priority to the improvement of infrastructure and services to these less affluent and developed city sections	The specific city sections' residents' satisfaction	5*	No information currently	5*

*On a scale of 0 to 5.

Summary of strategic planning processes, lessons learned and outcomes

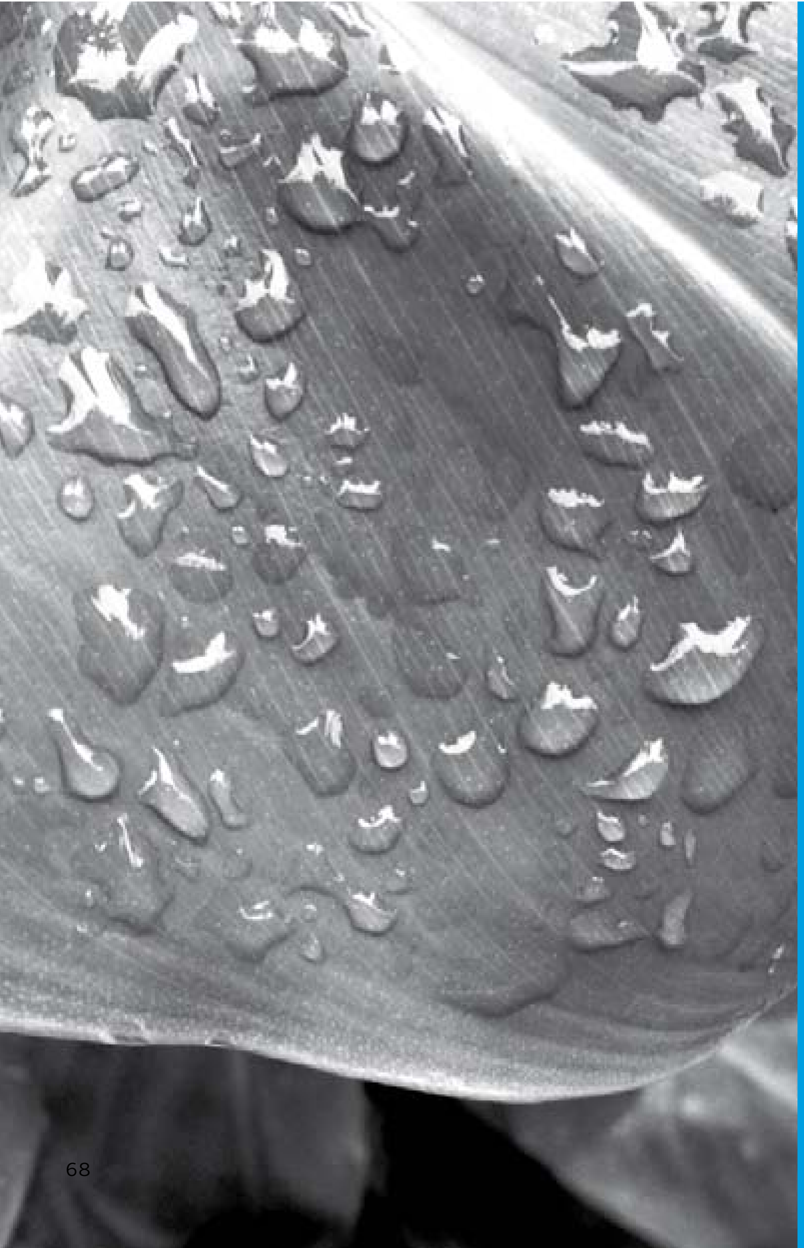
The cities' experience supported the value of the SWITCH strategic planning approach, but also showed the difficulties that it faces.

Common institutional issues included:

- The large number of organisations involved in limited technical areas of the urban water sector.
- Ambiguity in responsibilities for particular technical areas: for example in the Accra Metropolitan Area:
- a) The Sewage Unit, the Waste Management Department and the Urban Environmental Sanitation Project office all have responsibilities for wastewater management. b) The Drainage Unit of the Waste Management Department, the Metro Roads Department and the Hydrological Services Department all have responsibilities for stormwater drainage.
- Lack of co-ordination mechanisms and incentives for organisations to work together, both within technical areas (e.g. wastewater as in the Accra example above) and between areas: for example in Alexandria it took several high-level meetings of the Learning Alliance before the water company and wastewater company understood their common interests and that water use practices affect both demand for water and wastewater flows.
- Lack of responsibility and expertise in integrated urban water management in planning organisations (both at city and national level), which limited their ability to engage with the technical organisations and provide leadership or co-ordination.
- Difficulty in agreeing indicators for integrated urban water management, rather than a collection of indicators for various technical areas.
- The short to medium term focus of water management organisations, in accordance with political and funding cycles and priorities; they found it difficult to consider planning for a 30-50 year time-scale.
- The expertise of some organisations was stronger on design and construction using conventional technologies than on more holistic water management and planning disciplines and on unfamiliar technologies such as sustainable urban drainage, natural treatment systems and demand management.
- The failure to get groups like energy providers and developers involved in the process – these issues were generally represented by planning organisation.

Lessons learned

1. The strategic planning process, tailored to local conditions, is a powerful tool for improving water management.
2. Long term strategic planning gives direction to medium and short term plans, improves their rationality and therefore may also contribute to meeting short term needs. The visioning process was a powerful tool to help people think outside the box. Collectively agreeing on a future state that was desired by all helped to break down walls between organisations and individuals.
3. Planning a water system at the scale of a city is an enhancement to planning at the scale of a utility or river basin.
4. An integrated approach reveals better opportunities for innovation in urban water management than separate sub-system strategies.
5. Waterscapes in cities can be used to improve social and economic conditions.
6. The strategic analysis should indentify the priorities of the whole city rather than personal interests.
7. Having a mix of local stakeholders and external experts gave the process enhanced visibility and impact.
8. The strategic planning process proved an excellent means of getting the different disciplines within the Consortium to integrate their activities.
9. Strategic planning takes time. Trust needs to be built up between parties and data collection and analysis can be time-consuming and difficult. Five years was the minimum of a realistic timeframe for completing this process.



4.

Exploring the Options

Integration across the water cycle

Fragmentation of the urban water cycle into sectors the uncommon approach to water management in most cities. Wastewater, stormwater and water supply are each managed separately without being aware and taking advantage of the numerous links that exist between them. In the case of water supply, this lack of integration leads to the following:

- **Missed opportunities** – such as the failure to exploit rainwater and recycled wastewater as a source of water supply for non-potable uses.
- **Unexpected impacts** – such as the over-abstraction of water from a river, thus reducing its ability to dilute downstream wastewater effluent discharges.

The links between water, wastewater and stormwater management and the urban water cycle as a whole demonstrate the influence that one area of water management can have on other areas of urban water management and vice versa. These influences may be negative, such as overflows from combined sewer networks, but may also be positive, such as when recycling water provides an additional source of water supply for a city. A more sustainable approach to water supply is therefore not only concerned about efficiency and improved performance within the sectoral boundaries, but also with how management decisions affect other sectors in the urban environment. An integrated approach to urban water management makes it easier to identify and exploit these positive links while minimising the negative implications throughout the system.

Some of the links that need to be recognised between water supply and wastewater and stormwater management of the urban water cycle are shown below. More detailed information on these linkages can be found in the SWITCH Training Modules 3 to 5 (www.switchtraining.eu)

Water supply > Stormwater management

- ☺ When collected, stormwater can be used for non-potable water supply such as irrigation of parks and gardens, toilet flushing and industrial use.
- ☺ Stormwater can be used to recharge aquifers, from where it can be re-abstracted for supply purposes at a later date.
- ☹ Stormwater is a pollution threat, as it can convey contaminants such as oils, heavy metals, nutrients and sediment into water supply sources, increasing the cost of treating the water to drinking quality.

Water supply > Wastewater management

- ☺ The reuse of greywater and treated wastewater is an alternative water supply source that can supplement a city's water demand needs, particularly non-potable uses such as parkland irrigation and industrial use.
- ☹ Residential, commercial and industrial water use is directly related to the volume of wastewater to be treated. Rising consumption increases pressures on wastewater treatment infrastructure.
- ☹ Poorly treated wastewater discharges due to leakages, overflows and inadequate treatment can pollute water supply sources such as aquifers and lakes.

Wastewater > Stormwater management

Wastewater collection: Stormwater collection is linked to wastewater management through combined sewer networks. Heavy rainfall can cause overflows from the network releasing untreated sewage into the environment.

Wastewater treatment: Combining stormwater with wastewater increases the volume and cost of wastewater treatment. Treatment measures also need to cope with additional pollutants contained in stormwater such as heavy metals and oils.

Water management is also closely linked with urban development as a whole. Looking at the bigger picture, this link is obvious, as most economic activities in a city are dependent on a reliable supply of water and a healthy living environment. But there are also other examples of urban sectors such as energy, waste and transport that are influenced by, and have an influence on, the successful management of water in a less obvious way.

Some of the most significant links, both positive and negative, between water management and urban planning and development are shown in figure 6.

SWITCH research and demonstrations have occurred across the water cycle. For organisational purposes, results and information have been nominally allocated to the areas of water, wastewater or stormwater, but it is important to understand and consider the links between these areas.

figure 6 **Examples of how the urban water cycle is linked to other urban management sectors**

Parks and recreation
- ← Increased water use for irrigation
- ← Ornamental lakes provide storage for fresh water
- → Wetlands contribute to biodiversity and birdwatching
- → Flooding and drought damages plants and playing fields
- → Lakes and waterways provide recreational opportunities such as water sports and fishing

Health
- ← Watercourse pollution caused by pharmaceutical waste
- → Waterborne and parasitic diseases caused by contaminated and stagnant water

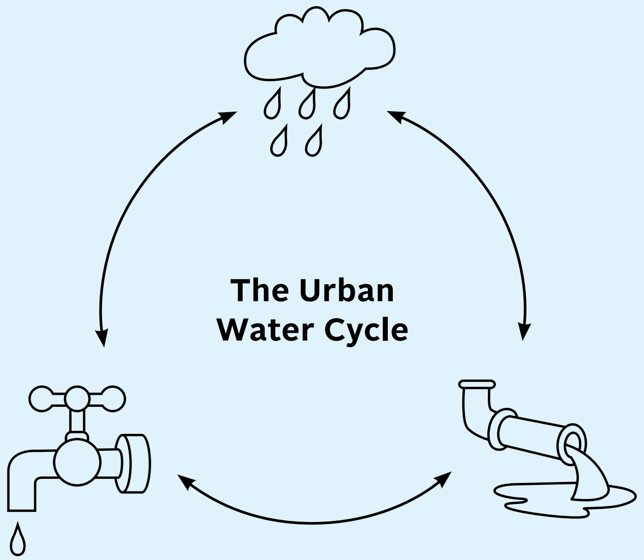
Housing
- ← Additional water supplies and water and wastewater infrastructure required
- ← Opportunities for small scale water management solutions
- → Flooding of property

Waste
- ← Pollution of water resources and blocking of drainage channels
- → Flooding of waste collection sites

Transport
- ← Increased surface runoff and diffuse pollution from roads
- → Damage to transport infrastructure caused by floods

Economic development
- ← Increased water demand and risk of pollution from wastewater discharges
- → Water scarcity can restrict economic productivity

Urban agriculture
- ← Runoff containing fertiliser and pesticides can pollute local water bodies
- → Water scarcity restricts productivity in urban farms



Energy
- ← Water costs heavily influenced by energy costs
- → Water resources are used for energy generation

Land-use planning
- ← Changes in land use alter the local hydrology
- → Water scarcity and flood risk restrict land development

← impact of urban management sector on water cycle
→ impact of water cycle on urban management sector

Tanner Springs Park has become a much-appreciated place for quiet recreation. Courtesy (© J. Hoyer).

figure 7

Linkages between the urban form and the urban water system

Water

The need for sustainable water supply management

Despite being arguably the most important factor affecting the quality of life in a city, when operating smoothly, water supply services are not given much thought. That of course changes quickly when problems occur and inhabitants are reminded of the severe impacts that a limited supply of good quality water can have on their standard of living. In some cities this is part of every day life with significant social and economic consequences. In others it is a rare occurrence but one which typically results in a public outcry.

The public usually associates the quality of water delivery services directly with the amount of rainfall that falls on a city. Shortages are understandable if there has been a prolonged period of drought. This is of course valid to some extent but what many people don't consider is the challenges and related costs involved in collecting, treating and distributing this water throughout the city. The management of these aspects is however crucial if a city is to provide an acceptable level of service to its citizens.

The overall goal for water supply in a city can be described as follows:

Provision of a safe, reliable and affordable supply of sufficient quantities of water for all citizens

The Conventional Approach
The conventional approach to urban water supply is based on the concept of developing water resources and the accompanying infrastructure to meet user demand.

By damming rivers, sinking boreholes, constructing treatment facilities and laying distribution networks, most cities are able to provide a piped supply of clean water to homes on a 24 hour basis. This approach to water supply has been in operation in some cities for well over 100 years and today it remains the most sought after solution in those that continue to rely on water vendors and unregulated abstractions. The management of the different components of water supply under the conventional approach are as follows:

Demand: Supply is provided to meet demand. Water use is charged either on a fixed cost or in relation to the volume consumed. Different charges typically apply to different uses, for example domestic supplies are priced differently to industrial or agricultural ones. Demand is forecast using current data and historical trends.

Resource: Resources are developed to ensure water availability on a consistent basis. This includes the damning of rivers and the construction of dams to capture high river flows for use in drier periods as well as sinking of wells to access groundwater.

Abstraction: Required volumes of water are abstracted from the most economically efficient resources available. Abstraction regimes are devised based on the predicted demand and the hydrological, infrastructural and licensing constraints of the different sources.

Treatment: Treatment techniques are employed according to the quality of raw water abstracted from the source. A clean groundwater source can require as little treatment as a dose of chlorine to render it potable whereas water from a polluted lake may require a series of energy and chemical intensive treatment measures to achieve the same result.

Distribution: Water is distributed to demand nodes through a piped distribution network. Depending on typography, this may be pumped or gravity fed. Leaks from the system are located and repaired only if it's economical to do so.

The concept on which the conventional approach to urban water supply is based on can achieve the overall objective of delivering a safe and reliable supply of water directly to the user. However, the sustainability of the technologies used are in many cases questionable. A large number of issues are associated with the approach that can result in inefficient operation, poor service and environmental damage in cities in developed and developing countries alike.

A more sustainable approach makes use of proactive measures to maintain operational efficiency and influence user demands. Rather

Issues that are commonly associated with urban water supply systems.

- Unsustainable use of local resources: The need to meet increasing demands can cause over-abstraction from local resources. This leads to depleted groundwater levels and low river flows which have consequences for future supplies and downstream users, as well as causing damage to aquatic ecosystems
- Energy use: Water supply is reliant on energy for treatment and pumping, as well as when supplies are imported from elsewhere. This leaves the service vulnerable to power cuts and variations in fuel costs, and typically increases a city's carbon emissions.
- Pollution: Upstream water pollution increases treatment costs and can cause reduced use and abandonment of water supply sources.
- Non revenue water: In some cities as much as half of the treated water entered into the distribution network is lost through leakages and illegal connections.
- Waste of resources: Water treated to potable standard is used for non-potable purposes such as toilet flushing, garden use and industry. This, along with leakage from the distribution network, results in expenditure in unnecessary treatment.
- Cost: The cost of constructing, operating and maintaining water supply pumping, treatment and distribution infrastructure is high and can not always be reclaimed from the customer.
- Non-flexible: Water treatment plants and distribution infrastructure have a design capacity based on forecasted water demands. These systems are not easily adapted if the forecasts prove to be too high or too low.
- Inefficient use: Where water is heavily subsidised or charged based on a fixed rate, users have little financial incentive to use it sparingly. This leads to wasteful usage and high consumption rates.

than accepting deteriorating quality at the source and increasing water usage, the approach looks to prevent these from occurring in the first place.

This approach applies not only to water demand management options but also to solutions that are directly relevant for other sectors. Rainwater harvesting is linked to urban runoff and can form part of a more sustainable approach to stormwater management. Greywater reuse and the recharging of aquifers with treated effluent is likewise closely related to sustainable wastewater management. The options should therefore always consider the benefits and costs elsewhere and look for combinations of solutions that maximise and minimise these respectively. It should be noted, however, that the degree of sustainability associated with any option is highly dependent on the local conditions in which it will be implemented. An option that ticks all sustainability boxes in one city may do the complete opposite in another.

One of the main benefits of managing demand, using alternative sources and controlling resource pollution is the added resilience to future uncertainty that this approach offers. Most supply infrastructure is inflexible and cannot easily be adapted if the forecast conditions for which it was designed fail to materialise.

Increased flexibility is just one of a number of economic, social and environmental benefits that a shift from a conventional to a more sustainable approach can deliver. Additional benefits include:

More efficient treatment: Source control of resource pollutants and the use of natural systems such as riverbanks to pre-treat abstractions reduce the treatment required to produce water of drinking standard.

Economic savings: Reducing water demand results in less water to abstract, treat and distribute. This saves in chemical and energy costs.

Environmental protection and enhancement: Reduced demand results in less water needing to be abstracted from the environment. This helps to maintain and restore ecosystems that rely on a healthy aquatic environment.

Improved service: Reduced demand and the use of alternative supplies relieve pressure on resources such as reservoirs and aquifers that may be scarce during dry periods. This lessens the risk of water use restrictions and supply interruptions for households, businesses and industry.

Reduced carbon emissions: Managing demand and source pollution results in less energy consumed for the abstraction, treatment and distribution process. This reduces carbon emissions in cities where non-renewable energy is used for this purpose.

Flood control: The collection of rainwater from roof surfaces for non-potable water supply reduces the volume of runoff that has to be managed by a city's drainage system. This reduces the risk of downstream flooding and erosion. [Link to Module 3b]

Reduced volumes of wastewater: Low-flush toilets and greywater reuse for non-potable purposes reduces the volume of wastewater to be collected and treated. This improves the performance and economic efficiency of the wastewater treatment process. [Link to Module 3c]

Greater resilience: Uncertainty surrounding future demand and availability of supplies complicates decision-making for water supply investments. Solutions that target demand reductions and the use of alternative sources rather than resource development and infrastructure expansion are less vulnerable to inaccurate forecasts and predictions.

Options for sustainable water management

Despite the fundamental differences in approach, a more sustainable water supply system is still made up of the same structural components as a conventional system (resource, abstraction, treatment, distribution, demand). The difference is in the options selected to operate the system efficiently and maintain the supply-demand balance. Figure 8 illustrates these differences.

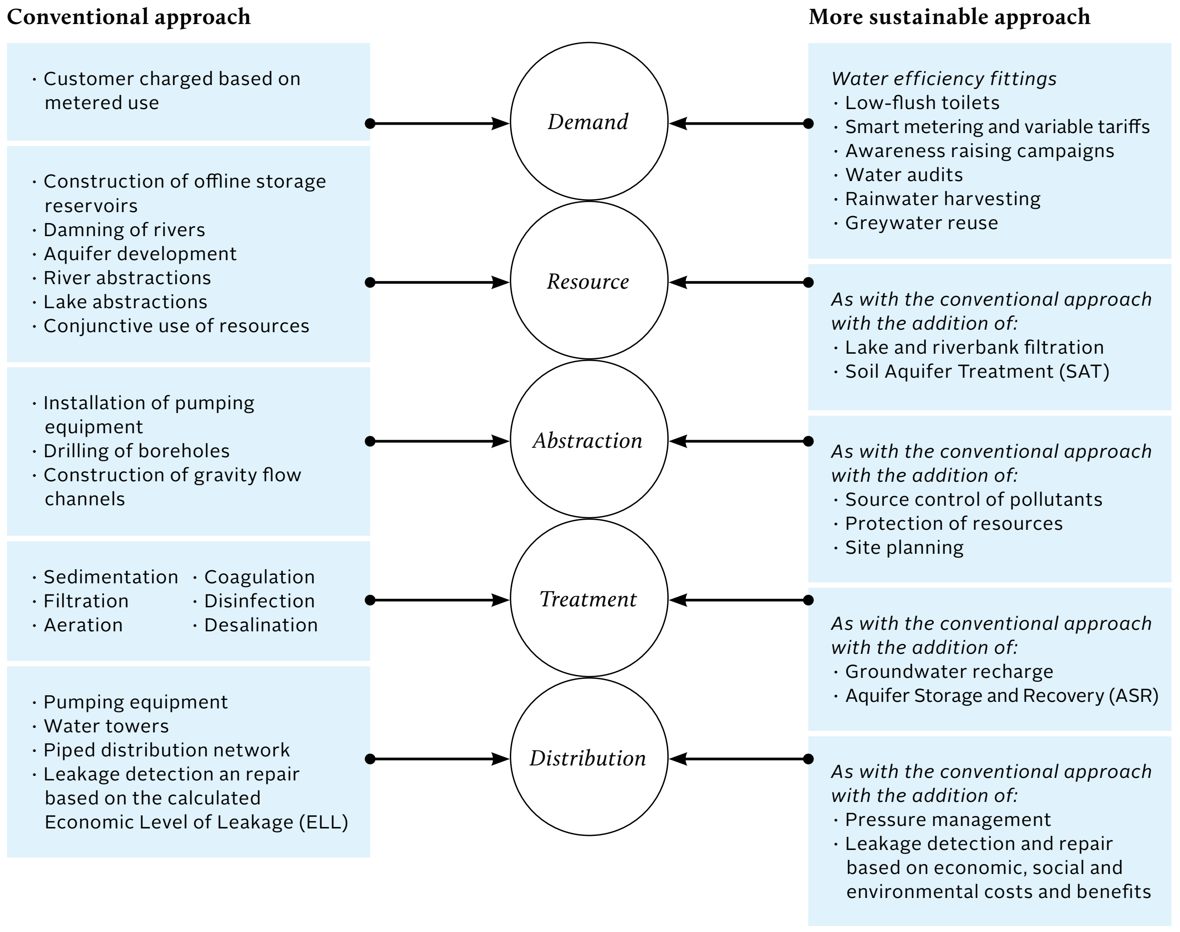


figure 8 **Water supply management components**

In line with an integrated approach to urban water management, many of the options to reduce demand and provide alternatives to increased water abstraction from natural sources should be implemented in tandem with a range of other solutions that achieve similar aims. This is particularly the case for options that aim to reduce water consumption by users. These solutions are mostly compatible so can easily be implemented together to maximise savings. A combined approach is also the most practical. If the opportunity exists to retrofit low-flush toilets then chances are that low flow showerheads and taps could also be installed at little extra cost beyond the price of the fittings. By implementing a combined suite of measures the unit cost of water saved becomes cheaper and the options more attractive to investors.

SWITCH Water Research

Managing Demand
The overall objective of SWITCH work on water demand management was to develop and test holistic demand management tools, which would assist water service operators to effectively manage water demand in their water supply systems. To develop these tools, research was mainly carried out in Zaragoza (Spain), Alexandria (Egypt), Accra (Ghana) and Kampala (Uganda). The results of this work have been condensed into a book (Kayaga, S., Smout, I. (2011)

End use analysis is an emerging area of research, particularly in the developing country context. Activities in Alexandria, focused on modelling water end uses to create a composite picture of the cities overall demands and options to maintain the demand and supply balance (Retamal, M, White, S, 2011). This analysis was undertaken using an integrated resource planning framework. It identified the need for new institutional frameworks including national regulation of appliance efficiency and local regulation of new buildings and developments. Indicative costing of options suggested that there were some highly cost-effective options, particularly water efficiency options, that could be the subject of investment.

Modelling of options using end-use analysis was taken further in SWITCH through the application of the VENSIM model, a system-dynamic, simple decision support tool for ranking demand management options using economic cost-benefit analysis. The tool is freely available for download at: http://www.switchurbanwater.eu/res_software.php

table 5 **Demand and Supply Options modelled for Alexandria**

Code		Water saved or supplied in 2037 (mm³/year)	Unit cost (PV$/PVm³)
DM1	Household water saving fittings retrofit	26	0.08
DM2	Toilet replacement program for households	6	0.53
DM3	Tourist & commercial buildings audit & retrofit	30	0.11
DM4	Government buildings audit & retrofit	41	0.08
DM5	Industrial facilities audit & retrofit	34	0.06
DM6	System leakage reduction	59	0.02
DM7	Tariff reform	57	0.00
DM8	Agricultural efficiency offsets (to increase supply to the city)	75	0.01
DM9	Appliance efficiency regulation (at the national level)	21	0.02
S1	Desalination for coastal resorts	42	1.15
S2	Wastewater reuse for industrial properties	32	0.60
S3	Agricultural drainage water desalination & reuse for industries & coastal resorts (non-potable use)	62	0.63
S4	Wastewater reuse for agriculture	63	0.48
S5	Groundwater for urban green space irrigation	18	0.48
S6	Local wastewater reuse for new developments (incorporating decentralised sewer systems)	37	0.40
S7	Local wastewater reuse & nutrient recovery (incorporating decentralised sewer systems & urine diversion)	37	0.58

Source: Retamal and White 2011

Promoting behavioural change

ZARAGOZA, SPAIN

Unlike water efficiency measures such as low-flush toilets and water efficient washing machines, changing consumer water use behavioural patterns can achieve substantial water savings without the need of technical interventions.

Education and awareness raising campaigns reduce water consumption by encouraging consumers to change their water use behaviour. Highlighting the economic and environmental benefits of efficient water use can persuade people to think of water as a commodity, like electricity or gas, that should not be used wastefully.

In Zaragoza water saving devices were installed in people's homes in Actur, and information on good practices were distributed. This was followed by a systematic survey of how these interventions affected household water consumption. In addition to general public education, a combination of economic instruments was applied in Zaragoza to contribute to the city's 'water-saving culture'. The activities were a partnership championed by a non-governmental organization, and composed of other stakeholders such as individual households, governmental institutions, and private sector organizations.

Leakage Reduction

ALEXANDRIA, EGYPT

Informal settlements have grown in Alexandria, as in other cities in developing countries, and now accommodate more than 40% of the population of Alexandria. Recognising the needs in these areas, the Alexandria Learning Alliance picked the Ma'awa el Sayadeen informal settlement for a SWITCH demonstration which included various aspects of Water Demand Management. Non Revenue Water (NRW) was reduced by creating a District Meter Area (DMA), by pipeline survey with leak detection equipment, by identifying and repairing leaks and by replacing mal-functioning consumer meters. Water saving devices were installed in houses, mosques and a youth centre. A borehole was drilled to use groundwater for landscape irrigation, rather than drinking water.

The demonstration also included a water efficiency study, which showed how a range of water demand management options could be analysed (e.g. water efficiency measures in government, tourist and commercial buildings, industries and agriculture, tariff reform, household fittings, leakage reduction) and compared with water supply options (e.g. wastewater reuse and desalination).

As well as the technical innovations, this demonstration is an example of the institutional challenges that governments face with informal settlements and how governments and local communities can work together to provide services in an economical and equitable manner.

http://switchurbanwater.lboro.ac.uk/demos/5.php

Active leakage management

ZARAGOZA, SPAIN

Leakage can account for the wastage of a large proportion of treated water that is pumped into a city's distribution network. Active, rather than reactive, leakage management such as leak detection and repair, water mains replacement and pressure reduction in the network can reduce the amount of drinking water that is lost from the system saving both costs and resources, and improving levels of service.

Leakage from water pipes is a major issue around the world. Under SWITCH, the Zaragoza Municipality instituted a demonstration on water loss management. Four District Meter Areas (DMAs) were set up in Actur District of Zaragoza, with flows and pressures monitored through a Supervisory Control and Data Acquisition System (SCADA), linked to a Geographic Information System and simulation model. Practical guidelines were developed for sectorization of a water system into DMAs, and for setting up the control system, with practical recommendations for wider application in Zaragoza and elsewhere.

Zaragoza water loss management demonstration activities.

Aquifer Storage and Recovery (ASR)

An issue for many cities facing water shortages is not so much a lack of total rainfall but rather a lack of rainfall at the right times. An inability to capture sufficient amounts of high flows during wet weather results in insufficient supplies for use during the dry season when resources are low and demand is high. The construction of storage reservoirs is one solution to this although these are costly, require space, have high evaporation losses and can have environmental consequences. An alternative is Aquifer Storage and Recovery (ASR) which stores high flows underground for abstraction when conventional sources are not available.

ASR works by injecting surplus supplies into existing aquifers during periods of high water flows. This water displaces the native water in the aquifer to form a 'bubble' that can be abstracted using the same injection well when the supplies are needed. The aquifer used for this purpose does not have to be of good quality and it is therefore possible to use saline or polluted aquifers which would not usually be considered for water supply purposes.

The source of water used for ASR can vary. Sources include abstractions from rivers during periods of high flow, captured stormwater runoff and treated wastewater . Treatment of the water often takes place before it is injected although this depends on the quality of the source and the final use of the water. Certain contaminants are also removed through natural treatment processes that occur within the aquifer itself.

Soil Aquifer Treatment

TEL AVIV, ISRAEL

Water security can be increased through the reuse of water. Soil Aquifer Treatment (SAT) and Engineered Environmental Buffer technologies are two methods of treatment that enable water to be used multiple times and returned to the supply side of the infrastructure. The removal of contaminants by different combinations of SAT, membrane systems and conventional pre-treatment and post-treatment systems was demonstrated and analysed in SWITCH.

Conventional long-term Soil Aquifer Treatment (SAT) is one of the oldest, largest and efficient natural tertiary treatment system in Israel and the world. Although a proven technology a solution was needed to address the lack of land for construction of new fields, gradual decrease of the infiltration velocity and manganese precipitation causing clogging of the irrigation systems.

In the EU Reclaim Project-018309 an ultra filtration (UF) - short SAT (30-35 days retention in the aquifer compared to 6-12 months in the current full-scale system) solution was investigated The technique produced good chemical and microbiological quality water but did not remove all measured micro-pollutants effectively due to the short retention time in the aquifer before the water is pumped out.

In SWITCH demo secondary effluents were treated by a short SAT-nano filtration (NF) process for indirect potable reuse. The efficiency of short SAT as pretreatment on the performance of nano-filtration membranes (DOW NF 270 and NF 90) was investigated. This technique efficiently reduced micropollutants including hardly biodegradable antibiotics and organic iodine. It showed that short SAT as pretreatment prior to NF can be an effective technology for unrestricted water reuse and indirect potable reuse while also reducing GHG emissions (smaller carbon footprint) as compared to the more conventional UF-RO systems. Guidelines for design and operation and maintenance of SAT and Hybrid-SAT systems were produced based on these investigations. City to city learning occurred when researchers involved in the Tel Aviv demonstrations work-shopped the possible use of the technology with their Accra counterparts.

Tel Aviv pocket wetlands using treated grey-water from neighboring apartment buildings.

River bank filtration has been recognized as a proven method for drinking water treatment in Europe. But facilities have all been based on local experiences and thus far, there are no tools or a methods that would help to transfer these experiences or the design and operation of a system from one place to another. Surface water sources are vulnerable to a range of pollutants that have to be removed through costly treatment processes. Depending on the quality of the source, riverbank filtration can be an effective way of naturally removing certain common pollutants thereby reducing the cost and energy consumption of drinking water treatment.

RBF works by abstracting surface water through intake wells dug in the river's banks. Pollutants are removed as the water is drawn downwards through the sediment in the riverbank and bed. Understanding the fate of effluent organic matter and natural organic matter through bank filtration is essential to assess the impact of wastewater effluent on the post treatment requirements of bank filtrates. Their fate during drinking water treatment can significantly determine the process design. Laboratory-scale batch and soil column experiments as well as analysis of the data from full-scale bank filtration and artificial recharge sites were conducted to obtain insight into the effect of source water quality (especially organic matter characteristics) and process conditions on the removal of organic micropollutants during soil passage. (Maeng, S.K, 2010)

Water quality from natural treatment systems such as engineered environmental buffers, SAT and bank filtration systems looked at viral fate and transport in aquifers. Removal of pharmaceutically active compounds and endocrine disrupting compounds during bank filtration and artificial recharge was also investigated. A spreadsheet-based tool was developed for prediction or preliminary assessment of removal of these compounds.

With few exceptions, centralised urban water supply systems deliver only water of potable quality (or as close as possible thereof). However, potable use makes up only a portion of total urban use. Water demand for toilet flushing, cleaning, garden use, industrial and agricultural purposes does not require the same quality standards as that of water for drinking yet that is what is typically used.

The use of collected rainwater, greywater and treated wastewater effluent for non-potable purposes reduces demand for potable supplies saving freshwater resources as well as treatment and energy costs for the service.

Rainwater Collection

BEIJING, CHINA

Confronted with severe water shortages, peri-urban farmers in Beijing looked develop multifunctional urban farming systems to deal with the growing problem of lack of water for irrigation. As part of SWITCH, a demonstration project on greenhouse production combined with rainwater harvesting was developed.

Involving several institutions and a vegetable cooperative in the Huairou district of Beijing, the project has shown that rainwater harvesting can provide a useful source of water for intensive agriculture in greenhouses and is particularly feasible and profitable if the multiple functions of agriculture are combined. An example of this is the covered rainwater storage pond used in the demonstration. The pond has the dual purpose of storing irrigation water for use in the greenhouses as well as generating humid conditions which are ideal for growing mushrooms providing the farmer with a higher economic return.

The farm in Huairou depended totally on groundwater, since there was no access to surface water, but this groundwater needed to be pumped from about 40m. Using rainwater reduced the cost of water and increased the total amount of available water. Other innovations demonstrated were: improved production for the Beijing market (grapes, dragon-cactus, mushrooms); agro tourism; groundwater infiltration; and involving the (often new) sectoral institutions (water and agricultural bureaus).

The demonstration project showed positive results providing high quality irrigation water and increasing farmers' income substantially. The higher returns did not only compensate for water fees, but also enabled farmers to pay for the relatively high investment of rainwater harvesting facilities. Local government, which participated in the working group (Huairou District), acknowledged these results and support further application of the developed technology. The results have been integrated into current policies and under China's 12th five year plan (2011-2015).

The rainwater harvesting technology as such is not new. The combined innovations: the technology of combined greenhouses, the storage pool, the improved production, as well as the organisational model (the cooperative) and institutional linkages were. The Beijing Agricultural Bureau has been experimenting with several RWH models, and is now including the one supported by SWITCH. The system developed with the Huairou cooperative is seen as a promising technology.

Hairou Cooperative Greenhouse Rainwater Harvesting System.

Rainwater Collection

BELO HORIZONTE, BRAZIL

In Belo Horizonte, rainwater harvesting demonstrations were developed with a focus on municipal schools and urban agriculture. The first demo was on the use of rainwater for irrigation of gardens, agriculture plots and cleaning of impervious surfaces at the Anne Frank High School. The demo showed a high potential for education on water issues (e.g.: water consumption, saving water, water quality). A local Learning Alliance was established at the school and surrounding neighbourhoods. The project has been intensively discussed with students, teachers, school staff and parents of students. Students are in charge of monitoring the system and reporting back to the school community.

The focus of the second demo was on urban agriculture. A plot was developed in cooperation with the local community and IPES. Technical development of the project was done by UFMG students, the system construction by Belo Horizonte municipality, and operations are done by the local community. Participants were trained on general concepts of urban water sustainability as well as on the techniques for cistern construction. Results showed that rainwater can supply up to 50% of volumes required for irrigation.

In parallel to the demos, a research project on the economics of rainwater harvesting was conducted according to typical water consumption and dwelling characteristics for different socio-economic classes in Belo Horizonte.

BH Stormwater Collector at Barreiro Productive Garden (Thiago Salles).

Greywater Recycling

CHENGDU, CHINA

Greywater recycling can provide significant additional water supplies. Approximately 300 decentralised wastewater reclamation systems are in operation in China, producing 50,000 – 60,000 m^3 / day of secondary quality water that is used for toilet flushing, landscape irrigation, street cleaning and car washing. The Ministry of Construction aims to upscale this approach across China within its current program on sustainable building.

The SWITCH demonstration, at the Chengdu CMC New Campus, aimed to assess the potential benefits of decentralised urban wastewater systems with use of treated grey water for landscaping.

Due to construction delays, all monitoring results could not be finished by the end of SWITCH, However, a design report of the system and the monitoring plan are available.

It is expected that the demonstration will have a China wide exposure because it is part of a wider sustainable building program of the Chinese Ministry of Construction. As such it may contribute to alleviating water scarcity in over 450 cities in China.

Wastewater

The need for sustainable wastewater management

Within the urban water cycle, the management of the wastewater component is often the most complex. When systems are well designed and maintained the water based waste of a city is safely collected, treated and disposed or reused without impacting on the quality of urban life. However, when systems are inadequate or non-existent the resulting pollution leads to disease and environmental degradation.

Despite its importance in our cities, for most urban dwellers wastewater management, particularly the human waste aspect, is an unpleasant subject, a cultural taboo and a topic best ignored. If a system exists that allows users to flush the toilet, take a shower and wash the dishes without having to think about what happens next there are likely to be few complaints.

Looking beneath the surface however there are considerable requirements concerning the management of the used water flows to ensure that:

- The threat of contamination and human disease is eliminated
- Damage to the natural environment is minimised

The management of urban wastewater involves the collection, conveyance, treatment and reuse or disposal of various flows differing in composition and treatment and disposal requirements.

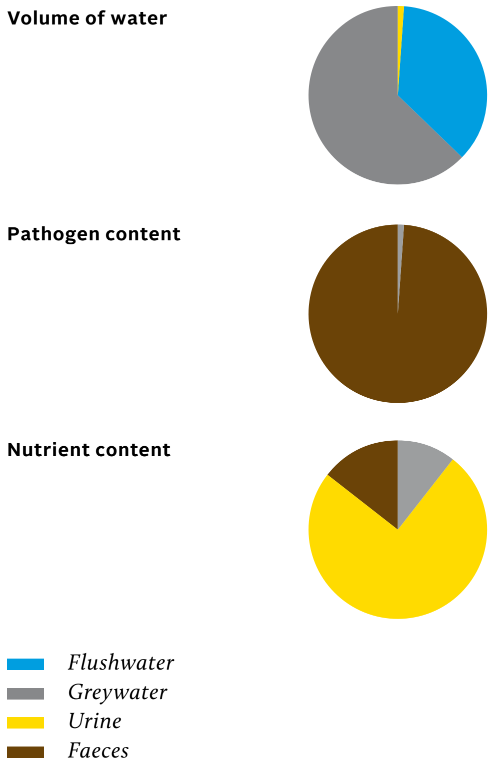
These include:

- Faeces: (Semi-solid) excrement without urine or water.
- Urine: Liquid waste produced by the body to rid itself of urea and other waste products.
- Flushwater: Water that is used to transport excreta from the user interface to the next technology.
- Blackwater: The mixture of urine, faeces and flushwater.
- Greywater: The total volume of water generated from washing food, clothes and dishware as well as from bathing.
- Stormwater: The general term for the rainfall runoff collected from roofs, roads and other surfaces before flowing towards low-lying land.

Source: Tilley, E. et al, 2008

Each of these elements is made up of different quantities of water, pollutant loads and nutrient content. The challenge facing cities is to manage the different elements in an affordable and beneficial way (i.e. to capture nutrients, water and energy) with minimal impact on human health and the natural environment.

Distribution of main contents among the different elements of wastewater (excluding stormwater)



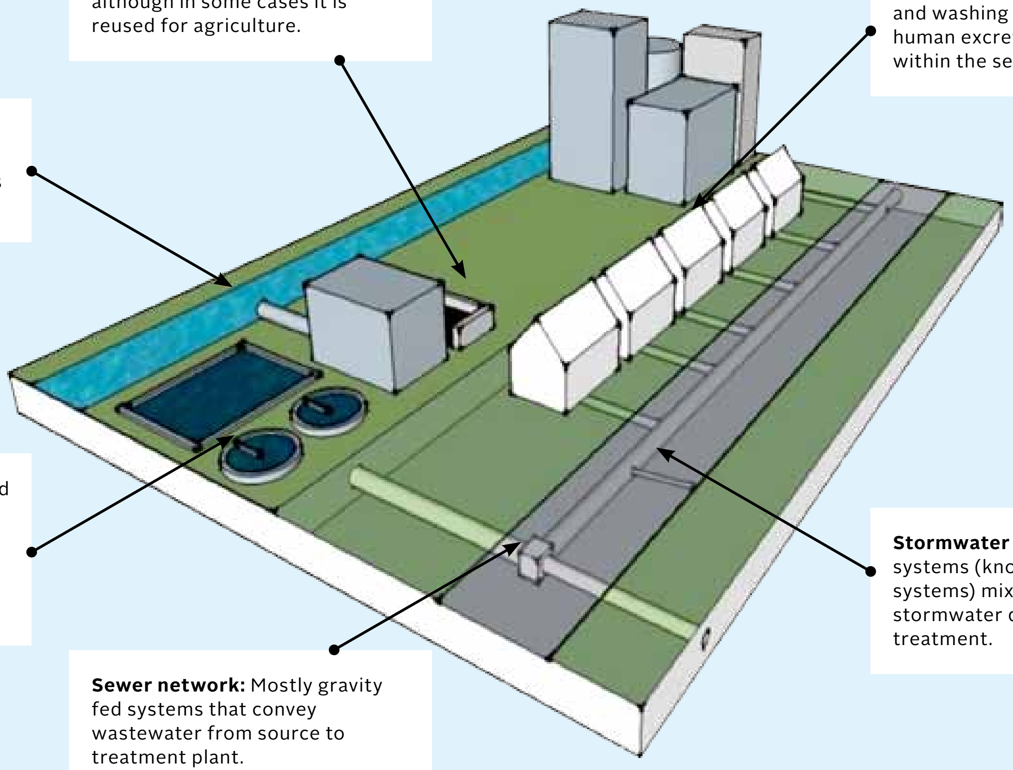
The conventional approach to wastewater management

The conventional approach to urban wastewater management is based on a centralised system that collects and treats a combined flow of most or all of the wastewater elements.

This approach dates back to Roman times but was developed in its current format during the industrial revolution as cities were growing in size, population and density. The increasing volumes of untreated human waste severely affected the health of inhabitants resulting in outbreaks of diseases such as cholera. To overcome the problem, water based toilets, piped sewer networks and centralised treatment facilities were constructed which proved to be an effective solution to prevent the spread of disease through human contact with wastewater in the city.

Over 150 years later this concept remains the most common and most sought after approach to urban wastewater management throughout the world. As shown in Figure 9, the system uses a network of sewerage pipes to collect wastewater from individual households, businesses, industries and, in some cases, rainfall runoff. The pipes convey the mixed flows to central treatment facilities where the combined effluent is treated and discharged to surface water bodies.

figure 9
Conventional wastewater management



The issues facing a conventional approach to wastewater management

The perceived notion that successful wastewater management is dependent on a centralised collection and treatment system is not necessarily true. Although when well designed and maintained the system protects public health and has few environmental consequences, not all urban settings are compatible with conventional designs and even in the ones that are, a range of limitations raise the question of sustainability in the long-term.

Some of the issues currently confronting conventional urban wastewater management are as follows:

- **Dilution of flows:** By combining all wastewater streams, treatment techniques are required for large volumes of diluted wastewater. This results in an inefficient treatment process.
- **High water use:** Conventional systems require a reliable supply of water to operate (for the flushing of toilets and conveyance of waste). The water needs for the system typically account for around a third of a household's water consumption.
- **Pollution risk:** When functioning poorly or combined with stormwater collection, wastewater transportation networks may leak or overflow causing untreated wastewater to be dispersed to the environment.
- **Cost:** The cost of constructing, operating and maintaining centralised wastewater collection and treatment infrastructure is high.
- **High energy demand:** Conventional centralised wastewater treatment is energy intensive and therefore requires a reliable and affordable power supply to operate effectively.
- **Waste of a valuable resource:** Centralised systems fail to exploit the valuable resources present in human excreta and grey water such as the nutrients and energy it contains, and the potential for non-potable water supply uses.
- **Nutrient overload:** Typical discharges from centralised wastewater treatment plants contain high levels of nutrients. These cause an increase in algal blooms and a depletion of oxygen in receiving water bodies.
- **Non-flexible:** Large wastewater treatment plants have a limited capacity based on forecasted volumes of wastewater and, in combined systems, the predicted stormwater runoff rates. These systems are not easily adapted if design specifications prove to be too high or too low due to population growth, migration or change in climate patterns.
- **Inappropriate for local conditions:** Technology and infrastructure are based on 'one-size-fits-all-solutions' which may not be suitable for the needs of the location in which they are placed.

Conventional wastewater management is a rigid solution and this lack of flexibility means that it is vulnerable when confronted by future uncertainty. In cities where sanitation systems are either non-existent or badly designed and maintained, the ability to keep up with rising pressures such as rapid urbanisation and population growth is obviously a massive challenge. But even in cities where effective centralised systems have been in place for decades, anticipated future challenges are raising increasing doubts over an approach to wastewater management that was previously unquestioned.

Box example: The European Urban Wastewater Treatment Directive
Adopted in 1991, the European Urban Wastewater Treatment Directive (91/271/EEC) addresses the need to protect Europe's groundwater, rivers, lakes and seas from the impacts of poorly treated wastewater. The Directive requires that all wastewater generated in areas with a population in excess of 2000 or equivalent must receive at least secondary treatment. In addition, cities identified as being in vulnerable, or 'sensitive', areas face more stringent treatment requirements. The Directive is closely related to the European Water Framework Directive (2000/60/EC) which requires that all waters in the European Union achieve good ecological status by 2015.

Despite being introduced almost 20 years ago, the Directive continues to pose a significant challenge for cities throughout Europe. In particular the more stringent treatment requirements for big cities located in 'sensitive' areas is still a major issue and 50% of the load from these cities is still being discharged without adequate treatment (5th Commission Summary on the Implementation of the Urban Waste Water Treatment Directive).

Further information on the Urban Wastewater Treatment Directive can be found at: *http://ec.europa.eu/environment/water/water-urbanwaste/index_en.html*

A more sustainable approach to wastewater management

An alternative approach to wastewater management views wastewater not as a problem that needs to be disposed of but rather as a variety of resources that, when managed correctly, can be reused.

An integrated approach that is based on the cyclical processes observed in nature on the other hand encourages the separate collection, treatment and reuse of urine, faeces, greywater and stormwater. This approach is considered more sustainable as solutions can be applied that improve treatment performance at less cost and enable resources to be recycled more efficiently.

figure 10 **Linear versus cyclical wastewater management**

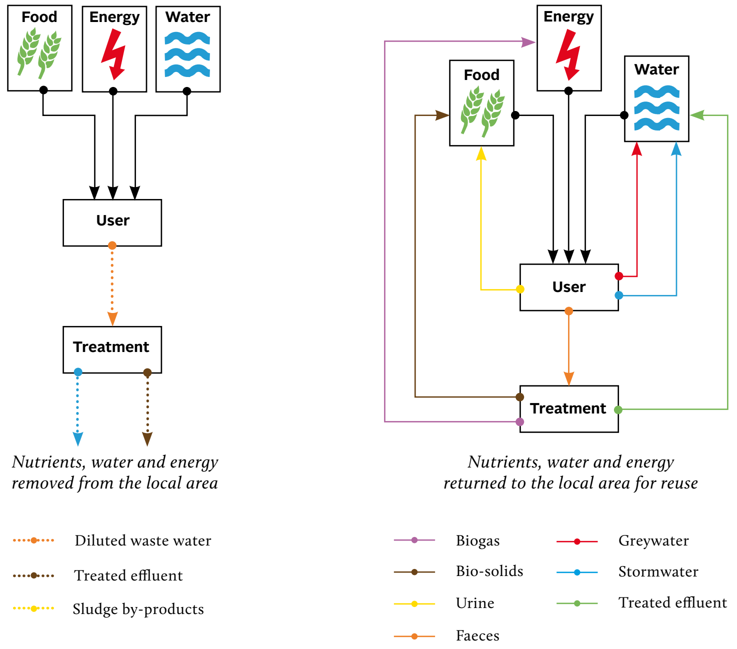


table 6 **Key differences between a conventional approach to wastewater management and a more sustainable approach**

Aspect of wastewater management	Conventional approach (wastewater management as a linear process)	Integrated approach (wastewater management as a cyclical process)
Collection	Faeces, urine, greywater and stormwater are combined and conveyed through an expensive sewer network to a centralised treatment facility	Faeces, urine, greywater and stormwater are collected separately and managed close to the source
Treatment	Centralised treatment of combined wastewater elements based on energy and chemical intensive infrastructure and technology	Decentralised treatment of separated wastewater elements based on innovative technologies and natural systems
Treated effluent	Treated effluent is discharged downstream to receiving water bodies such as rivers, lakes and estuaries	Treated effluent is reused locally for non-potable water supply purposes
Nutrients	Nutrients are disposed of in the environment through discharged effluent and sludge	Nutrients are recycled and reused locally through the recycling of urine and creation of biosolids from faecal sludge
Sludge by-product	The sludge by-product is disposed of in landfill or through incineration	Sludge is digested to create biogas and converted to biosolids for use as fertiliser and soil conditioner
Energy consumption	Large amounts of energy are used for treatment and pumping	Low energy consumption through the use of natural treatment processes.

When operating as intended, the conventional approach to wastewater management prevents disease and environmental pollution – the most important objectives for any system. But as highlighted above this approach also fails to take advantage of the many opportunities that exist when wastewater is recognised as more than just a waste product to be disposed of as efficiently as possible.

By adopting an approach to wastewater management that is based on decentralised solutions for separation and reuse, the key health and pollution control objectives are achieved as well as the following additional benefits:

- **Increased access to sanitation:** Decentralised systems can provide low-cost sanitation at the household and community level in areas where lack of funds and logistics prevent the provision of centralised infrastructure.
- **Water savings:** Recycling greywater, stormwater and treated blackwater (water containing urine and faeces) for irrigation and other non-potable uses reduces demands on the water supply network. In addition, recycled wastewater can be used to recharge aquifers during dry periods.
- **Flexibility to change:** Urban population growth challenges the design capacity of centralised sewers and treatment facilities. Decentralised systems prevent infrastructure overload by separating greywater and stormwater and managing human waste at the household and community level.
- **Recycling of plant nutrients:** Urine and biosolids from faeces provide a cheap and environmentally friendly source of fertiliser and soil conditioner for agriculture and urban greening. The extraction and reuse of nitrogen and phosphorus also prevents nutrient overload in local water bodies.
- **Financial savings:** The construction and operation costs of many decentralised wastewater management options are low compared to centralised systems. Savings are made through reduced energy and chemical costs, and additional revenue can be gained through the reuse of wastewater and the nutrients and energy it contains.
- **Employment generation:** Resource recovery and productive reuse creates additional employment and may stimulate private (micro-) enterprises.
- **Energy recovery:** Blackwater can be digested to create biogas. This can be used as a cheap, renewable source of energy for cooking, electricity generation and vehicle fuel.
- **More efficient treatment:** The separation of wastewater flows and confinement of specific pollutants allows the most effective and cost efficient treatment techniques to be employed. Pathogens, heavy metals and micropollutants such as pharmaceuticals can therefore be isolated and removed more easily than is possible in diluted flows.
- **Urban biodiversity and amenity:** The construction of wetlands and other natural systems for wastewater treatment provides habitats for biodiversity and increases the area of green space in a city.

The benefits listed above clearly show that the management of wastewater is closely linked with other areas of the urban water cycle as well as urban planning as a whole. Rather than selecting options based on narrowly defined problems and objectives, a more sustainable approach can identify multi-purpose solutions that provide urban benefits within and beyond the sanitation sector.

SWITCH Wastewater Research

The SWITCH activities in the wastewater area were concentrated on “ecosan” and wastewater treatment methods and recycling of wastewater and its nutrients for urban agriculture. Cleaner production technologies and conflict resolution measures were also explored with the Bogota, Colombia tanneries.

Ecosan
Ecosan (ecological sanitation) research focussed on the issues related to implementing and operating urban ecosan systems. A comprehensive overview of drivers and barriers for ecosan implementation, operational experience and user perception based on over 100 case studies was conducted. The practical implementation of source-separating sanitation systems in urban and rural settings has shown to be rather complex due to the involvement of many actors, such as project developers or housing corporations, future inhabitants, the local municipality, water authorities and water utility companies. Another important barrier in implementing new sanitation systems is that in most cities, sewer systems already exist and investments in assets have already been made. Development of new sanitation options in most western countries therefore requires a long-term vision. Despite the complexity, a number of demonstration projects based on source-separation have been realized inside and outside the European Union in the past 15 years.

At present the source-separating systems can be divided into two basic approaches. In the first approach grey water (shower-, washing-, and bath water) and black water (toilet water) are separated at household level and treated separately and reused as fertilizer (urine, composted feces) or as second quality water (for toilet flush and irrigation). The treatment is decentralised at the neighborhood scale or off-site. In the second approach urine is separately collected and treated or used as fertilizer. Urine separation can be implemented in combination with conventional sewerage discharge or in combination with grey and black water separation.

In order to assess the potential of source-separating sanitation systems for wide-scale application in the long run, it is important to learn from these practical experiences. One of the outputs of the wastewater research area is an investigation into practical experiences with source separation in urban settings.

Practical experiences with implementing and operating various types of source-separation in urban settings in China, Germany, Norway, Sweden and The Netherlands, including urine separation and reuse as fertilizer, vacuum systems for black water removal and grey water reclamation systems were documented.

Ecosan implementation is complex due to the involvement of many actors, such as project developers or housing corporations, future inhabitants, the local municipality, water authorities and water utility companies. Different stakeholders were approached and performance assessments were conducted. Two questionnaire surveys were undertaken between August 2007 and March 2008 with experts in the North and South who have been strongly involved in ecological sanitation. Respondents ranged from field workers testing pilot ecological sanitation schemes to researchers working full-time on understanding specific aspects of ecological sanitation. In response to the first questionnaire, champions of ecological sanitation mentioned various reasons why ecological sanitation did or did not work. Responses to the second questionnaire, gave further information on the important factors for scaling up ecological sanitation from the user perspective: driving forces and barriers for implementing and using ecological sanitation; the Government perspective - creating an enabling environment; the product user perspective - the end users of excreta and/or urine in agriculture

The study shows that Ecosan, in its various forms, can generally successfully be implemented. In some cases operational problems were identified, however by using innovative solutions found in other projects these could be overcome.

Ecosan technologies still have higher initial investment costs, compared to conventional technologies. This is a barrier for upscaling. The potential of reuse water and other resources (e.g. nutrients) may provide a pay-back mechanism which might even be very attractive if water is scarce and expensive as was shown in the case of Beijing.

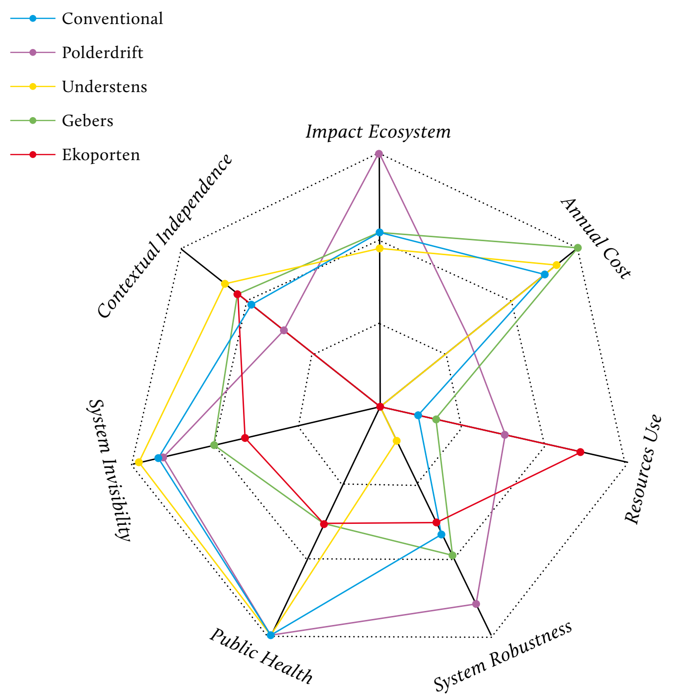
From a user perspective, there remains a reluctance to accept dry ecosan toilets as an option, mainly because of reluctance to handle the by-products (urine and faeces).In order to find acceptable solutions, it is of critical importance that stakeholders ranging from government personnel to households are more aware of the potential benefits of ecosan In particular, it needs to be made clear that the end product is no longer faeces, but a nutrient rich derivative that is no longer unsafe or impure.

There is a general lack of support and co-ordination at all governmental levels, national, intermediate and municipal. Several countries lack any general policies and/or regulation focusing on sanitation, let alone consider ecological sanitation as one of a range of options. Consequently, ecosan is often not taken seriously or takes place only in small scale pilot schemes which are not converted into large scale sustainable projects.

A particular focus of the Ecosan work was on treatment processes for pharmaceuticals with research on biological and physico-chemical removal of these compounds from concentrated wastewater flows including the potential uptake by plants. An inventory of the most important compounds was compiled. Urine from public toilets in Accra provided a case study of pharmaceuticals content.

Current best practice in urban ecosan systems was also explored and an approach for technology selection based on a multi criteria approach developed. The developed approach uses a set of seven scores describe system performance: contextual independence, public health, impact on environment, resources use, system robustness, invisibility and cost. The framework was tested by evaluating 5 systems. Results are shown in Figure 11.

figure 11 **Graphic from Decision Making Tool**



Urine collection and use

ACCRA, GHANA

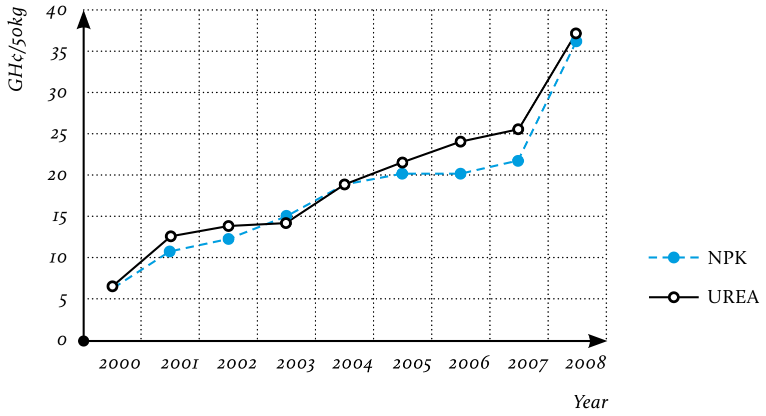
Proper liquid waste collection and management technologies are generally absent in most public urinal facilities in Accra. The initial agreement between the Accra Waste Management Department and the entrepreneur who has the franchise to operate the urinals in a section of Accra was that, the urine generated from these urinals should be collected and disposed of at one of the government's waste disposal sites. Unfortunately this agreement has not been adhered to. Consequently, all the urine that comes from these urinals was discharged directly into the Korle lagoon untreated seriously polluting this water body. A study (Cofie et al 2007) on 14 of these urinals which are located within the Central Business District revealed that 7.3 m^3 of urine is generated per day. This is approximately 2.2 thousand m^3 of urine per year. In terms of nitrogen alone this volume represents 6.6 tonnes of plant available nitrogen. Rising costs of fertilizer in Accra (see Figure 12) prompted an economic analysis of this urine to see if it could compete with locally available fertilizers.

By harvesting and using urine for urban agriculture, a win-win situation could be achieved. Relief could be achieved for the urinal entrepreneur who is thinking about where to dump his waste. The city authorities could also be relieved of the burden of the pollution that the current urine discharge is causing and the urban farmer may obtain a reliable and cheaper fertilizer source.

Wageningen University developed a method to evaluate Ecosan options with case studies in Accra and Alexandria. Transport methods to take the products from the urban areas to the agricultural sites were also assessed.


Urban agriculture in Accra, Ghana (R. van Veenhuizen).

figure 12 **Trends in fertiliser prices in Ghana, 2000-2008**



Wastewater treatment and urban agriculture
Wastewater treatment and reuse followed a sequence of implementation Based on situation analysis and stakeholder review working groups were formed in Beijing, Lima, Accra, and Hamburg. The groups met and were linked to the Learning Alliances. They received training in multi-stakeholder action planning and were involved in, and informed on, specific research by consultants, MSc and PhD or action research linked to the demonstrations. Information gained was widely disseminated in publications, magazines and newsletters and guidelines and related training material was developed. The coordinating institute for this activities was ETC in The Nethlerlands with other leading institutes being IWMI (Accra), IGSNRR (Beijing) and IPES (Lima). Other institutions involved were WUR, IRC and NRIGUEL. Agricultural use of nutrients strategies, guidelines, market value and logistics associated with use of sewage based nutrients were also explored.

Urban agriculture contributes to a wide variety of urban issues; it provides multiple benefits for urban inhabitants and can have many different functions. An assessment was conducted to determine which institutions should be involved in the SWITCH working groups on urban agriculture, what need there was for a particular demonstration, and what research should be undertaken. Demonstrations were implemented in Chongqing, Beijing, Lima, and Accra.

Urban Agriculture

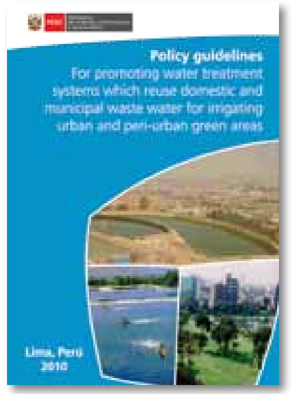
LIMA, PERU

Due to scarcity of rain and the pressure on the water supply, green spaces and productive activities around Lima use piped water, raw wastewater, treated wastewater or river water for irrigation. Agriculture in urban areas has increased in the last decade as a strategy to increase access to food (vegetables) and to generate income and improve the environment. The potential of using treated wastewater for these productive uses has generated interest as national and municipal authorities respond to the need to reduce demand for piped water for uses other than consumption, and to monitor and increase the quality of water used for irrigation of crops in peri-urban areas and green spaces in urban areas.

The demonstration project was designed and implemented in the district of Villa el Salvador, Lima. The Eco-Productive Park, named OGAPU (in Spanish: Optimising Water Management to Combat Urban Poverty), was designed in a participative way through a series of workshops with the community and community based organisations, architects, and authorities. It has four components: recreation (games for children, chess table); sports (a grass football field, cycle path); production (growing ornamental bushes that are sold to city parks); and a tertiary treatment pond for wastewater. OGAPU aimed to show how this decentralised (re) use of treated wastewater could green a 2Ha plot of what was a fairly typical desert like area. The project looked into the possibility of using the water for food production, but it appeared not possible because legislation did not permit using treated wastewater for this purpose.

The demo has shown overall improvement in the area: social (community building, recreation, social inclusion, etc.), economic (income), and environmental (green space, improvement of air, reuse of waste, etc.).

The reuse guidelines were reviewed and finalised with members of the National Learning Alliance in October 2008 and presented in December 2008 at a special session of the National Conference on Water and Sanitation (PERUSAN). The Peruvian Government formally approved them in November 2010. The Policy Guidelines will act as a strategic agenda for the institutions involved. IPES and the Ministry have developed a training package for capacity building of these institutions.



Peru Policy guidelines for Reuse.

Water Recycling

ACCRA, GHANA

Irrigated urban vegetable production in Accra provides up to 90 per cent of the city's need for the most perishable vegetables, especially lettuce, which benefits around 250,000 people daily. Production yields an average monthly net income of US$ 40-57 per farm. Nevertheless, it is associated with health and environmental risks from the use of polluted water and attendant contamination of vegetables with pathogens. Local and international initiatives have responded to some of these constraints. Notably are research projects on safer vegetable production as supported by IWMI, WHO, IDRC, FAO, and RUAF.

SWITCH built upon these experiences by developing technological and institutional innovations designed to minimise risks associated with **urban water recycling for agriculture**. The action research and demonstration took place with farmers at the Dzorwulu-Roman Ridge site, within the Accra Metropolitan Area – the Odaw-Korle catchment.

The first demo and related action research focused on improvement of farmer innovations, using dugout ponds. Based on the principle of sedimentation and the use of multiple ponds and macrophytes, improvement in treatment was developed in a farmer field school setting.

In a second demo, some of the farmer groups were involved in linking production with sustainable sanitation. It involved the collection of urine from a slum area followed by, treatment and use of urine for farming at the demo site. Urine is a readily available resource for use in urban agriculture, but the cost of transportation is usually too high, hence farmers were encouraged to store urine on their farm site in mini disposal units. In addition agronomic field trials, economic feasibility and perception studies were undertaken, where farmers and extension staff were trained.

Cleaner Production
In industrial activities, Cleaner Production aims to achieve eco-efficiency by anticipating, preventing and reducing the polluting effects of emissions.

Cleaner Production for Tanneries

BOGOTA, COLOMBIA

In Bogotá, the cleaner production demo focus was on reducing pollution from micro-tanneries upstream of the city. One hundred and eighty four micro-tanneries at Villapinzón and Chocontá (Colombia) annually produce a high volume of solid wastes, approximately 3,700 tons of hair and 7,200 tons of fleshings. Without adequate handling, those wastes harmfully impact the water, ground or atmosphere. In SWITCH the preventive approach, relative to the traditional end-of-pipe approach, was promoted as an environmental solution.

Bogota River tanneries demonstrating cleaner production improvements.

Composting was selected as the preferred treatment option based on technical, economic and environmental criteria. During 2010, a demonstration was conducted at Villapinzón, composting three tons of solid wastes: hair filtrated in dehairing, and fleshings (i.e. flesh trimmings generated in defleshing after liming).

As a result, discharges of tannery wastewater into the Bogotá river were strongly reduced (BOD were reached up to 84%, TSS up to 98%, KNT up to 99% and Cr up to 94%) in some parts of the productive process. Water use was reduced by 68% in the tanning process. The community has organized itself to continue with the handling of the solid waste in a combined way.

In the Bogota situation, long-standing conflicts between the Government, the Environment Regulator and the tanneries had escalated to a critical situation with the closure of the tanneries eminent. Conflict resolution was a large component of the research. Without this the technical solutions would not have been realized.

Stormwater

The need for sustainable stormwater management

For most people living in cities, when it rains the biggest concern is to avoid getting wet. Unless their houses and streets become flooded, few would give much thought to what happens to the rainfall once it has flowed through their drainpipes and into their gutters. However, this is only the beginning of stormwater management in the urban environment and the tasks that follow are an essential requirement to maintain a city's social and economic development.

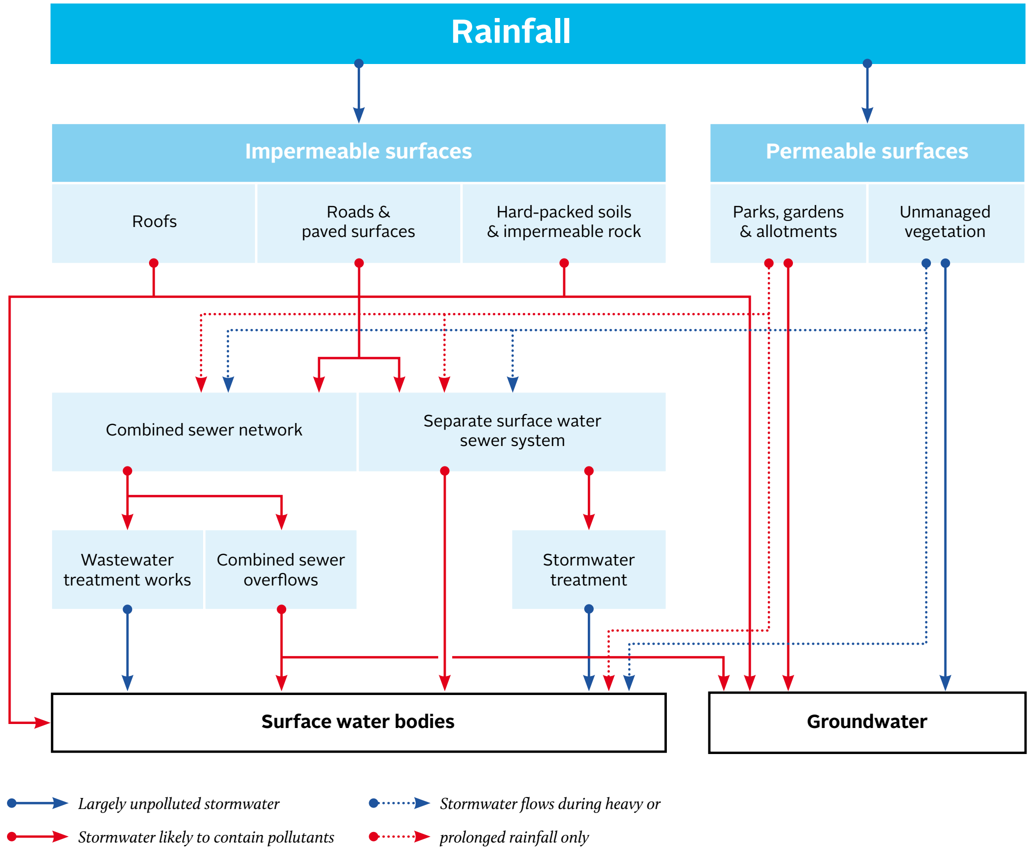


figure 13 **Stormwater flows and the urban environment** *(note: evaporation and evapotranspiration have been excluded from the diagram)*

(Source: SWITCH Training Package Module)

Management of stormwater needs to consider the interaction between the amount of rainfall that falls on a city, the existing natural and man-made infrastructure through which it flows, and the water bodies into which it ultimately ends up. Figure 13 shows a simplification of the flow of stormwater through the urban environment and the various routes it can take before entering receiving water bodies.

The conventional approach to stormwater management

The conventional approach to managing urban stormwater is to convey it away from the city as quickly as possible using drainage channels and underground pipes. Typically this approach uses a combination of two systems to achieve this aim:

- A combined sewer system in which stormwater is mixed with domestic and industrial effluent before being treated at a centralised wastewater treatment plant and discharged to a receiving water body.
- A separate surface water sewer system which collects only stormwater and discharges it to receiving water bodies with little or no treatment.

These systems are mostly designed based on available historical meteorological data and predicted urban development patterns. The overriding objective is to reduce the risk of localised flooding although they are often implemented with little consideration for downstream impacts.

Drains: Rainfall runoff from roofs, roads and other impermeable areas flows from drain pipes and gutters into an underground pipe or channel to ensure rapid removal from the surface.

Pipelines: Pipelines provide fast and efficient delivery of stormwater flows to point of discharge.

Concrete drainage channels: Channels with little hydraulic resistance convey stormwater rapidly to the point of discharge.

Centralised wastewater treatment plant: In combined systems, collected stormwater is mixed with human and industrial wastewater flows and treated at centralised sewage treatment works.

Discharge: In separated systems stormwater is discharged directly at high volumes to receiving water bodies. In combined systems discharges occur as treated effluent from wastewater treatment plants.

The issues facing a conventional approach to stormwater management

Conventional drainage systems remain the most common, and most commonly sought, method to manage stormwater in cities throughout the world. This is despite a number of issues that question the sustainability of such systems in the long-term, particularly their increasing inability to prevent flooding, pollution and environmental damage.

Some of the issues currently confronting urban stormwater management include:

- **Combined sewer overflows:** Heavy rainfall causes combined sewers to exceed capacity resulting in overflows of untreated wastewater to the environment.
- **Diffuse pollution:** Non-point source pollutants such as heavy metals and oils from roofs, roads and car parks, and nutrients, pesticides and herbicides from gardens, parks and allotments are dispersed by runoff into receiving water bodies.
- **Decreased base flow:** Increases in impermeable surfaces depletes aquifers by reducing natural recharge
- **Erosion and sedimentation:** High velocity runoff causes erosion and increased sedimentation in receiving streams, rivers and estuaries.
- **Costs:** End of pipe treatment for stormwater is costly and energy intensive.
- **Heat island effect:** The rapid removal of stormwater from urban areas reduces evapotranspiration. When combined with the heating effect of sealed surfaces this results in a hotter urban microclimate.
- **Waste of a valuable resource:** The rapid removal of stormwater from urban areas prevents it from being used for non-potable water supply uses and urban landscaping.
- **Downstream flooding:** The rapid collection and disposal of stormwater into receiving water bodies such as rivers and streams increases the risk of downstream flooding.

Solutions for urban drainage are often selected based on the local priority of removing stormwater from a defined area. However, such solutions may not consider impacts on a larger urban scale, such as a lack of sewage capacity elsewhere in the system to cope with additional flows and the damage caused by increased and possibly polluted runoff entering rivers and streams.

City management structures are rarely set up to deliver the integrated approach required for a field such as stormwater that cuts across many areas of responsibility. Roads, housing, parks and wastewater treatment are just some of the city departments that influence, or are influenced by, stormwater management but which typically operate independently. This increases the risk that the management (or mismanagement) of one area of responsibility causes unintended impacts to another. For example:

- The planning department approves the construction of a new shopping mall. The resulting stormwater runoff causes erosion in an urban stream and the collapse of nearby infrastructure.
- The housing department builds a number of new housing estates with stormwater connections to the city's combined sewer system. The sewer system is unable to cope with the additional volumes and overflows from the system become more frequent causing pollution in the local river.
- The roads department lays impermeable surfaces to improve drainage from previously unpaved roads. This increases the volume of rainfall runoff from the roads which disperses traffic pollutants into a local river causing fish kills.

Cities are also facing changes that are set to increase the pressure on urban stormwater management. Formal and informal urban expansion, population dynamics, tougher legislation on water quality standards and climate change are all increasing the need to reassess the way that stormwater is managed in urban areas.

Box example: Climate change and stormwater management
Climate change is expected to have significant impacts on urban stormwater management. This is particularly the case in cities where, due to temperature rise, the atmosphere's capacity to hold water increases causing a greater total depth of rainfall during storm events. Under such a scenario conventional urban drainage systems will struggle to cope. Designed on the basis of statistical recurrence criteria derived from available historical meteorological data (Picouet, Soutter 2006), the infrastructure may no longer be adequate and lacks the flexibility to adapt when design parameters are no longer applicable for the local climate.

Other less obvious impacts of climate change are also relevant. Changes in air temperature influence evaporation and transpiration rates thereby altering the water retention capacity of soils and vegetation. This has a knock-on effect for stormwater as the natural attenuation and infiltration of runoff becomes unbalanced. Similar effects can also be caused by changes in mean rainfall which lead to differences in soil moisture saturation (Shaw et al 2005).

Conventional stormwater systems are not well suited to the uncertainty of climate change and in many cities the existing infrastructure may prove to be inadequate. The challenge facing cities is therefore to somehow adapt the existing infrastructure in a way that it has the robustness to cope with a wide range of potential scenarios.

For more information on stormwater planning and climate change see the paper 'The implications of climate change on urban stormwater management: Scenario building' (Picouet, Soutter 2006, Resource Ref. D.2.1.1)

SWITCH Stormwater Research

Sustainable Urban Drainage Systems (SUDS) and Water Sensitive Urban Design (WSUD) were the two main areas that were explored in SWITCH. The research viewed stormwater not just as a hazard but as a potentially valuable resource. This dual characterisation of stormwater is increasingly important given the general transition to more dynamic climate conditions in many cities that are also suffering increasing water scarcity. Stormwater mitigation technologies and management practices are increasingly desirable in any sustainable urban water management plan. Sustainable urban drainage systems offer important approaches to stormwater mitigation and complementary benefits, yet have possible serious implications for institutional coordination and planning. Resolving these issues lies at the heart of the research undertaken in this area.

The adaptability of stormwater best management practices (BMPs) to a range of environmental and socio-economic condition was investigated. The research supported learning alliances in identifying city-specific threats and impacts on stormwater control strategies over both short and longer term timescales. A database of stormwater threats and uncertainties was created along with a design manual incorporating best practice guidleines for stormwater management options and treatment under extreme conditions.

Demonstrations of various types of stormwater best management practices were conducted in Lodz, Birmingham, Emscher and Belo Horizonte.

Urban Eco-Hydrology

LODZ, POLAND

Lodz focused on the restoration of the Sokolowka river using the principles of eco-hydrology to manage stormwater, increase water retentiveness and improve water quality and overall improve the quality of life for residents who live close to the river or use it for recreational purposes.

The demonstration included installation of on-line hydrological and meteorological monitoring systems, construction of sedimentation basins and specially designed reservoirs and planting of vegetation. Larger scale analysis of the basin was undertaken to allow upscaling of the demo. Wide engagement and dissemination was undertaken through production of three documentary films, publication of a series of maps and guides for Łódź's rivers and establishment of an educational path at the demo site.

Success of the demo resulted in further uptake by developers and in the formulation and adoption of spatial planning for the city around the concept of a 'blue-green' network.

Key findings of the research were that:
- SUDS can be retrofitted in existing urban areas.
- The challenge for stormwater source control is not technical issues but decision making.

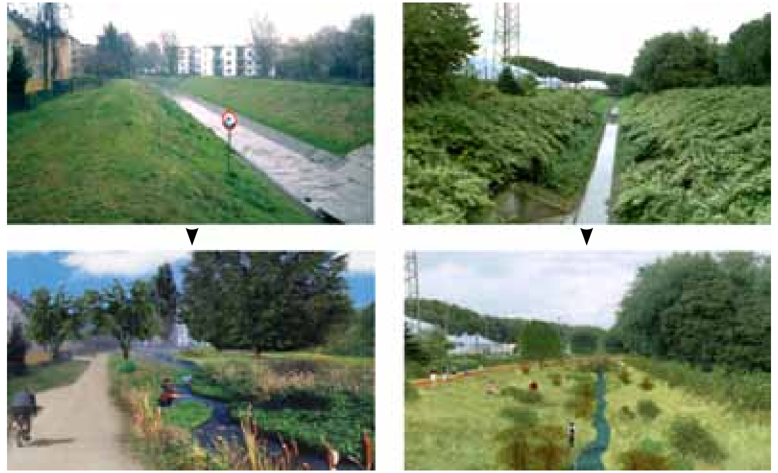
Stormwater Best Management

EMSCHER REGION, GERMANY

The river Emscher is located in Western Germany in one of Europe's most densely populated and industrialized areas. Due to the impact of mining activities from the beginning of the 19th century onwards and the related subsidence of extensive areas. The Emscher system was developed as an open sewer system in which freshwater as well as wastewater flows. With the ceasing of the mining activities in the 1980's an opportunity for a restoration of the Emscher catchment emerged.

Due to the high level of urbanization the flow regime of the Emscher is strongly influenced by stormwater runoff. In addition, overflows of the dominant combined sewer system caused water quality problems and hydraulic stress. Aware of these problems, the Emschergenossenschaft introduced new source oriented stormwater management strategies and since the 1990's many pilot projects for BMPs have been realized.

In coordination with the Emschergenossenschaft four different ongoing projects were selected as demonstration examples for SWITCH (Sieker et. al. 2006):
- In the settlement Welheimer Mark in Bottrop, roof areas were disconnected to reduce runoff volume and peak flow;
- While in the settlement Klöcknersiedlung in Waltrop the runoff from roads was managed in 'pocket wetlands' to minimize the hydraulic load of the combined sewer system;
- The Drainage-Infiltration-System (DIS) in Herne was a pilot project for the combined management of stormwater and groundwater, and finally
- Lake Phoenix demonstrated how open water systems could be integrated into urban space



Naturalising stormwater channels in the Emscher Region.

Stormwater infiltration trench in Belo Horizonte (Nilo Nascimiento).

Infiltration and Detention Device Performance

BELO HORIZONTE, BRAZIL

Belo Horizonte, a city of 2.4 million inhabitants located in a tropical climate environment, has major issues with flooding, wet weather diffuse pollution and wastewater contamination of receiving bodies. Because of this sustainable urban drainage systems (SUDS) became the focus of SWITCH demonstrations in Belo Horizonte.

Three demo sites were equipped with infiltration or detention devices. Two of them focussed on the performance assessment of SUDS in terms of runoff control and wet weather pollution abatement. Also, alternatives for retrofitting these kinds of devices in the urbanised environment of a developing country city were explored.

The SWITCH demonstration that has been monitored for the longest period in Belo Horizonte receives runoff flow from a 3,880 m^2 contributing area including a stretch of a 4-lane avenue. The runoff generated from this road is drained through gutters to an inlet where it is collected and conveyed to the experimental area. The experiment monitoring protocol included rainfall, inflows to the devices, storage and water quality monitoring by means of inflow and outflow samples, including the following parameters: conductivity, temperature, turbidity, total suspended soils, metals (Cu, Ni, Zn, Cd, Mn, Cr, Pb). The devices proved to be very effective for their purposes during the period of operation under SWITCH. For instance, the wet weather pollution abatement in the detention device could reach Class 2 water quality limits for stormwater overflow according to Brazilian standards.

Green and Brown Roofs

BIRMINGHAM, UK

Green roof research in SWITCH has focused on extensive green roofs. These roofs are characterised by thin growth substrates, low maintenance and lower costs compared with traditional green roofs. Specific interest has been on brown roofs, a type of extensive green roof that is designed to mimic brownfield sites at an early stage of succession. Roof design influences the environmental benefits and designing a roof to maximise one environmental benefit can potentially trade off against other environmental benefits (runoff reduction, thermal insulation, thermal cooling, biodiversity and roof longevity among others). SWITCH research has addressed specifically the collection of data and simulation studies to investigate the tradeoffs as well as the potential benefits of brown roofs. A research facility is erected on one of Birmingham University's buildings and will continue to function as a teaching facility post SWITCH. Demonstrations of brown roofs have also been undertaken in Birmingham using two roofs developed on buildings in the City Centre.

Outputs from the research include:

- Reports on the experimental arrangement of roof tiles for green and brown roof systems and the hydrology and effluent quality of these systems;
- A long-term experimental study and demonstration facility for information dissemination;
- Extended data sets showing eco-hydrological development of a range of green and brown roof types.

Birmingham Early development of the brown roof experimental plots (Adam Bates).

Stormwater can be a valuable resource as a part of integrated urban water management, both as a source of water supply and as a physical amenity for urban areas. A deeper analysis of decision-making processes involved in managing urban stormwater, with a particular focus on the identification of opportunities for reusing stormwater and its potential to contribute to meeting the needs of other sectors of the urban water cycle was undertaken. The work began with an evaluation of decision making processes currently used in stormwater management and a catalogue of the options available for the reuse of stormwater.

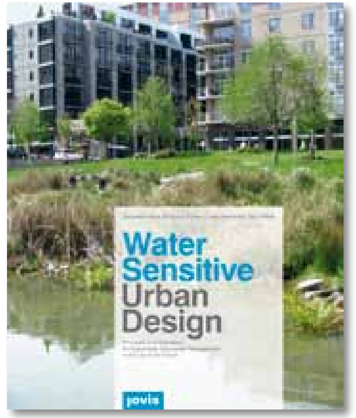
Stormwater Best Management Practice Principles facilitate the integration of stormwater within a sustainable urban water management approach and its inclusion as a resource within the wider urban landscape, providing inspiration for a creative, artful and healthy handling of stormwater within urban areas. (BMP principles for stormwater management as integrated urban water resource management strategy)

SWITCH developed a number of decision support tools to assist in modelling of stormwater BMPs from a range of perspectives including site and BMP selection, water quality and quantity (SUDSloc), the analysis of life-cycle costs (LCCCA) and a relative risk modelling approach to managing uncertainty (COFAS).

Institutional change is a fundamental need to upscale stomrwater best management practices. SWITCH researchers documented the current institutional arrangements for stormwater management in selected SWITCH cities and sets out guidelines for the development of stormwater management institutional maps.

Through the development of multi-objectives integrated urban planning processes, which can reconcile the often conflicting objectives that define the urban form, significant opportunities exist to significantly enhance a city's landscape and environment.

Water Sensitive Urban Design
Principles and Inspiration strives to harmonise the urban built environment and the urban water cycle, combining the functionality of water management with the principles of urban design. The approach embraces an interdisciplinary cooperation of water management, urban design, architecture and landscaope planning in order to reach WSUD goals as well as the integration of water management concerns into overall concepts and development plans. The book gives recommendations on how the approach of WSUD can be applied to cities in different scales. It is meant to inspire innovation in urban planning.



Exploring the Options - Key lessons learned

Water Supply

Demand Management

- Economic instruments will make a significant contribution to water consdervation only if implemented in combination with other water demand management measures
- Research is needed to accurately map the socio-economic status of the consumers so as to design effective economic instruments
- Water conservation tariffs have greater potential benefits in developing country cities where water services are usually ex cessively under-priced
- Decision support tools are often too complex and inaccessible to practitioners. The SWITCH WDM options model in VENSIM compares option cost/benefits over the long term making it useful for strategic planning
- Agent-based modeling (as used in VENSIM) is emerging as a powerful tool for analyzing the dynamic interaction between water stakeholders.

Soil Aquifer Treatment efficiently reduced micropollutants including hardly biodegradable antibiotics and organic iodine. The SWITCH Tel Aviv demo of short SAT as pretreatment prior to NF found that it can be an effective technology for unrestricted water reuse and indirect potable reuse while also reducing GHG emissions (smaller carbon footprint) as compared to the more conventional UF-RO systems.

Bank Filtration is an effective multiple objective barrier for removal of different contaminants present in surface water sources including organic micropollutants like PhACs and EDCs. The bank filtration removal efficiencies for these contaminants can be maximised by proper design of the recovery wells taking into consideration source water quality characteristics and local hydrogeological conditions.

Wastewater

Conventional wastewater management is a rigid solution and this lack of flexibility means that it is vulnerable when confronted by future uncertainty. In cities where sanitation systems are either non-existent or badly designed and maintained, the ability to keep up with rising pressures such as rapid urbanisation and population growth is obviously a massive challenge. But even in cities where effective centralised systems have been in place for decades, anticipated future challenges are raising increasing doubts over an approach to wastewater management that was previously unquestioned.

By adopting an approach to wastewater management that is based on decentralised solutions for separation and reuse, the key health and pollution control objectives are achieved as well as the following additional benefits: increased access to sanitation, water savings, flexibility to change, recycling of nutrients, financial savings, employment generation, energy recovery, more efficient treatment and an increase in urban biodiversity and amenity.

Ecosan
The study shows that Ecosan, in its various forms, can generally successfully be implemented. In some cases operational problems were identified, however by using innovative solutions found in other projects these could be overcome. However, there is a general lack of support and co-ordination at all governmental levels, national, intermediate and municipal. Several countries lack any general policies and/or regulation focusing on sanitation, let alone consider ecological sanitation as one of a range of options. Consequently, ecosan is often not taken seriously or takes place only in small scale pilot schemes which are not converted into large scale sustainable projects.

Stormwater

Conventional drainage systems remain the most common, and most commonly sought, method to manage stormwater in cities throughout the world. This is despite a number of issues that question the sustainability of such systems in the long-term, particularly their increasing inability to prevent flooding, pollution and environmental damage. Solutions for urban drainage are often selected based on the local priority of removing stormwater from a defined area. However, such solutions may not consider impacts on a larger urban scale, such as a lack of sewage capacity elsewhere in the system to cope with additional flows and the damage caused by increased and possibly polluted runoff entering rivers and streams.

The adaptability of stormwater best management practices (BMPs) to a range of environmental and socio-economic condition was investigated. The research supported learning alliances in identifying city-specific threats and impacts on stormwater control strategies over both short and longer term timescales. A database of stormwater threats and uncertainties was created along with a design manual incorporating best practice guidleines for stormwater management options and treatment under extreme conditions.

One of the key findings of the research was that the challenge for stormwater source control is not technical issues but decision making. Institutional change is therefore a fundamental need to upscale stormwater best management practices. Through the development of multi-objectives integrated urban planning processes, which can reconcile the often conflicting objectives that define the urban form, significant opportunities exist to significantly enhance a city's landscape and environment.

5.

Monitoring and Learning

Sustainability should be thought of as a journey of discovery where the change processes should not be fixed but reflective and iterative, in order to consider changing circumstances and the appraisal of new interventions (Dirven et al. 2002). The transition to a city of the future will consist of integrating, replacing and transforming complex and dominant socio-technical regimes with next-generation urban water systems that need more accountable, adaptive and flexible management approaches. Overall, one of the essential benefits of monitoring and learning when solving problems by implementing scientific interventions is the encouragement of continued improvement. This is because innovations do not emerge in a perfect form; rather, they require adaptations before becoming fully effective solutions that can address both current and future risks at local and global levels (Loorbach, 2007). New technologies are often developed and refined over many years and it is this aspect that is referred to as reflexive governance: modulating "hopeful monstrosities" (Grin et al., 2010).

State of the Art

Change does not come easily, especially (as in the SWITCH approach) if the change targets empowerment, sector integration, stakeholder participation, improved governance and integration of new technologies. A project's life seldom follows a straight line, as many kinds of situations occur which often force a project to adapt its course. Barriers to progress should be viewed as opportunities to learn from and to increase the impact of a project (Shouten, 2007). Understanding the dynamics of a transition as it is happening provides insights into the opportunities, limitations and conditions under which it is possible to influence change. Monitoring and evaluation (M&E) are an integral part of good project management.

Process documentation is a valuable tool, as it triggers reflection and debate and helps projects to become smarter. It also provides outputs that engage a wider group of stakeholders in important socio-technical development processes such as the delivery of water and sanitation services (Shouten, 2007). Good process documentation should ensure that a project continues to move forward in a direction that results in pre-defined sustainable outcomes (pursuing the vision), incorporating new knowledge, insights and lessons learned after each phase of the process.

Capacity-building programmes should support capacity development for all water users, decision-makers and the media in order to embed sustainability and transitioning concepts. They should help mitigate resistance to switching to more innovative urban water practices, e.g. overcoming issues relating to institutional and technological lock-in (Heslop & Dixon, 2008). This ensures that users, operators and managers involved with the new technologies are aware of the shift in mindset that will be required to encourage sustainable practices, which may involve changes in patterns and expectations of daily life (Shove & Walker, 2007). The media should be used as a tool for raising awareness of the issues and the solutions that can be delivered through the uptake of sustainable practices, as they are a primary channel for interpreting and communicating technical, institutional and economical issues to the public at a level that they can relate to (Duffy et al, 2010).

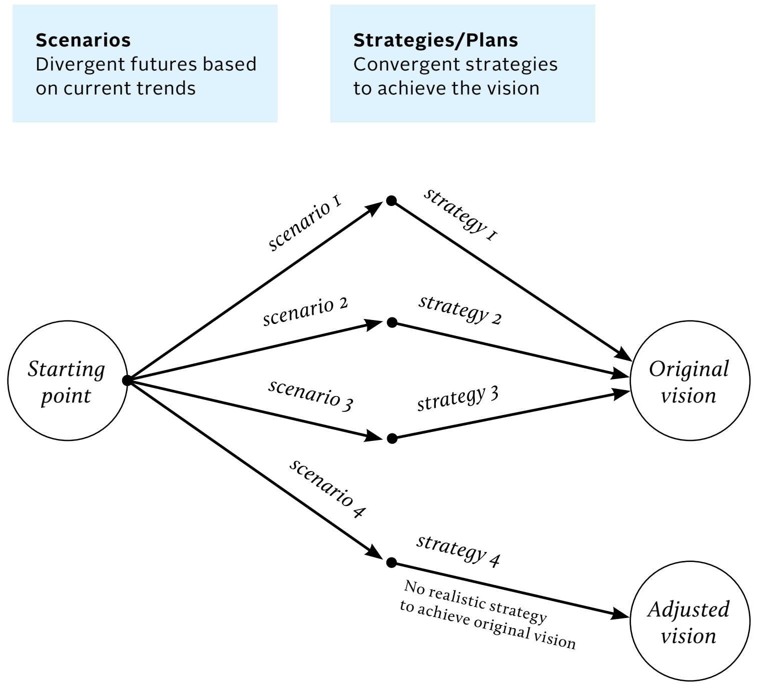
SWITCH approach: Process documentation and capacity building

Monitoring and Evaluation

One of the key activities during the SWITCH project was to monitor and evaluate the process of change as it was happening in the individual cities. Process documentation captured what happened in the change process in each city by enabling stakeholders to reflect on and analyse why changes happened and disseminate results. Periodic review ensured that the desired direction continued to reflect changing circumstances in most cases by allowing adaptations to plans or proposed activities and potential adjustments to strategic directions in order to achieve project objectives and the developed vision. In several cases, the quest for sustainable outcomes generated the need for the learning alliances to include new knowledge areas, resulting in readjustment of outputs (Shouten, 2007).

Evaluation of the actions that promoted or hindered change, via process documentation such as the city assessments, was an activity that was built into the project goals in order for learning alliances to learn from recent past experiences as they attempted to shift the focus of water management practices towards the new paradigm. This enabled reflection and analysis of barriers in order to gain a better understanding of what was happening and how and why it was happening (Shouten, 2007).

figure 14 **SWITCH Strategy for IUWM**



Source: Moriarty, p.c.

Learning alliance stakeholder quotes supporting M&E activities
"I have picked up the idea of an integrated approach to issues, not what is in the box. ...The project helped me to have a broader picture." EU researcher
"We have shared experiences and learned from ourselves. I met a good group of people I don't meet normally, realised it is an opportunity to meet a lot more partners; now I've started meeting some of them on other issues, e.g... sustainable development." Accra stakeholder

"Before, we had our perspective and our way of doing things. We still have our perspective, but now we have a different viewpoint on planning in the city. We can bring these views to our boss who is involved in decision-making. We don't use the language of the researchers, but put the message into a language that he can understand. We write briefs for him and he is able to use these to influence decisions." Lodz city planners

As part of the SWITCH monitoring and evaluation exercises, the learning alliances were encouraged to focus on evaluating change at the outcome level. This helped the cities to reflect on the more immediate changes that were happening in their respective processes (Butterworth and daSilva, 2007). The city assessments involved the 'micro-scenario' scoring ladder method which was used to compliment other process documentation. The scoring ladders involved self-assessment in a participatory but subjective way through peer review. This method provided a starting point for reflection on the key SWITCH objectives: breaking down barriers to both horizontal and vertical information sharing and learning within cities, and speeding up processes of identification, development and uptake of solutions related to urban water management.

table 7 **Example scoring ladder result from Birmingham**
Example of Framework for monitoring LA performance (scoring ladder): Birmingham LA Objective 1: Regular, effective and innovative events capture and sustain interest of learning alliance members.

Scenarios for objective 1	Score
This is no accessible record of learning alliance members, and their involvement in various events and activities	0
There is an out-of-date record of learning alliance members, and their involvement in events and activities	25
There is an up-to-date record of LA members, and their involvement and some basic communication tools are systematically used (e.g. email, phone) between events	50 benchmark
Up-to-date record of LA members and their involvement, and archives are maintained through systematic use of advanced communication tools (e.g. google group)	75
Members information is accessible to all (e.g. online database), participation in all events and activities is systematically recorded and a combination of methods is used effectively (based on feedback received) to communicate between events	100
Justification of score (with date)	**Score awarded**
November 2010 Up-to-date LA contact List includes contacts with other similar groups working in the city e.g. Climate Change and Marking Space for Water. Contact list updated 6 monthly	50

Although M&E activities were viewed as an additional burden, they were completed by most cities, where they quickly realised the benefits to be gained. The activities helped to focus and refocus the cities on delivery of the ambitious IUWM transition agendas that they had developed with their learning alliances. The main limitations to delivering on this activity were competing priorities such as the strategic planning process and demonstrations, lack of skills and in some cases resources and language barriers.

Accra M&E Results
Re-evaluation of the transition agenda and strategies to achieve the vision and in particular the project objectives because of M&E activities was demonstrated in Accra. The stakeholders fully engaged with transition management activities to successfully develop a transition agenda with the delivery of the Strategic Directions Report. The learning alliance recognised the value of focussing efforts on developing missing datasets that were required to inform the stakeholders of the real issues with water systems and services delivery in Accra. This was achieved by developing a robust RIDA (Resource Infrastructure Demand Access) analysis which ultimately informed the Strategic Directions Report. Overall, the delivery of the strategic directions report is contributing to a transformative change to integrated thinking for urban water management in Accra – if the city decision-makers can sustain a mindset that continues to consider and then implement sustainable practices that best suit existing local and predicted future circumstances. SWITCH acted as a catalyst for the onset of this paradigm shift by forming a stakeholder platform that is now open to the benefits that IUWM can offer. Delivery of the vision for Accra may not be such an uphill struggle if an IUWM planning and coordination platform is realised, as recommended in the Strategic Directions report for the next round of transitioning.

Capacity-building

The learning alliances facilitated capacity-building through the strategic development processes, which included activities such as visioning, stakeholder analysis, scenario planning, process documentation, monitoring and evaluation, and active encouragement of strategic niche development or action research (the demonstrations). SWITCH Learning Alliance briefing notes or 'how-to' guidelines were prepared by IRC for all the capacity-building activities and were produced at workshops and training sessions. Learning alliances placed the briefing notes on their websites for further dissemination to a wider audience. The briefing notes also focused on essential areas of the transition management steps, with an emphasis on developing partnerships in IUWM.

table 8 **Essential components of SWITCH briefing notes and Transition Management Steps**

	SWITCH Briefing Notes	Transition Management Steps
1	An introduction to learning alliances	Develop the transition arena
2	Facilitating communication in networks and Undertaking a stakeholder analysis	Organise and facilitate stakeholders
3	Rapid urban water assessment	Identify problems and issues
4	Scenario building/Visioning	Develop long-term integrated vision
5	Strategy development	Develop transition agenda
6	Action research	Transition experiments
7	Social inclusion	Engage the community
8	Process documentation Revisiting consortium thinking	Process documents Capacity building
9	Monitoring and evaluation for LAs	Evaluation and Learning
10	Review of thinking within SWITCH consortium and Transitioning Urban Water Systems	Next round of transitioning and visioning

Policy briefing notes in four key SWITCH knowledge areas were developed by WEDC, based on discussion documents and subsequent interviews and feedback from the SWITCH City Water Future's Global Summit in Delft 2009. These notes have already been distributed at several international conferences and will continue to be distributed for several years. They are aimed at decision-makers on IUWM, local governments (including urban planners), water utilities and major international agencies working in developing countries.

They can be downloaded from http://switchurbanwater.lboro.ac.uk/pubs.php

figure 15 **Briefing note front cover**

The SWITCH Training Kit prepared by ICLEI is a comprehensive contribution to building the capacity of local governments and water utilities and any other interested parties through dissemination of SWITCH outputs. The kit addresses the overarching issues of integration in the urban water cycle and examines some of the innovative options available for putting IUWM into practice. The aim of this resource is to raise awareness and develop knowledge and skills for switching from conventional to sustainable approaches by encouraging an integrated approach that concentrates on links between the different components of the urban water cycle, and by promoting multi-stakeholder collaboration at all stages of local management processes. Materials are constructed from easy-to-use segments of information that are illustrated by practical examples and supported by graphic elements such as tables, diagrams, flowcharts and photographs. The training kit consists of six modules which include methods and tools to assist scenario-building, informed decision-making and long-term strategy development.

It can be downloaded from *http://www.switchtraining.eu/index.php?id=7198*

Communication

The SWITCH approach is a practical example of promoting thinking and deepening knowledge in cities of how to manage a transition to a future paradigm of integrated and sustainable urban water management. SWITCH attempted to embed an inter-sectoral approach to the process of change at the city, national and global levels in a relatively short time. City-level niches were developed to provide experience and valuable lessons in the niche areas; these were effectively case studies that were documented to show the process in action. The case studies were then disseminated through the global learning environment created within SWITCH via the workshops, training events, scientific meetings and international conferences, such as the SWITCH 'Global City Water Futures Summit', the UN-Habitat 'Sustainable Water Management in Cities' conference and the 'Water and Urbanisation' themed World Water Day, to other SWITCH learning alliances and non-SWITCH cities.

Specific details can be found on the SWITCH website at: http://switchurbanwater.lboro.ac.uk/docs/SWITCH_events.pdf

Many workshops were organised, which primarily involved bringing international expert knowledge to the cities. Stakeholders were also encouraged to attend key international events. These forms of knowledge transfer promoted continued support for IUWM amongst stakeholders who were exposed to new ideas; they could see that a difference was being made in cities that were attempting to meet the challenges of achieving sustainable practices within their own regional context. It is worth noting that SWITCH participation in and organisation of several international events, including the following:

- SWITCH delivered the City Water Future's Global Summit in Delft, September 2009. The aim of this event was to share lessons learned between a global network of cities, researchers, local government and water utilities with a focus on joining forces to accelerate change to more sustainable urban water management. The Media Briefings undertaken at the Summit had particular merit for SWITCH; they involved training journalists to convey technical knowledge and were expanded to the World Water Day in Cape Town.
- The UN Decade of Water for Life (2005-2015) is spreading the SWITCH message all over the world. The Water Decade focuses on encouraging countries to build on the efforts made to date to protect, use and manage freshwater resources in a sustainable manner, as the water challenge is primarily seen as a governance challenge. The primary goal of the 'Water for Life Decade' is to promote efforts to fulfil international commitments made on water and sanitation issues by 2015. In 2010, a conference was jointly organised by the United Nations Office, the city of Zaragoza, and the SWITCH consortium - Sustainable Water Management in Cities conference: Engaging Stakeholders for effective change and action. The conference was a meeting of experts, local government, media specialists, water operators and political representatives to discuss issues, propose practical ways to move forward to meet the challenges of achieving water and sanitation for all, and disseminate results to a wider audience. Two SWITCH thematic sessions included: 'Streams to the sea, Stakeholders in the city: integrating and strengthening sustainable water management' and 'What the compass tells us. Highlights of the work with tools and approaches for stakeholder engagement'.
- UN-Habitat/UN-Water World Water Day, Water for Cities: Responding to the Urban Challenge, Cape Town March 2011. This event aimed to focus international attention on the impact of rapid urban population growth, industrialisation and uncertainties caused by climate change, conflicts and natural disasters on urban water systems. SWITCH took part in several sessions, including a session themed 'Radical versus incremental change – how to SWITCH urban water systems to meet current and future challenges' and SWITCH scientific director Kala Vairavamoorthy's contribution to the 'Water and Cities Debate'.

SWITCH examples and insights

A key outcome for the SWITCH project was to move a city towards an IUWM paradigm using the model of stakeholder engagement that actively encouraged experimenting with new innovations and methodologies.

Movement towards the new paradigm would happen more quickly if learning alliances made progress towards delivery of the key SWITCH objectives. The SWITCH Approach of learning by doing and doing by learning is an approach where investigation and learning take place at the same time. The support of knowledge flows between key stakeholders and between the stages of a process are key factors to facilitating the uptake of sustainable practices (Grin et al., 2010). This was achieved in the cities through M&E activities and documentation of the processes that were driving the changes. Evaluation of the actions which promoted or hindered change showed concrete results that influencing and accelerating the uptake of more sustainable practices for water services to meet the challenges of the city of the future through the 'learning alliance' approach was indeed occurring in several of the cities. The SWITCH philosophy that was driven by the learning alliances ultimately achieved several results: it deepened knowledge, broadened experiences, and began to scale up innovative ideas and practices (Loorbach, 2007).

- Deepening knowledge through social learning: Social learning is where problems are defined through the process of working together and understanding each other's long-term aspirations at the local level. SWITCH learning alliance activities in the transition arena and the strategic planning process enabled a shift towards developing long-term visions and strategies to achieve the vision – activities which excited, integrated, strengthened commitment and ultimately empowered LA members.
- Broadening experiences through experimentation with innovative ideas and techniques: This was achieved through research and demonstrations which took place in each of the cities. Several cities took longer than others to implement demonstrations, and some cities found that the demonstrations did not lend themselves to scaling up. However, in most cases, the demonstrations engaged the stakeholders and provided insights into the possibilities for moving towards the IUWM paradigm through replication of new ideas and methodologies.
- Scaling up to embed the new systems and philosophies by gaining support and involving key players: By the end of the project, several cities had embedded or were beginning to embed new governance structures within city and/or national institutions to facilitate scaling up the research. These were primarily cities which had engaged key stakeholders at all levels, including the urban community, ministries, NGOs and the media.

SWITCH experiences: documenting the process of change

In Belo Horizonte, the facilitator and others in the team registered activities but analysis and synthesis of the process was difficult, primarily due to the lack of skills and expertise in process documentation, since such activities are rarely undertaken in public offices such as the municipality. It was also found to be very time-consuming and hard to fit in with facilitation activities. It was felt by the team that additional resources could have been allocated to the documentation role.

In Lodz, the assessment focused on research impact and how pilot interventions and the learning alliance processes were influencing stakeholders, water management strategies and implementation within the city. The 2010 assessment revealed a strong appreciation by city stakeholders of changes that the project has helped to achieve in the city. For example, PhD Student Wojciech Fratczak stated: "SWITCH is a milestone project for the city, and for me as a researcher as well. It has made a difference in how water is managed in the city and how decisions are taken." And according to the Department of Strategy and Analysis: "SWITCH has introduced new vocabulary into our strategic planning process. We would like to see Łodź develop into the green capital of Poland". According to ERCE Director Professor Zalewski, the learning alliance process has been central to more integrated urban water management: "Thanks to the learning alliance and many meetings held through SWITCH, we are now at a point where our ideas are accepted by city stakeholders."

In Lima, one person was responsible for process documentation and communication, ensuring that follow-up and results were monitored. SWITCH Lima did not participate in all the options offered by SWITCH internationally, due partly to language barriers and partly to the costs of travel to Europe. However, through regular contact with other SWITCH partners, and to a large extent because of the experience with similar processes by IPES, the project outcomes were achieved.

In Tel Aviv, process documentation and the city web site, learning alliance reports, etc. were found to be lacking in content. This was recognised as a weakness and has been put down for the most part to budget and time constraints and other commitments that left these activities low on the agenda. It is clear that the positive results such as an active learning alliance and very relevant research have nevertheless been achieved, despite this "missing" element in the process.
In Cali, the project focused on the planning process and completion of studies, with less emphasis on process documentation. Resources in the project were mainly utilised for the strategic studies and thus were insufficient to address all the process documentation that was initially envisaged. However, two very good city assessments were delivered with the resources that were available.

6.

Measures of Success

What difference did SWITCH make?

To achieve the key project objectives, the city learning alliances were encouraged to develop, apply and demonstrate a range of tested scientific, technological and socio-economic solutions and approaches that contributed to the delivery of sustainable and effective UWM schemes in the 'city of the future' with a projection of 30-50 years from the present. To this end, the cities were encouraged to apply a systemic approach that took the entire water system into account (natural systems, water supply, sanitation and stormwater), with sustainable and integrated design and operation of all water networks being the ultimate goal or vision. It became very clear that the learning alliances were the motor driving a transition management process in which the learning alliances represented the arena, strategic planning processes represented the activities that developed an agenda, and the science and demonstrations represented the experiments. Many types of socio-technical transitions happen as a result of niche development (Loorbach, 2007). Strategic niche management is the creation of technological niches in which players such as stakeholders in the SWITCH learning alliances provide a safe space for experiments in e.g. environmentally sound practices. Niches should be aligned with future visions so that they can develop and mature, thus embedding or up-scaling the innovation into the existing regime. To close the loop and ensure that a city continued to move towards more sustainable outcomes for water systems, reflection on progress was promoted through the use of monitoring and evaluation practices via the city assessments.

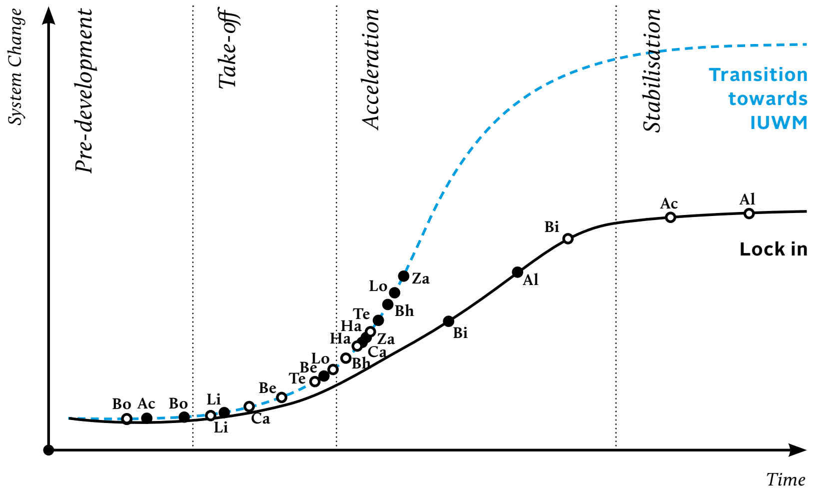
	Key SWITCH Objectives	**Transition Area**
1	Improve the scientific basis for long-term strategies for Sustainable Urban Water Management, equipped to resist negative effects of global change.	Monitoring and Evaluation
2	Achieve a switch in UWM practices, towards sustainability in the SWITCH demonstration cities.	Agenda
3	Develop an overall strategic approach to achieve sustainable UWM in the city of the future.	Agenda
4	Develop effective stormwater management options in the context of the hydrological cycle at urban and river basin level.	Experiments
5	Provide effective water supply services for all at minimum impact on water resources and the environment at large.	Experiments
6	Develop effective sanitation and waste management options based on the principles of 'Cleaner Production'.	Experiments
7	Integrate UWS into the ecological and other productive functions of water at city and river basin level.	Arena
8	Develop innovative, effective and interactive institutional arrangements covering the entire UWC in the urban and broader river basin setting.	Arena
9	Increase impact and visibility by dissemination to stakeholders through a learning alliance approach and teaming up with other international initiatives.	Monitoring and Evaluation

In the Cities

The cities were analysed according to the Transition Management Curve (Grin et al., 2010) to ascertain if there was a sustainable trajectory towards IUWM practices during the time span of the SWITCH project. Results are illustrated in image 16 by using the transition management 'S' curve which broadly considers the dynamics of transitions over time as a series of phases from one relatively stable state to another. Movements along the curve effectively reflect on progress made in the cities that resulted in delivery of (or progress towards the delivery of) the key SWITCH objectives (i.e. measuring successful outcomes of the SWITCH Approach by achieving SWITCH objectives).

Several cities such as Belo Horizonte (which has always been viewed as a 'city of the future)', Lodz, Tel Aviv and Zaragoza already had strong IUWM agendas and they had generally engaged with SWITCH to speed up the progress of this trajectory. In effect they were already moving into either the take-off or acceleration phases of transitioning whereby engaging in the SWITCH Approach assisted in identifying where they had weak areas in order to sustain a sustainable trajectory. These cities were beginning a new transition management cycle at the beginning of SWITCH and are now entering another cycle with the biggest challenge being to continue this momentum though to stabilisation with the innovative technologies and methodologies that are being up-scaled such as the blue-green network philosophy, sectionalisation of water supply networks and influencing participatory budgeting in favour of alternative drainage solutions becoming 'business as usual'.

image 16 **SWITCH City transition trajectories illustrated on the 'transitioning' curve**



Ac = Accra, Al = Alexandria, Be = Beijing, Bh = Belo Horizonte, Bi = Birmingham, Bo = Bogota, Ca = Cali, Ha = Hamburg, Li = Lima, Lo = Lodz, Te = Tel Aviv, Za = Zaragoza

Other cities such as Accra, Alexandria and Birmingham were 'technologically locked in' with path dependant, high investment water networks which were operated by stakeholders who were resistant to change making it difficult for newly developed technologies to enter day to day operations (Duffy et al., 2010). These cities benefitted mainly by bringing isolated stakeholders where each group had its own vested interest together into forward looking arenas where they developed visions which attempted to improve their city of the future. Yet other cities such as Cali, Lima and Beijing were beginning to shift towards an IUWM agenda with a desire to experiment and implement more sustainable practices. They entered SWITCH to learn how to manage this transition by targeting the operational activities of the SWITCH Approach where innovation could address integration issues, and mainly relied on other known and trusted institutional mechanisms for stakeholder engagement and decision making (Sutherland et al, 2011).

To measure the degree of success in each city, engagement with activities was examined to identify to what extent change was actually influenced by the project and its approach: specifically, where a city built strong learning alliances, developed strategies for achieving a vision or sustainable trajectory and implemented demonstrations that were upscaled or had the potential for scaling up within a city. The defining characteristic of SWITCH is that its research findings and insights will influence practice and policy through the SWITCH Approach (SWITCH Final report V2, 2010). This would subsequently result in the maximisation of upscaling potential of the new research by linking important players in the city with researchers (Sutherland et al, 2011). The use of decision making tools supported changes and permitted different options to be identified and evaluated in the cities.

It must be remembered that SWITCH was only a five year project which is very short in transitioning terms but results during the timescale surpassed expectations in most cases. As already highlighted in Chapter 1 SWITCH had nine key objectives against which success was measured. The following symbols which are linked to achieving the SWITCH objectives have been applied to each city where successful outcomes were realised or were in the process of being realised by the end of the project. Policy changes include objectives 2 and 8. Up-scaling new technologies include objectives 1, 2, 4, 5 and 6. Use of decision making tools include objectives 2, 4, 5, 6 and 7. Greater adoption of the SWITCH Approach include objectives 1, 3, 8 and 9.

LAW — *Policy changes*

Up-scaling new technologies

Use of decision making tools

SWITCH — *Greater adoption of SWITCH approach*

Accra

Accra had a strong coordinator and facilitator who provided leadership and motivated key players in the municipality and agencies involved in water service delivery to build an LA that became committed to developing an IUWM agenda. High level support was also captured. Although demonstrations were identified and implemented (illustrating for example the potential for nutrient recycling) they faced several setbacks such as securing match funding, occupant land ownership issues. and financial viability issues. However at the strategic and tactical levels it was recognised that a key barrier to delivering an IUWM agenda was the lack of baseline documents to fully inform the agenda building process and enhance stakeholder capacity. The LA focussed its efforts on providing this information which subsequently resulted in the IUWM Greater Accra Metropolitan Area Strategic Directions Report – noted as a 'gift from SWITCH' by an LA stakeholder. This was the first time actual data had been collated across the whole water sector in Accra. The city also engaged with the suite of decision support tools that were developed in the SWITCH City Water decision support system (CWIS).

The strategic direction report is highly likely to form the basis of the continuation of an IUWM platform for future more sustainable water services delivery. The National Development Planning Commission is currently developing an Urban Policy. This provides a window of opportunity for including IUWM issues as a strategic direction for urban authorities through the creation of a planning and coordination platform (as proposed in the report) to include enabling and regulating legislation and policies for improved water management (Jefferies and Duffy, 2011). The Accra LA facilitator participated in a large number of sector meetings and events, including the annual Mole conferences, organised by the Coalition of NGOs in the Water and Sanitation Sector in Ghana. As more research results emerged, SWITCH gained recognition and the LA facilitator and city coordinator were increasingly approached for input into sector processes related to IUWM such as World Bank project identification workshops, providing feedback on sector policies, and assistance in developing the Municipality of Ledzekuku-Krowor Water Master Plan (Butterworth et al, 2011).

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Strong coordinator and facilitator to guide capacity and agenda building activities. Key players at all levels - national ministries, water utilities, local governments, NGOs, civil societies groups, regulatory body, universities, development partners (world bank), users (farmers).	Accra starter kit morphed into RIDA analysis to Strategic Directions Report.	Ecosan – nutrient reuse in urban agriculture. Natural systems in the urban water cycle. Social inclusion – water supply for the urban poor.	City assessments. Workshops. Website. National MOLE conferences. Presidential debate in 2008. Use of City Water suite of decision support tools. PhD / MSc.	Strategic plan for Accra is viewed as a 'gift' from SWITCH and set to form basis for IUWM platform. Input to World Bank project workshops. Advisors for Ledzekuku-Krowor Water Master Plan.

Alexandria

Alexandria LA was built slowly over three years to include key players. This is primarily due to the difficulty faced by many institutions that have embedded infrastructures and networks to change the way they plan and make decisions. Water is a high profile issue in Alexandria with a highly evolved institutional water management framework where the city is technologically 'locked-in' with an unsustainable dominant infrastructure operated by stakeholders who were resistant to change (Sutherland et al, 2011). However as a result of the strategic studies that were delivered through the project, stakeholders in the LA began to realise just how unsustainable the water systems were in the light of additional pressures that the city may be exposed to and also how the aspects of the water cycle were linked and interdependent. The commitment to niche development through the demonstrations at Ma'awa El Sayadeen, especially in an area that pushed the boundaries in engaging with marginalised communities in the country, is evidence of a desire to move towards more sustainable solutions that benefit all by focusing on the extension of the network to an informal settlement. The LA now have a clearer understanding of the issues (and costs related to these issues), barriers and constraints that they face as individual organisations and those which other stakeholders face as they attempt to improve their city for the future together and a change in mindset is happening (Jefferies and Duffy, 2011). For many stakeholders, strategic planning activities such as 'future visioning' represents the trade mark of SWITCH as they had not undertaken visioning exercises before, and saw it as an exciting, integrative and empowering process (Butterworth et al., 2011).

Alternative water resource for football pitch irrigation – Borehole drilling at Ma'awa El Sayadeen Sports Facility

BOX _ Quotes from members of the Alexandria LA
"The SWITCH project has increased my knowledge and exposure to so many things. It has created a good thinking environment for me. In the field of waste water management and waste water use it is changing decisions where we are moving towards integrated urban water management". "Thinking about the future brought about new and innovative strategies to achieve the vision. We started to look at new concepts such as desalination, using waste water and ground water and not just relying on the Nile River". "The studies have brought a focus on outcomes rather than a focus on meetings and reports". "Alexandria is a good example of a city of the future. It is the second largest city in Egypt which urgently needs integrated water management. Through SWITCH we have achieved changes in decision making and we are making changes towards real integrated water management".

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Key players at all levels – Governate, ministries, utilities, regulatory body, local government, political parties, NGOs, users (urban slum community) and university.	Focus on seven strategic studies to compliment the National Water Resources Plan and develop IUWM plan (still under development).	Ma'awa El Sayadeen Fisherman's village (informal settlement): Water demand management: Household water survey; District Metering Approach (DMA); Leakage detection; Implementation of water saving devices.	City assessments. Workshops. Website. Media articles. City Water decision support tools. MSc.	Utility policy change to service informal settlement through innovative local community partnership. AWCO will include strategic studies results in its master plan.

Beijing

It became obvious during the course of the SWITCH project that the LA process in Beijing would not happen according to the planned route taken by other SWITCH cities. This is primarily due to Chinese cultural norms and institutional arrangements whereby it is not common practice to bring stakeholders from different disciplines together to develop joint strategies due to the complexity of water management and institutions involved in water service delivery. Thus the LA concept is relatively new in China. The key in China is to provide a strong evidence base for the potential of new technologies which follows the 'learning by doing' concept, (where the experiments are aligned with with official city planning and strategic vision of city development policies) before presenting results to higher level authorities. There were limited formal LA meetings (three) during the timespan of SWITCH. These meetings were primarily to discuss development progress of the informal 'Beijing and Chongqing Working Groups'. There were also annual meetings with other SWITCH partners involved in the same work package. Multi-stakeholder training did not take place directly but was organised around the local organisations that were hosting the demonstration which often included selected authorities (Veenhuizen et al., 2010a).

Mushroom production using rainwater harvesting in Huairou, China

The demonstration focused on building on the existing rainwater harvesting RUAF (Rural Urban Agriculture Foundation)-China programme. Results were positive from the very beginning of the project with innovations in the storage system developed. It is expected that these results will be integrated into ongoing policies and the 12^{th} five year plan (2011-2015). Development of policy guidelines for effective water reuse and management is underway. The research was replicated in six other districts (nine sites) with another ten sites being analysed at the time of this report.

Due to the limited meetings that took place it was therefore important to monitor, and document the activities undertaken and outcome of these inputs. Unfortunately, regular documentation was not undertaken, but instead, short notes of activities were made by the team members, however most of these were in Chinese which was a major barrier to undertaking an overall assessment (Veenhuizen et al., 2010).

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Informal LA -'Beijing Working Group'. Key stakeholders: University, regulatory, municipal and district authorities, public and co-operative bodies.	Main agenda: visioning and flexible response scenario planning; developing a co-operative platform for communication and sharing municipal water resource use and management experiences for improving scaling up potential; influencing future policies.	Huairou Rainwater harvesting greenhouse for mushroom production and agro tourism. Flow and cost benefit analysis. Waste water reuse.	City assessment. Website. Translation of training materials. Attendance at the annual SWIF committee meeting showcasing SWITCH outputs. PhD / MSc. Resource Recovery and Reuse for Urban Agriculture Guidelines.	Applied for RWH technology patent. Integrate Huairou results into policies and five year plan (2011-2015). Policy guidelines and training material for water recovery and reuse. Nine sites have replicated the RWH technology with another ten sites being analysed.

Belo Horizonte

Belo Horizonte had a strong facilitator who provided leadership, nurtured relationships between stakeholders and academia and motivated the key players at all levels to build an LA (BELHA) which was committed to speeding up the implementation of an already developed IUWM agenda. Towards the end of the project SWITCH was viewed by stakeholders as an important 'brand' that should be continued.

After the end of the military dictatorship in 1985, the Municipality of Belo Horizonte (PBH) put much effort into democratisation, focusing on establishing mechanisms for citizen participation in decision-making about local planning and services provision. This is exemplified by Participatory Budgeting (OP) where citizens can propose works to be included in the municipal budget (Smits et al., 2008). Since the mid 1990s, the city has invested in wastewater interception and treatment, restoration of urban creeks and piloting of technologies such as detention ponds and wetlands.

SWITCH organised training courses and sessions for the participatory budget commission, specifically to facilitate a shift in the public mindset regarding urban drainage that moves towards more sustainable outcomes. These reached out to 400+ opinion makers exemplified by a shift towards scaling up the implementation of alternative drainage solutions by the OP committees. A typical example of BELHA investment was an educational programme at the Lagua do Nada Park infiltration trench pilot which is part of the France Libertés Association and Water Messenger Program. BELHA organised a workshop about water (pollution, waste etc) at this event which included attendance by Danielle Mitterand former first lady of France and president of the Association who handed out certificates to attendees at the end of the workshop. Many outputs from SWITCH led strategic flood studies and application of the CWIS suite of tools have been implemented into local level forums such as the water technical group for climate change and the environmental planning board (Knauer et al., 2010).

A lesson to be learned from attempted M&E activities in Belo Horizonte was that limited process documents and subsequent reflection was due to lack of skills, expertise and time being available within the public body which was a key member and facilitator for the project. Language barriers also existed for international knowledge transfer to LA members.

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
LA (BELHA) key stakeholders: municipal, city, academic, utility, NGO, private, community / user levels to progress existing IUWM agenda.	Enhance operator / manager capacity of SUDS technologies. Strengthen participatory governance (OP) models. Showcase and upscale demonstrations across municipalities.	River restoration using SUDS / BMPs. Rainwater harvesting.	City assessments. Website. 'SWITCH News'. Translation of training materials. Strategic flood studies. Community education / training sessions. Use of City Water suite of decision support tools. PhD / MSc.	SWITCH Approach 'institutionalised'. Strengthened capacity building towards OP to facilitate demonstration scaling up. Inputs to climate change water group and environmental planning strategies for 2014 football world cup.

Birmingham

The LA in Birmingham had a somewhat fragmented attendance from key stakeholders. The SWITCH model of integration did not fit well with centralised UK institutional/governance arrangements: the SWITCH approach did not take account of the existing largely centralised institutional arrangements, powers and duties relating to water management in the UK. Many stakeholders were unable to sustain involvement in LA activities if they did not have the support of their superiors. This often resulted in the team relying very much on the good will of members who could fit meetings into their day job 'I have to account for every hour – it is difficult if I don't have something concrete to book my time against'. Recommendations from the LA assessors are that future projects should consider the inclusion of 'reward mechanisms' so that less senior stakeholders were able to account for their involvement in multi-stakeholder activities. By the end of SWITCH, it was agreed that the project 'has helped to support the development of strategic alliances within the city around opportunities for more integrated water management' (Darteh et al., 2010).

Like Alexandria, Birmingham is technologically 'locked-in' with stakeholders who were resistant to change, however this city is part of a growing 'wave' of policy reform in the UK that is more supportive of integrated approaches to water management such as the Flood and Water Management Act 2010. This ethos enabled the introduction and support for the brown / grey roof demonstrations which are seen as a particular SWITCH success in Birmingham – they have made a considerable contribution to research in stormwater source control measures.

Two other notable successes from the IUWM research agenda that was supported by the Birmingham LA were the development of the decision support system City Water in collaboration with EPFL in Switzerland and the SUDS Design Manual developed by Middlesex University.

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Slow progress in establishing committed LA - most of the key sectors except the planning sector.	Institutional mapping and visioning activities.	Risk associated with groundwater reuse. BVSC and ICC Brown roof demonstrations. Eastside SUDS. CWIS scoping model.	City assessments. Workshops. Website. Young SWITCH, Use of City Water modelling suite of tools. SUDS Manual. SUDSLOC – GIS based BMP decision support tool. MSc / PhD. Presentations at ICE / CIWEM climate change groups. Stakeholder in DEFRA 'Making Space for water' study group. Sustainable Urban Drainage Systems Design Manual.	SWITCH IUWM research agenda internalised initiating new 'demand driven' research. Green roofs strategy incorporated into Eastside urban regeneration programme. Key SWITCH members participate in Birmingham Water Group.

Bogota

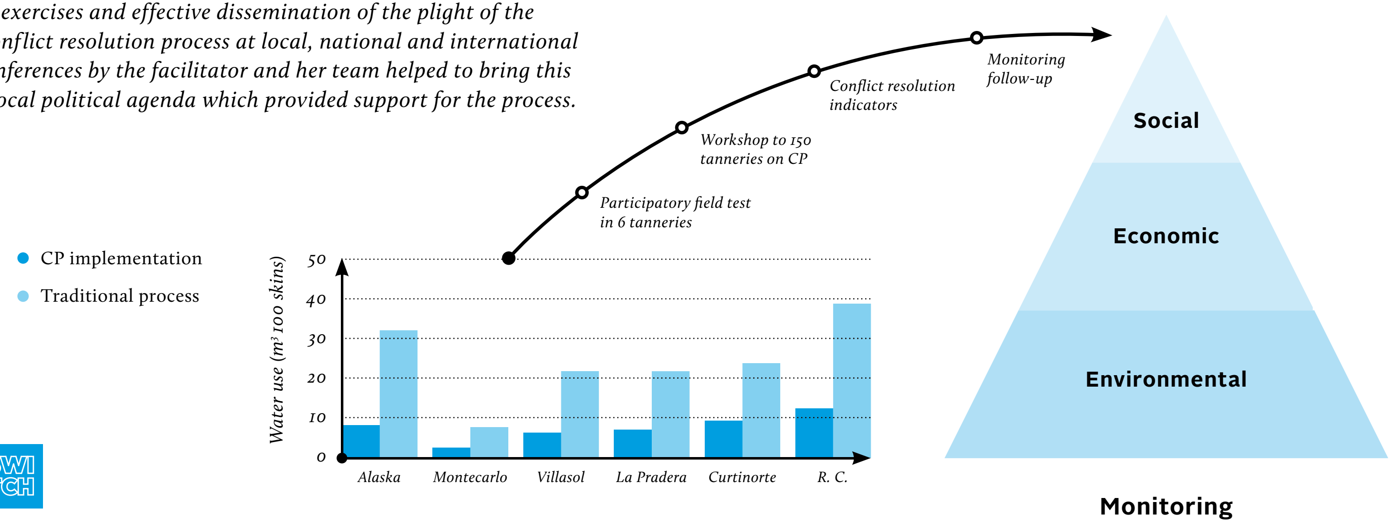
A strong facilitator united an LA that was built around the players involved with preventing pollution of the River Bogata by small scale and informal tanneries on the upper part of the river: an issue which could not be resolved through normal legal and institutional avenues. The cleaner producution technologies implemented through SWITCH have resulted in 90% pollution reduction with the outcome being that the conflict resolution approach (SASI) and capacity building programmes developed are now being rolled out across other catchments in the River Bogata as part of a follow up project (Butterworth et al., 2011).

Capacity building exercises and effective dissemination of the plight of the tanners and the conflict resolution process at local, national and international workshops and conferences by the facilitator and her team helped to bring this issue high up the local political agenda which provided support for the process.

Targets

- 162 tanneries (Villapinzón y Chocontá, Bogotá, Colombia)
- 105 tanneries trained on CP
- 17 strategies on CP to be tested on pilot industries
- Expected impact reduction: water use (50%), COD (40-70%), Sulphates (50%), Chromium (80-95%) emissions.

CP implementation



ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
LA – tanneries, local governmt, regulator, NGO, University, Chamber of Commerce	Strategic plan developed for the tanneries of Villapinzón.	Implement cleaner production (CP) methods for micro-tanneries using conflict resolution on the Rio Bogata.	City assessment. Workshops. Strong attendance at international workshops / conferences. Development of Systematic Approach for Social Conclusion (SASI).	Court Order where CP is mandatory. SASI approach is being expanded across other catchments.

Cali

The LA was built slowly and by late 2007/2008 there was a small team with key players.. However, a critical analysis into alternative technologies, both for wastewater management and in-house water devices, illustrated the feasibility of these options in the local context which opened perspectives to new alternatives in the city. Results from this research has been included into two official planning processes with the main opportunity being inclusion into the CONPES 3624 national policy for the upper Cauca river which is driven by the national ministry. The CONPES 3624 Document: "Program for the Treatment, Management, and Environmental Recovery of the Upper Cauca River Basin" was issued in 2009.

A CONPES is a document that the National Council for Social and Economic Policy prepares in order to set up the main courses of action, including strategies, programs, projects, activities, actors, goals and resources which are needed to solve different kind of development problems including environment, health, education, economic activities, etc.

In parallel to the process of formulating the CONPES, a Regional Working Panel was created by local institutions. The creation of this working panel was led by Cinara/Universidad del Valle, within the context of the SWITCH Project, and through the strategy of the learning alliances it was established to discuss issues related to water problems in this city. The main results were presented to the CONPES team and several were also incorporated into the final CONPES 3624 2009 Document.

The Working Panel continues to meet and has now developed a technical document aimed at providing support to the action plan with five key components proposed in the CONPES. The SWITCH project contribution to the development of the CONPES has been outstanding. The proposals made by the regional panel to the CONPES are related to three of Cali Learning Alliance's issues, taking into account all actions designed and projected for the SWITCH demonstrations. But most importantly, the project team has been able to establish a dialogue with institutions which has started to create a very slow process of paradigm change among institutional staff; additionally, they have demonstrated that alternative and creative solutions are feasible (Smits *et al., 2010b).*

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Began late '07 with a small team - gradually added key stakeholders. Now inputs to the Regional Working Panel -identifies water related issues and solutions to support CONPES.	Strategic action lines for: the South Drainage System, the South Cali Expansion Zone – Cali- Jamundí corridor, and the quality of the Cauca river water, and its impact on the city's water supply.	No activities. A critical analysis into alternative wastewater options and water saving devices are generating interest by developers, contractors and authorities	All activities are published on the LA website. City assessments. International short courses, brochures, posters, media broadcasts.	Input to CONPES 3624 National Policy for the upper Cauca river – includes LA strategic action lines.

Hamburg

Developing a transition arena was a challenge in Hamburg due to the several arenas' already in operation, the lack of continual facilitation due to staff turnover, and delays with the International Building Exhibition plans which the LA work was planned around. Continual facilitation is key to not only successful change management but action-research processes. Its importance is illustrated by a quote from a city stakeholder who lamented the departure of the facilitator: 'Since X went away, there has been very little communication' (Sutherland et al, 2011). The Learning Alliance Hamburg held four meetings in total during the SWITCH project. An IUWM plan for Wilhelmsburg was developed and a university staff was involved in the design of the 'Haulander Weg' greenfield development. Unfortunately the project could not be fully integrated in SWITCH as a demonstration project.

The research work in Hamburg on Water Sensitive Urban Design resulted in the publication of a manual on Water Sensitive Urban Design. The target audience of the publication are all those involved in the planning, design and maintenance of stormwater management and in urban design. Its intention is to explore the possible innovations spanning the topic of sustainable stormwater management and to show how it can be applied in cities while taking up the opportunities to use it for increasing the cities' amenity and quality of life.

WSUD manual front cover

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Several projects already in participatory activities. Small SWITCH LA core membership in 2007 then expanded to include NGO's and citizen groups.	Wilhelmsburg Island: 1. water regulation systems 2. recreation and conservation	Stop / start due to leadership difficulties. Planned 'Haulander Weg' is an Innovative project which highlights best practice for WSUD implementation.	Workshops. City assessment 2010. WSUD Design Manual.	'Haulander Weg' demonstration project will be part of IBA Hamburg 2013 International Building Exhibition.

Lodz

SWITCH introduced a package of measures which equipped the extremely dedicated LA with skill sets that enabled the breaking down of existing barriers by forming an LA that was capable of putting an IUWM agenda firmly into the institutional and public domain. Lodz LA had a very strong coordinator and facilitator who nurtured links between science, decision makers, the media and key stakeholders. This laid the foundations for the potential to replicate demonstration projects across the city by broadening horizons in key organisations such as the City Office and the Bureau of Entrepreneurship, Development and Investor Relations. There is also interest from other Polish cities. Another tangible outcome is the successful application for the EU funded LIFE+ EHREK project for the revitalisation of one of the City's major rivers and recreational areas - the Bzura River and Arturowek reservoirs (Wagner et al., 2010).

M&E activities were embraced by the coordinator and facilitator as was dissemination of demonstration and research results at international events, through the media and the LA website. The LA also enthusiastically engaged in the international knowledge exchange opportunities provided by SWITCH and this activity combined with regular communication of progress was key to the speed with which the LA progressed its IUWM agenda.

Lodz Green zone (SWITCH Project)

ARENA	AGENDA	EXPERIMENT	MONITOR / LEARN	SUCCESS
Early LA establishment with key stakeholders. Creation of sub- LA subject group platforms which fed results back to LA.	Develop Strategic Plan with clear timeline, budgets and activities.	Revitalisation of urban river valley using eco-hydrological and SUDS principles. Use sewage sludge to grow energy crops.	All activities (meeting, workshops, seminars, field trips, brochures, posters, videos, broadcasts, social events etc) are documented on the website. City assessments. Strong attendance at international workshops / conferences. Use of City Water suite of decision support tools. PhD / MSc. Ecohydrology in Urban Areas book.	Visioning activities and Blue-Green network philosophy adopted into City's spatial and strategic development strategies. Resulted in upscaling demos across the cities' rivers. Successful application for LIFE+ EHREK project

Lima

The LIMA LA exists as two multi-stakeholder platforms at national and local level with active feedback loops between all levels of the key players. The LA focused on upscaling waste water reuse in green productive areas. The demonstrations were specifically chosen with the objective to influence and progress the development of national policy guidelines for safe waste water reuse. Formal approval by the Ministry of Housing, Building and Sanitation has been achieved (Butterworth *et al.* 2011).

Planning wastewater reuse for city greening in Lima

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
National (policies) and Local (research and results) LAs with feedback between the two platforms.	No formal Strategic Plan. Develop policy guidelines and regulations through new knowledge acquired from demos.	Villa El Salvador – six studies: Decentralised waste water reuse in green areas and agriculture.	City Assessment 2010. Workshops. FIETS analysis (Financial, Institutional, Environmental, Technical, Socio-cultural). Website. Training ministry staff on guidelines.	Results from demos developed Policy guidelines and regulations. Links to 'Safe Water' – national sub-committee.

Tel Aviv

Due to the existence of several water focused stakeholder platforms that already integrated key organisations, it was felt unproductive to develop a new 'water platform' in the city. The objective of SWITCH in Tel Aviv was to add to waterscape initiatives by building on existing research projects to further develop and showcase innovative technologies. The LA concept was adopted in the form of an informal 'Water Club' which not only enhanced internal communications but also resulted in the identification of water issues that were not being addressed, primarily the lack of water indicators within the Tel Aviv City Master Plan with which to monitor progress (Sharp *et al., 2010*).

The Soil Aquifer Treatment and Nanofiltration (SAT+NF) demonstration has shown itself to be a low cost, less land intensive and easy to replicate option for treating waste water effluent to a high quality for use in large scale irrigation of crops. There is much global interest in the technology. The inclusion of water indicators into the existing strategic plan and potentially the City Master Plan is viewed as a lasting SWITCH impact in not just Tel Aviv but the whole of Israel (Aharoni *et al, 2010*).

Letter to the Tel Aviv Municipality submitting the final strategic plan including indicators

A letter to the high TA administration

To: Dr Benjamin Maor
Director of Infrastructure and Construction Administration
Tel Aviv – Yafo Municipality

Dear Dr. Maor,

Re: Strategic Planning for the Urban Water Systems of Tel-Aviv-Yafo City

After long and fruitful discussions with your staff and yourself and with the encouragement of Tel Aviv-Yafo Mayor Mr. Ron Huldai, we are very pleased to submit to you the Tel-Aviv-Yafo water profile and the final report of the Strategic Planning for the Urban Water Systems of Tel-Aviv-Yafo.

Kind Regards

Prof. Avner Adin
The Hebrew University of Jerusalem
Faculty of Agriculture, Food and Environment

Avi Aharoni
Mekorot
National Water Company

Cc:
Mr. Ron Huldai, Mayor of Tel Aviv - Yafo
Prof. Kala Vairavamoorthy, SWITCH Scientific Manager
Ms. Carol Howe, SWITCH Project Manager
Dr. Peter van der Steen, Department of Environmental Resources, UNESCO-IHE

ARENA	AGENDA	EXPERIMENTS	MONITOR / LEARN	SUCCESS
Several water-related multi-stakeholder platforms already established. SWITCH LA named the 'Water Club'.	Develop water SP indicators. Disseminate results from the Shafdan waste water reclamation pilot.	Monitor and improve SAT treatment and recovery system for reuse in agriculture. Electroflocuation as pre-treatment for constructed wetlands.	City assessments. Workshops. Field trips. Organised 'Water and Irrigation' Conference. SP indicators = 49 (future and current situations with 5 yr targets). Strong attendance at international workshops / conferences. PhD / MSc. Guidelines for design, O&M of SAT (and hybrid SAT) systems	Water indicators included in the city water master plan. Global interest in SAT-NF process. SWITCH involvement in university 'Green Building' project.

Zaragoza

Zaragoza has long standing experiences in addressing IUWM problems. There were already several IUWM arena's already established so the decision was taken to not develop a formal SWITCH LA. The Municipality was interested in joining the SWITCH partnership, with the aim of becoming a demonstration city with objectives being that SWITCH would develop capacity for the showcasing Zaragoza experiences in urban water management and strengthen water demand management / leakage identification measures through research and demonstration activities. This was successfully achieved through Zaragoza Expo event in 2008 and the establishment of the United Nations Office to Support the International Water Decade.

Another key SWITCH contribution is in the development of the new municipal by-law on eco-efficiency and integrated water management, which draws together and strengthens a number of existing by-laws dealing with water management. The process began in 2009 through the Municipal Water Commission and it includes sections dedicated to management of the water supply network and conditions for household connections and water saving measures at household level. A final draft of the by-law is ready for approval by the City Council. SWITCH work in the sectionalisation approach (re-design of the city's water supply network into sectors) is now institutionalised and is being upscaled well beyond the pilot area (Smits et al., 2010a).

ARENA	AGENDA	EXPERIMENT	MONITOR / LEARN	SUCCESS
Several IUWM arena's already established so decision taken not to form SWITCH LA.	Showcase IUWM. Input research results into existing Strategic Plan based on Agenda 21.	Strengthen Actur water demand management and sectionalisation measures. Network water loss reductions.	City Assessment 2010.Limited SWITCH documentation and publication of experiences and results to date due to contractual difficulties. But SWITCH provided a dissemination framework for outcomes. Demonstrate experiences through Expo 2008 and UN-Habitat 'sustainable water management in cities' 2010.	SWITCH concepts and results input to municipal Strategic Plan and by-law on 'eco-efficiency and IUWM. Input to Ebro River Basin Commission documentation. Sectionalisation approach now institutionalised and is being upscaled well beyond the pilot area.

Synopsis of the degree of success in the cities

Table 9 provides a synopsis of the degree of success that was achieved by applying the SWITCH Approach in the cities to meet the nine project objectives.

- **Blue box** – Fully meeting the objective by demonstrating that an actual change had taken place. For example: strategic plans were actually being implemented at the city / river basin level).
- **Yellow box** – Meeting the objective indicates that a tangible impact was made. For example: several features of a strategic plan or agenda were implemented, or official approval of strategies developed during the SWITCH strategic planning process was pending. Although one of the key objectives of SWITCH was to cover the entire urban water cycle, when developing research agendas, most cities had clear drivers for improving their water systems. Cities focused on the problematic areas of the UWC in their own city whilst maximising the potential gains that could be made in other areas where possible. If a city was achieving objectives that resulted in secondary or indirect gains then this was also considered as meeting an objective. For example: Water demand management approaches such as stormwater reuse in Zaragoza results in decreased potable water use whilst also delivering stormwater drainage gains with the potential for an overall reduction in pollutant load to watercourses or sewers which also creates gains in combined sewer network in the form of reduced stormwater volumes.
- **Blank box** – Signifies that this particular objective was not a key city objective and the objective was not being achieved indirectly through successful implementation of another objective.
- **Red box** – The objective was not met. This was not a common outcome, but would have occured when communication links were broken and relationships that had been developed between the key players at all levels were suspended which effectively brought the strategic planning processes to an end.

table 9 **SWITCH Approach and meeting objectives**

City	Scientific Base	SWITCH to IUWM	Strategic Approach	Stormwater	Water Supply	Sanitation/ Waste Management	Urban Water Services	Institutional Arrangements	Exposure/ Dissemination
Accra	Yellow	Yellow	Blue	Yellow	Yellow	Yellow	Yellow	Yellow	Blue
Alexandria	Yellow	Yellow	Blue		Blue		Yellow	Yellow	Yellow
Beijing	Blue	Yellow	Yellow	Blue	Blue	Blue	Yellow	Blue	Yellow
Belo Horizonte	Blue	Blue	Yellow	Blue	Yellow	Yellow	Blue	Blue	Blue
Birmingham	Blue	Yellow	Yellow	Blue	Yellow	Yellow	Yellow	Yellow	Blue
Bogota	Blue	Yellow			Yellow	Blue	Yellow	Blue	Blue
Cali	Yellow	Yellow	Blue	Yellow	Blue	Blue	Yellow	Yellow	Yellow
Hamburg	Yellow	Yellow	Yellow	Yellow			Yellow	Yellow	Yellow
Lima	Blue	Yellow	Yellow	Blue	Blue	Blue	Blue	Blue	Blue
Lodz	Blue	Yellow	Blue	Blue	Yellow	Blue	Yellow	Blue	Blue
Tel Aviv	Blue	Yellow	Blue	Blue	Blue	Blue	Yellow	Blue	Blue
Zaragoza	Blue	Yellow	Yellow	Yellow	Blue	Yellow	Yellow	Blue	Blue

Blue: Met the objective — Yellow: Meeting the objective — Red: Objective not achieved — Blank: Not a city objective and not met indirectly through other objectives

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http://www.un.org/waterforlifedecade/swm_cities_zaragoza_2010/confprog.shtml - conference jointly organized by the UN Office, the city of Zaragoza, and the SWITCH consortium to Support the International Decade for Action 'Water for Life' 2005-2015. Sustainable Water Management in Cities conference, Engaging Stakeholders for effective change and action - Zaragoza Dec 2010 – a meeting of experts, local government, media specialists, key water operators, political representatives to discuss issues and propose practical ways to move forward to meet the challenges of achieving water and sanitation for all, of disseminating results to a wider audience, and considering different development contexts and regional characteristics.

6. Measures of Success

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SWITCH PhD and MSc Research Activities

Theme 1. Urban Water Paradigm Shift

Lead by UNESCO-IHE – P. van der Steen

1.1 Development of a strategic approach and indicators for risk and sustainability

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Development of risk indicators for IUWM and inclusion in decision making processes	K.Khatri	K. Vairavamoorthy, P. van der Steen	UNESCO-IHE	x		
Development of sustainability indicators for IUWM; emphasis on public health indicators	I. Lunani	K. Vairavamoorthy, P. van der Steen	UNESCO-IHE, IWMI, KNUST		x	Accra
Development of sustainability indicators for IUWM; emphasis on public health indicators	I. Suleiman	K. Vairavamoorthy, P. van der Steen	IHE, IWMI, KNUST		x	Accra
Development of sustainability indicators for IUWM; emphasis on LCA type of conceptual model	G. Penagos	K. Vairavamoorthy, P. van der Steen	UNESCO-IHE, Mun. Zaragoza		x	Zaragoza
Development of sustainability indicators for IUWM; emphasis on LCA type of conceptual model	M.Mahgoub	K. Vairavamoorthy, P. van der Steen	UNESCO-IHE, CEDARE		x	Alexandria
LCA analysis of the urban water system of Zaragoza	E. Benedi	P. Lens, P. van der Steen	UNESCO-IHE, AYTO		x	Zaragoza
Microbial risk assessment of the Accra urban water system	H. Labite	P. Lens, P. van der Steen	UNESCO-IHE, IWMI		x	Accra

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Application of a total urban water cycle and energy balance model to develop sustainable urban water systems, a case study in Hamburg, Germany	J. Reid	P. Lens, P. van der Steen	IHE, HCU, TUHH		x	Hamburg
Urban water cycle modeling: An approach for future urban water supply alternatives case study Accra, Ghana	M. R. Situmorang	P. Lens, P. van der Steen	UNESCO-IHE, IWMI		x	Accra
Urban Water Management and energy use in the water system of a new development in Hamburg	R. Steendam	K. Vairavamoorthy, M. Siebel, P. van der Steen	UNESCO-IHE, TUHH, HCU		x	Hamburg
Effect of urban water management options on flooding events in Birmingham	M. P. Thuy	K. Vairavamoorthy, Z. Vojinovic, P. van der Steen	UNESCO-IHE, UNIBHAM, Severn Trent		x	Birmingham
Urban water management options for Tel Aviv; water balance and energy consequences	T.T.H. Duong	K. Vairavamoorthy, P. van der Steen	UNESCO-IHE, HUJI, MEKOROT, Mun. of Tel Aviv		x	Tel Aviv
Application of QMRA for analyzing public health risk from drinking water supply in a low income area in Accra, Ghana	E. Machdar	P. Lens, P. van der Steen	UNESCO-IHE			Accra
Development of Stormwater Management Strategies in Tel Aviv, by Application of City Water Balance Model to Describe Material Flows	E. Ndetei	P. Lens, P. van der Steen	UNESCO-IHE			Tel Aviv
Application of City Water Balance in Accra	R. Villados	P. Lens, P. van der Steen	UNESCO-IHE			Accra
Application of City Water Balance model to develop strategies for urban water management in Hanoi, Water balance, Contaminant fluxes	T. B. N. Duong	P. Lens, P. van der Steen	UNESCO-IHE			

1.2 Modeling of urban water systems and development of decision support system

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
A systems analysis framework for sustainability assessment in IUWM	E. Last	R. Mackay	UNIBHAM	x		Birmingham
Agent Based Models for integrated urban water management	A. Sanchez	Z. Vojinovic	UNESCO-IHE	x		
Integrated Urban Wastewater Systems Modelling for	S. Seyoum	Z. Vojinovic	UNESCO	x		
Strategic Planning Purpose	S. Seyoum	Z. Vojinovic	UNESCO-IHE	x		
Multicriteria Optimization in Rehabilitation of Urban Drainage Networks	W. Barreto	Z. Vojinovic	UNESCO-IHE	x		
Integrated urban water management under climate change: modeling and strategic planning	Zhuo	A. Mynett, Z. Vojinovic	UNESCO-IHE		x	
Integrated urban wastewater system modeling with conceptual surrogate models	Y. Chen	A. Mynett, Z. Vojinovic	UNESCO-IHE		x	
A GIS-based framework for urban flood modelling and disaster management	Ediriweera	Z. Vojinovic	UNESCO-IHE		x	
Urban flood forecasting using high resolution radar data	A. D. Teklesadik	Z. Vojinovic	UNESCO-IHE		x	
Evolution of Urban Drainage Networks Using Agent Based Models	M. M. A. Waly	Z. Vojinovic	UNESCO-IHE		x	

1.3 Integration of existing infrastructure

No MSc or PhD studies in this work package.

1.4 Strategic planning, implementation and performance assessment

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Data-indicator system for a "water aware" collaborative urban planning approach "A Systems-Based Generic Decision Support System. Application to urban water management"	C. Schenk	M. Soutter	EPFL	x		Birmingham
Evolution scenarios and performance assessment of IUWM strategies "Integrated resources management: A systems modelling framework for managing environmental information and scenario data"	B. Roquier	M. Soutter	EPFL	x		Alexandria
Spatial indicators for urban water management "Prototype d'un système d'indicateurs géoréférencés pour la gestion de l'eau urbaine"	E. Gex	M. Soutter	EPFL		x	
SMURF prototype in Accra "Intégration du domaine de l'eau dans des approches multi-acteurs de planification et de gestion urbaine participatives à Accra ; Ghana"	A. Mulon	M. Soutter	EPFL		x	Accra
SMURF prototype in Belo "Gestion de l'eau a Belo Horizonte (Bresil) : état des lieux et implementation de l'outil sig smurf (systeme de monitoring urbain fonctionnel)".	C. Lador	M. Soutter	EPFL		x	Belo Horizonte
Systems approach "Application of an 'information system on the water system' in the city of Birmingham, UK"	J. J. Dessimoz	M. Soutter	EPFL		x	Birmingham
Systems approach "Analyse systémique de la gestion de l'eau par l'application d'un système d'information du système: le cas de Belo Horizonte, Brésil"	P. Brandenberg	M. Soutter	EPFL		x	Belo Horizonte
In Integrated modeling for the "Upper Rea flood problematic integrated modeling"	P. Oldendorf	M. Soutter	EPFL		x	Birmingham

Theme 2. Storm Water Management

Lead by Middlesex University – M. Revitt

2.1 Technological options for storm water control under conditions of uncertainty

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Climate change and stormwater management strategies "A Generic Framework to Produce Probabilistic Rainfall Scenarios Incorporating Climate Change. Application to Sustainable Urban Management Strategies"	X. Beuchat	M. Soutter	EPFL	x		Various
Climate change and stormwater management strategies "Gestion et modélisation des eaux de pluie en milieu urbain. Application au cas de la ville de Belo Horizonte, Brésil"	S. Piers de Ravenschoot	M. Soutter	EPFL		x	Belo Horizonte
Climate change and stormwater management strategies Modélisation de la gestion des eaux de pluie en milieu urbanisé : application au cas de la ville de Genève"	J. Baud	M. Soutter	EPFL		x	
"Climate change and stormwater management strategies Impact du changement climatique sur les precipitations: application doune méthodologie de simulation de series de pluies sous un climat altéré"	M. Ramos Plaza	M. Soutter	EPFL		x	Various
In stream treatment facility for creek revitalisation	P. de Castro Vieira	M. von Sperling	UFMG, PHB	x		Belo Horizonte
Risk assessment of soil pollution due to stormwater infiltration	F. Belotti	C. Oliveira	UFMG, PHB	x		Belo Horizonte
Assessment of infiltration and detention trenches wet weather pollution abatement	A. Silva	N. de Nascimento	UFMG, PHB		x	Belo Horizonte
An assessment of an urban stream restoration project in Brazil	D. Macedo	A. Magalhaes	UFMG		x	Belo Horizonte
Assessment of the environmental conditions of the main sources of water in Belo Horizonte	M. Felippe	A. Magalhaes	UFMG		x	Belo Horizonte

2.2 Decision-making processes for effective urban stormwater management

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Considering global change in urban stormwater management concepts – a local scale case study	B. Helm	H. Sieker, P. Krebs	IPS		x	
Water governance in Belo Horizonte, Accra and Birmingham – a comparative study	T. Nunes	H. Costa	UFMG, PHB	x		Belo Horizonte
Assessment of economic consequences of floods using agent based modeling	V. Cancado	N. de Nascimento	UFMG	x		Belo Horizonte
Flood emergency response in urban areas	C. Nunes	N. de Nascimento	UFMG	x		Belo Horizonte
Economic assessment of flood damages and evaluation of the viability of using flood	C. Parisi	N. de Nascimento	UFMG	x		Belo Horizonte
Urban Growth and water demand in Belo Horizonte	G. Umbelindo	A. Barbieri	UFMG	x		Belo Horizonte
Assessment of public perception of flood risk	R. Franca	N. de Nascimnento	UFMG		x	Belo Horizonte
Flood emergency planning in urban areas – traffic management	R. Bonatti	N. de Nascimento	UFMG		x	Belo Horizonte
An assessment of public perception of river restoration projects in Belo Horizonte	I. Medeiros	A. Magalhaes	UFMG		x	Belo Horizonte
Urban agriculture practices in Belo Horizonte	M. Neves Coutinho	H. Costa	UFMG		x	Belo Horizonte

2.3 Env. Change studies for stormwater control and reuse options

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Aquifer storage recovery	C. Woolhouse	R. Mackay	UNIBHAM		x	Birmingham
Hydrology of Brown roofs	N. Inverarity	R. Mackay	UNIBHAM		x	Birmingham
Groundwater Impacts and reuse	Various MSc students	R. Mackay	UBHAM		x	Birmingham
Combined Surface – Groundwater modeling	Various MSc students	R. Mackay	UBHAM		x	Birmingham
Adsorptive Removal of Heavy Metals from Urban Storm Water Run-off	D. Yadav	B. Petrusevski	UNESCO-IHE		x	
Effect of pH and Silica on Arsenci removal with IOCS	Y. Gebreyowhannes	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Adsorption of copper and cadmium from urban runoff on iron oxide based adsorbents	Bakhamas	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Optimization of IHE family filter for manganese removal under laboratory conditions	R. Shresta	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Effect of water quality matrix on chromium removal	K. Thapa	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Adsorptive removal of arsenic and chromium from groundwater by iron oxide based adsorbents	D. Saputro	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Critical review on the adsorptive removal of heavy metals by iron oxides based media	N. Stanic	G. Amy, B. Petrusevski	UNESCO-IHE		x	
Effect of Temperature and Redox Conditions on Removal of Contaminants during Soil Aquifer Treatment.	Y. N. Malalo	G. Amy, B. Petrusevski	UNESCO-IHE		x	

Theme 3.Efficient water supply and water use for all

Lead by Hebrew University – A. Adin

3.1 Demand management for optimization of urban water serices

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Incorporating energy use into the Economic Level of Leakage Model	C. Muñoz Trochez	S. Kayaga, I. Smout	WEDC	x		Zaragoza
Modelling a water conserving tariff for the city of Kampala	R. Motoma	S. Kayaga	WEDC		x	Kampala

3.2 Safe water reuse

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Hydraulic testing of the viral migration test array	H. Ferguson	M. Riley	UBHAM		x	Birmingham
The use of electrocoagulation to remove humic acid from water as pretreatment in membrane filtration	R. Bernstein	A. Adin	HUJI		x	Tel Aviv
Hydraulic Testing of the viral migration test array	Helen Fergus on + 1 student per year	M. Riley	UNIBHAM		x	Birmingham
Effect of SAT effluent on performance of MF and UF membranes	Al-Sakkaf	G. Amy, S. Sharma	UNESCO-IHE		x	
Effect of SAT pre-treatment on performance of NF membranes t	M. Fernando	G. Amy, S. Sharma	UNESCO-IHE		x	
Analysis of removal of multiple contaminants during soil aquifer treatment	C. Harun	G. Amy, S. Sharma	UNESCO-IHE		x	

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Soil Aquifer Treatment as a pre-treatment for organic micropollutants removal during membrane filtration	M. Caballero	G. Amy, S. Sharma	UNESCO-IHE		x	
QSBR-based decision support tool for the assessment oand prediction fo wastwater-derived organic micropollutants during riverbank filtration	H. Simarmata	S. Sharma	UNESCO-IHE		x	
Identification and quantification of biopolymers as major organic foulants in ultrafiltration	X. Zheng	M. Jekel	TUB	x		
Phosphate adsorption onto granular ferric hydroxide (GFH)	A. Sperlich	M. Jekel	TUB	x		
Investigation of phosphate adsorption onto granular ferric hydroxyde for membrane concentrate treatment (in German)	C. Wegmann	M. Jekel	TUB		x	
Regeneration of iron-based adsorbents and phosphorus recovery by precipitation (in German)	M. Riechel	M. Jekel	TUB		x	
Treatment of membrane concentrates by induced precipitation: phosphate removal and reduction of scaling potential (in German)	D. Warschke	M. Jekel	TUB		x	
Bio-filtration of treated domestic wastewater as pre-treatment prior to ultrafiltration	A. Conzalez Tomaskovich	M. Jekel	TUB		x	
Operational optimization of UF pilot plant filtering tertiary effluent for water reuse (in German)	Z. Liang	M. Jekel	TUB		x	

3.3 Urban water supply and use-other productive reuses

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Coupling physicochemical (Electroflocculation) with natural (Constructed Wetland) processes for tertiary effluent treatment	K. Ozer	A. Adin	HUJI		x	Tel Aviv
Electroflocculation-granular filtration pretreatment for constructed wetlands	A. Barash	A. Adin	HUJI		x	Tel Aviv
Particle Characterization in wastewater effluents	C. Cohn	A. Adin	HUJI		x	Tel Aviv
Electroflocculation-membrane filtration pretreatment for constructed wetlands	S. Bleich	A. Adin	HUJI		x	Tel Aviv
Electroflocculation of a model colloidal suspension: coagulation/flocculation mechanisms and their impact on flux in membrane ultrafiltration	T. Harif	A. Adin	HUJI	x		Tel Aviv
Membrane filtration of nano-particles	A. Dror-Ehre	A. Adin	HUJI	x		Tel Aviv
Modeling electroflocculation-membrane filtration fouling	M. Ben-Sasson	A. Adin	HUJI	x		Tel Aviv

Theme 4. Water use in sanitation and waste management

Lead by Wageningen University – A. Mels

4.1 Eco-sanitation and decentralized waste water management in an urban context

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Study on technology and economy of water-saving about green building community	C. Hongxiang	H. Qiang	CQU	x		Chongqing
Research and demonstration on sustainable water system of green residential district	H. Li	H. Qiang	CQU	x		Chongqing
Study on integrated design of water-saving and wastewater reuse about green building	Y. Jing	H. Qiang	CQU		x	Chongqing
Study on management and control of non-point source pollution from urban surface runoff	H. Yi	H. Qiang	CQU		x	Chongqing
Study on technology of eco-protection water quality in green building	W. Yan	H. Qiang	CQU		x	Chongqing
Assessment of innovative sanitation scenarios for Maawa el Savadeen, a demonstration in Alexandria	Shouk	A. Mels	WU		x	Alexandria
Removal of pharmaceutical residues from separated urine	Z. Junhua	K. Kujawa-Roeleveld, A. Mels	WU, Chonu	x		
Urban harvest/sanitation options models	C. Agudelo	A. Mels	WUR	x		
Evaluation of ecosan system alternatives for urban areas by multi-criteria analysis	K. Ahmed	E. von Muench, A. Mels	UNESCO-IHE		x	Alexandria

4.2 Management of industrial emissions

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Sustainable Small Tanneries in Colombia through a Systematic Approach on Conflict Resolution and Socialization of Cleaner Production	M. Sanz	M. Siebel	UNESCO-IHE	x		
Literature overview of (ecotoxicological) limits of industrial compounds	L. Alejandro Estevez	A. Rodriguez	UNAL		x	Bogota
Literature overview of (ecotoxicological) limits of industrial compounds and public health/economy	D. Andres Combariza	A. Rodriguez	UNAL		x	Bogota
To mobilize options to eliminating industrial emissions; Study of potential impacts of the modifications	V. Martinez	C. Castiblanco	UNAL		x	Bogota
To implement each of the selected cleaner production options in the Bogotá area and monitor the performance of each for a pre-determined length of time	J. C. Pulido	L. C. Osorio	UNAL		x	Bogota

Theme 5. Urban water environments and planning

Lead by University of Birmingham – R. Mackay

5.1 Urban waterscapes-planning & development in urban transformation processes

No MSc or PhD studies in this work package.

5.2 Use of urban water (fresh & wastewater) for urban agriculture and other livelihood opportunities

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Urban water quality characteristics related to livelihoods (food and income) and use of wastewater for productive activities in the Odaw-Korle catchment	E. Abraham	O. Cofie, A. Martin	IWMI, GUEL (NRI)	x		Accra
Demand and supply of water for productive use in Beijing; potential of different sources of water (inc. wastewater and water use efficiency)	L. Bin	L. Lijuan, C. Jianming	IGSNRR	x		Beijing
Demand and supply of water productive use in Beijing; water sources and cycles at the catchment level	L. Jiuyi	L. Lijuan, C. Jianming	IGSNRR	x		Beijing
Improved rainwater harvesting systems (using greenhouses) and use for urban agriculture)	J. Wenhua	C. Jianming, R. van Veenhuizen	IGSNRR, ETC	x		Beijing/Demo in Huairou
Impact of urban development and investment in water and sanitation infrastructure at city level and facilities at the household level on city scale water flows	D. van Rooijen	I. Smout, L. Raschid-Sally, P. van der Steen	WEDC, IWMI, UNESCO-IHE	x		Accra
Analysis of domestic water use for commercial activities among the poor in Alajo and Sabon Zongo communities of Accra, Ghana	K. Oyekan	L. Raschid-Sally, T. Henley	IWMI, Univ. of Manitoba		x	Accra/UK
Financial feasibility of the use of urine for agriculture in Accra	M. Kwame Ofei	C. Egyir	IWMI, Univ. Ghana		x	Accra
Assessment of perception and willingness to use urine for crop production	P. Koomson	O. Cofie, C. Egyir	IWMI, Univ. Ghana		x	Accra

5.3 Maximising the use of natural systems in all aspects of the municipal water cycle

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Hyporheic zone test site characterization, hydraulic testing and chemical investigations	C. Lydon, D. Conran	M. Rivett, R. Mackay	UNIBHAM		x	Birmingham
Assessment and maximizing the utilization of Eco Engineering for the effective management of urban water resources	A. Ali	D. Rousseau, de Kruijf	UNESCO-IHE		x	
Application of ecohydrology for urban river restoration with special consideration of harmonization of hydro-technical infrastructure with ecosystems,	W. Frątczak	M. Zalewski	UL	x		Lodz
Development and evaluation of the Ner River system quality indicators and their application for regional assessment and management of watershed.	K. Drzewiecka	M. Zalewski	UL	x		Lodz
Multiple objective treatment aspects of bank filtration	A. Maeng	G. Amy, S. Sharma	UNESCO-IHE, Korean Inst. of Sci. and Techn.	x		
Optimizing nitrogen removal in algea and duckweed wastewater stabilization ponds.	M. Babu	H. Gijzen, P. van der Steen	UNESCO-IHE	x		
Technology selection model to pollution prevention and control from domestic wastewater in small and medium towns	A. Galvis	H. Gijzen, P. van der Steen	UNIVALLE	x		Colombia
Greenhouse gas emissions	J. P. Silva	H. Gijzen, H. Lubberding	UNIVALLE	x		Colombia
Organic matter Characterisation and EDCs removal during riverbank filtration	M. O. Ibrahim	G. Amy, S. Sharma			x	
Development of algae bacterial biofilms for nitrogen removal in ponds	Munezvenyu	P. Lens, C.M. Hooijmans, P. van der Steen	UNESCO-IHE		x	

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Endocrine disrupting chemicals removal during riverbank filtration	S. Devkota	G. Amy, S. Sharma	UNESCO-IHE		x	
Impact of biodegradability of natural organic matter and redox conditions on removal of PhACs during riverbank filtration	C. Abel	G. Amy, S. Sharma	UNESCO-IHE		x	
Role of small reservoirs for the improvement of water quality in urban rivers and identification of secondary contaminents (toxic algal blooms) in reservoirs	N. Okyere	P. Lens, H. van Bruggen	UNESCO-IHE		x	
A laboratory study on the emissions of N_2O, CH_4 and CO_2 from activated sludge	A.F. Saeed	P. Lens, H. Lubberding	UNESCO-IHE		x	
Participatory processes in wetland management: The case of Urban Wetlands in Bogota, Colombia	A. Guzman Ruiz	E. Hes	UNESCO-IHE		x	
Comparison of PCBs, PCDDS, and PCDFs concentrations in the Solowka reservoirs sediments	M. Urbaniak	M. Zalewski	Dept. of Appl. Ecology, UL	x		Lodz
Application of ecohydrology for urban river restoration with special consideration of harmonization of hydro-technical infrastructure with ecosystems	W. Fratczak	M. Zalewski	Inter. Inst. of Polish Acad. of Sc. Eur. Reg. Centre Ecohydrology	x		Lodz
Benthic diatoms used to assessment of water quality of the Sokołówka River „Okrzemki bentosowe w ocenie jakości wody rzeki Sokołówki"	K. Nowak	J. Żelazna-Wieczorek	Dept. of Mycology and algology gy, UL		x	Lodz
Benthic diatoms of reservoirs on the Sokołówka River „Okrzemki bentosowe zbiorników na rzecze Sokołówce"	P. Nowicka	J. Żelazna-Wieczorek	Dept. of Mycology and algology gy, UL		x	Lodz

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Determination of land cover influence in cachment area of Pilica River on water quality, based on the GIS technology and CORINE data.	J. Mierzejewska	I. Wagner	Dept. of Appl. Ecology, UL		x	Lodz
The use of the natural valleys Sokolowka potential for improving environmental quality and create a friendly area residents (75%)	A. Sosnowska	M. Zalewski	Dept. of Appl. Ecology, UL		x	Lodz
Drivers and pressures of the city water resources – developing risk-based decision support system for implementation of Ecohydrology approach	R. Włodarczyk	P. Frankiewicz	Dept. of Appl. Ecology, UL		x	Lodz
The city gardens as a potential component of the Blue-Green Network – influence of people attitudes on quality of environment.	M. Zasepa	K. Krauze	Dept. of Appl. Ecology, UL		x	Lodz
Chemical and biological monitoring of Sokolowka River	N. Okyere	H. van Bruggen	UNESCO-IHE		x	
The use of nucleic acids as indicators in the anaslysis of ecohydrological processes	T. Kruk	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz
Land use and impermeability of ground in urban areas (the Sokolowka catchment case study)	A. Durys	A. Bartnik	Dept. of Hydr. and Water Management, UL		x	Lodz
Water supply and sewage disposal in Sokolowka catchment	P. Kujawski	A. Bartnik	Dept. of Hydr. and Watermgt, UL		x	Lodz
Hydromorphological evaluation and river bed retention of streams in sokolowka catchment	P. Kozuchowski	A. Bartnik	Dept. of Hydr. and Watermgt., UL		x	Lodz
Vermicomposting of sewage sludge as the method to obtain increase of biomass of the energetic willow and accumulation the heavy metals	K. Tomczyk	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
The habitats influences on the Salix viminalis increase on the protective zone of the Wastewater Treatment Plant (WWTP) in Lodz	B. Wojtyra	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz
Identyfication of the antropogenic contaminations in the Urban catchment Sokolowka River on the base of nitrates and Escherichia coli	C. Magdalena	M. Zaliewski	Dept. of Applied Ecology, UL		x	Lodz
The use of nucleic acids as indicators in the analysis of ecohydrological processes	M. Godowska	M. Zalewska	Dept. of Applied Ecology, Ul		x	Lodz
Optimization of use the sewage sludge to the bioenergy production on the field experimental, 100% completed	A. Drobniewska	M. Zalewski	Dept. of Applied Ecology, Ul	x		Lodz
Groundwater level as a driver of vegetation and regulator of its ecological functions – the case study of urban rivers of Sokolowka and Brzoza	M. Olejniczak	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz
Ecosystem biotechnolotgoes – modification of ecosystem properties as a method of recultivation and management of water resources, the case mof Sokolowka river revitalization project	L. Nowacki	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz
Dynamics of bottom sediments in a cascade of reservoirs, as an element of the systemic urban water management – the Sokolowka River case	M. Przybylak	I. Wagner	Dept. of Applied Ecology, UL		x	Lodz
The influences of the applied of the three-year dose of sewage sludge on the biomass of the different type of the energetic willow	R. Kolasa	B. Sumorok	Dept. of Applied Ecology, UL		x	Lodz
The use of phytotechnology to the utilization of the sewage sludge and compost on the WWTP in Lodz City	M. Klonowski	M. Zalewski	Dept. of Applied Ecology, UL		x	Lodz

Theme 6. Governance and Institutional Change

Lead by UNESCO-IHE – M. P. van Dijk

6.1 Governance for integrated urban water management

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Performance of learning alliances in urban water governance	B. Darteh	A. Sutherland	GUEL (NRI)	x		Accra, Birmingham
A comparative study of different models for environmental sanitation management	P. Heller	N. de Nascimento	UFMG	x		Belo Horizonte
Public policies on water supply and sanitation	P. Heller	L. Heller	UFMG	x		Belo Horizonte
Urban waters: assessing democratic practices and environmental perception in the cities	M. Welter	H. Costa	UFMG		x	Belo Horizonte
Assessing public perception of environmental sanitation services	S. D. Rubinger	L. Heller	UFMG		x	Belo Horizonte
An assessment of social control for sanitation policies: the case of COMUSA, Belo Horizonte	M. Crivellari Mello	L. Heller	UFMG		x	Belo Horizonte

6.4 Financing, cost recovery and institutional models

Research Topics	Researcher	Supervisors	Partner Org.	PhD	Msc	SWITCH City Links
Sanitation; the forgotten part of water services	Bigabwa	M. P. van Dijk, K. Schwartz	UNESCO-IHE		x	
Cost Benefit Analysis of Ecosan in Accra	R. Luwita	M. P. van Dijk	UNESCO-IHE		x	
Fresh Water Swaps: Potential for Wastewater Reuse A Case Study of Alexandria, Egypt	M. Hamdat	M. P. van Dijk	UNESCO-IHE		x	
Mapping pro-poor water supply services in Accra City, Ghana	H. Rachmadyanto	M. P. van Dijk	UNESCO-IHE		x	
The use of economic instrumes to assess ecological investmes in the city of the future	L. Xiao	M. P. van Dijk	UNESCO-IHE	x		Beijing

Journal Papers from the SWITCH Project

Year	Title	Authors	Journal
2007	Assessing the impact of VOC-contaminated groundwater on surface- water at the city scale	Ellis P.A. and Rivett M.O.	Journal of Contaminant Hydrology 91, 107-12
2007	Quantifying urban river–aquifer fluid exchange processes: A multi-scale problem	Ellis P.A., Mackay R. and Rivett M.O.	Journal of Contaminant Hydrology 91, 51-80
2007	Characteristics of aggregates formed by electroflocculation of a colloidal suspension	Harif T. and Adin A.	Water Research 41, 2951-2961
2007	Water Demand Management – Shifting Urban Water Management Towards Sustainability	Kayaga S., Smout I. and Al-Maskati H.	Water Science and Technology: Water Supply 7,4, 49-56
2007	Technology selection and comparative performance of source-separating wastewater management systems in Sweden and The Netherlands	Mels A., van Betuw W. and Braadbaart O.	Water Science and Technology 56, 5, 77-85
2007	Polychlorinated Biphenyls: Sources, Distribution and Transformation in the Environment – A Literature Review	Urbaniak M.	Review Papers, Acta Toxicologica 15, 2, 83-93
2008	Fate of effluent organic matter (EfOM) and natural organic matter (NOM) through riverbank filtration	Maeng S. K., Sharma S. K., Magic-Knezev A. and Amy G.	Water Science and Technology 57, 12, 1999-2007
2008	Characterizing Shape of Effluent Particles by Image Analysis	Mamanea H., Kohn C. and Adin A.	Separation Science and Technology 43, 7, 1737-1753
2008	Cost-effective mini drive-point piezometers and multilevel samplers for monitoring the hyporheic zone	Rivett M.O., Ellis P.A., Greswell R.B., Ward R.S., Roche R.S., Cleverly M., Walker C., Conran D., Fitzgerald P.J., Willcox T. and Dowle J.	Quarterly Journal of Engineering Geology & Hydrogeology 41, 1, 49-60

Year	Title	Authors	Journal
2008	Natural attenuation of a TCE plume at the groundwater – surface-water interface: spatial and temporal variability within a 50m reach	Roche R.S., Rivett M.O., Tellam J.H., Cleverly M.G. and Walker M.	(Edited volume) GQ07: Securing Groundwater Quality in Urban and Industrial Environments, IAHS Publ. 324, 475-482. IAHS Publ. 324 (2008) ISBN 978-1-901502-79-4
2008	Framework for assessment of performance of soil aquifer treatment systems	Sharma S.K., Harun C.M. and Amy G.	Water Science and Technology 57, 6, 941-946
2008	Predicting anion breakthrough in granular ferric hydroxide (GFH) adsorption filters	Sperlich A., Schimmelpfennig S., Baumgarten B., Genz A., Amy G., Worch E. and Jekel M.	Water Research 42, 8-9, 2073-2082
2008	An integrated wastewater reuse concept combining natural reclamation techniques, membrane filtration and metal oxide adsorption	Sperlich A., Zheng X., Ernst M. and Jekel M.	Water Science and Technology 57, 6, 909-914
2008	PCBs and Heavy Metals Contamination in Bottom Sediments from Three Reservoirs of Different Catchment Characteristics	Urbaniak M., Zieliński M., Wesołowski W. and Zalewski M.	Polish Journal of Environmental Studies 17, 6, 941-949
2008	Ekohydrologia terenów zurbanizowanych	Wagner I.	Ekopartner 10, 204, 14-15
2009	SWITCH in Birmingham, UK: experimental investigation of the ecological and hydrological performance of extensive green roofs	Bates A. J., Mackay R., Greswell R. B. and Sadler J. P.	Reviews in Environmental Science and Biotechnology 8, 295-300
2009	Iron-oxidation processes in an electroflocculation (electrocoagulation) cell	Ben Sasson B., Calmano W. and Adin A.	Journal of Hazardous Materials 171, 704-709
2009	The role of municipal committees in the development of an integrated urban water policy in Belo Horizonte, Brazil	Costa G. M., Costa H. S. M., Dias J. B. and Welter M. G.	Water Science and Technology 60, 12, 3129-3136
2009	Silver nanoparticle–E. coli colloidal interaction in water and effect on E.coli survival	Dror-Ehre A., Mamane H., Belenkova T., Markovich G. and Adin A.	Journal of Colloid and Interface Science 339, 521-526

Year	Title	Authors	Journal
2009	The management of urban surface water drainage in England and Wales	Ellis J. B. and Revitt D. M.	Water and Environment Journal 24, 1, 1-8
2009	The design and application of an inexpensive pressure monitoring system for shallow water level measurement tensiometry and piezometry	Greswell R.B., Ellis P., Cuthbert M. O., White R. and Durand V.	Journal of Hydrology 373, 416-425
2009	Framework For Assessment Of Pharmaceutically Active Compound Removal During Managed Aquifer Recharge And Recovery	Maeng S.K. and Sharma S.K.	Proceedings of the NATO Workshop (24-27 October 2009), Luxor, Egypt
2009	Sanitation services for the informal settlements of Cape Town, South Africa	Mels A., Castellano D., Braadbaart O., Veenstra S., Dijkstra I., Meulmand B., Singelse A. and Wilsenach J.A	Desalination 248, 330–337
2009	Characterization of bacterial alginate extracted from biofilm matrix	Lin Y., Zhang H. and Adin A.	Desalination and Water Treatment Science And Engineering 8, 1-3, 250-255
2009	Nickel removal from wastewater by electroflocculation-filtration hybridization	Sun L., Miznikov E., Wang L. and Adin A.	Desalination 249, 2, 832-836
2009	A system model for water management	Schenk C., Roquier B., Soutter M. and Mermoud A.	Environmental Management 43, 3, 458-469
2009	PCDDS and PCDFS compounds in sediments of two shallow reservoirs in central Poland	Urbaniak M., Zielinski M., Wesolowski W. and Zalewski M.	Archives of Environmental Protection 35, 2, 125-132
2009	Sources and distribution of Polychlorinated-Dibenzo-Para- Dioxins and Dibenzofurans in sediments from urban cascade reservoirs, central Poland	Urbaniak M., Zielinski M., Wesolowski W. and Zalewski M.	Environment Protection Engineering 35, 3, 93-103
2009	Managing water in the city of the future; strategic planning and science	Van der Steen P. and Howe C.	Reviews in Environmental Science and Biotechnology 8,115–120

Year	Title	Authors	Journal
2009	Ecohydrological system solutions to enhance ecosystem services: the Pilica River Demonstration Project	Wagner I., Izydorczyk K., Kiedrzyńska E., Mankiewicz-Boczek J., Jurczak T., Bednarek A., Wojtal-Frankiewicz A., Frankiewicz P., Ratajski S., Kaczkowski Z. and Zalewski M.	Ecohydrology & Hydrobiology 9, 1, 13-39
2009	Ecohydrology as a basis for the sustainable city strategic planning: focus on Lodz, Poland	Wagner I. and Zalewski M.	Reviews of Environmental Science and Biotechnology 8, 3, 209-217
2009	Effect of Slow Sand Filtration of Treated Wastewater as Pretreatment to UF.	Zheng X., Ernst M. and Jekel M.	Desalination 249, 2, 591-595
2009	Identification and Quantification of Major Organic Foulants in Treated Domestic Wastewater Affecting Filterability in Deadend Ultrafiltration	Zheng X., Ernst M. and Jekel M.	Water Research 43, 1, 238-244
2010	SWITCH project Tel-Aviv Demo City, Mekorot's case: hybrid natural and membranal processes to up-grade effluent quality	Aharoni A., Guttman Y., Tal N., Kreitzer T. and Cikurel H.	Reviews in Environmental Science and Biotechnology 9, 3, 193-198
2010	Fouling mechanisms and energy appraisal in microfiltration pretreated by aluminum-based electroflocculation	Ben Sasson M. and Adin A.	Journal of Membrane Science 352, 86-94
2010	Fouling mitigation by iron-based electroflocculation in microfiltration: Mechanisms and energy minimization	Ben Sasson M. and Adin A.	Water Research 44, 3973-3981
2010	Impacts of river bed gas on the hydraulic and thermal dynamics of the hyporheic zone.	Cuthbert M.O., Mackay R., Durand V., Aller M.F., Greswell R.B. and Rivett M.O.	Advances in Water Resources 33, 1347-1358
2010	Control of biofilm formation in water using molecularly capped silver nanoparticles	Dror-Ehre A., Adin A., Markovich G. and Mamane H.	Water Research 44, 2600-2609
2010	Urban water management solutions	Howe C. and Vairavamoorthy K.	International Innovation, Research Media

Year	Title	Authors	Journal
2010	Quantitative Microbial Risk Analysis to evaluate health effects of interventions in the urban water system of Accra, Ghana	Labite H., Lunani I., Van der Steen N.P., Vairavamoorthy K., Drechsel P.and Lens P.	Journal of Water and Health 8, 3, 417-430
2010	Financial and economic feasibility of decentralized wastewater reuse systems in Beijing	Liang X. and Van Dijk M.P.	Water Science and Technology 61, 8, 1965-1973
2010	Characterization of alginate-like exopolysaccharides isolated from aerobic granular sludge in pilot-plant	Lin Y., de Kreuk M., van Loosdrecht M. C. M. and Adin A.	Water Research 44, 3355-3364
2010	SWITCH city water balance: a scoping model for integrated urban water management	Mackay R. and Last E.	Reviews in Environmental Science and Biotechnology 9, 291-296
2010	Towards Sustainability in Urban Water: A Life Cycle Analysis of the Urban Water System of Alexandria City, Egypt	Mahgoub M. E.M., Van der Steen N.P., Abu-Zeid K. and Vairavamoorthy K.	Journal of Cleaner Production 18, 1100-1106
2010	Treatment of membrane concentrates: phosphate removal and reduction of scaling potential	Sperlich A., Warschke D., Wegmann C., Ernst M. and Jekel M.	Water Science and Technology 61, 2, 301-306
2010	Eco Cities, Better Cities, Better Life? Experiences of European and Asian Cities, in particular Beijing and Rotterdam	Van Dijk M.P.	Shelter, HUDCO/HSMI, New Delhi October 2010, 12, 2
2010	Are pharmaceutical residues in urine a constraint for using urine as a fertiliser?	Winker M.	Sustainable Sanitation Practice 3, 18-24
2010	Ryegrass uptake of carbamazepine and ibuprofen applied by urine fertilization	Winker M., Clemens J., Reich M., Gulyas H. and Otterpohl R.	Science of the Total Environment 408, 1902-1908
2010	Biopolymer fouling in dead-end ultrafiltration of treated domestic wastewater	Zheng X., Ernst M., Huck P. and Jekel M.	Water Research 44, 18, 5212-5221
2010	Pilot-scale investigation on the removal of organic foulants in secondary effluent by slow sand filtration prior to ultrafiltration	Zheng X., Ernst M. and Jekel M.	Water Research 44, 10, 3203-3213

Year	Title	Authors	Journal
2011	Resource management as a key factor for sustainable urban planning	Agudelo-Vera CM, Mels A.R., Keesman K.J. and Rijnaarts H.H.	Journal of Environmental Management, 2011
2011	Urban water management strategies based on a total urban water cycle model and energy aspects – Case study for Tel Aviv	Duong T.T.H., Adin A., Jackman D., Van der Steen P. and Vairavamoorthy K.	Urban Water Journal, 8, 2, 103-118
2011	Occurrence and fate of bulk organic matter and pharmaceutically active compounds in managed aquifer recharge: A review	Maeng S.K., Sharma S.K., Lekkerkerker-Teunissen K. and Amy G.L.	Water Research 45, 3015-3033
2011	RNA/DNA ratio as an indicator of the impact of long-term accumulative contamination for the assessment of river degradation – a pilot study	Mankiewicz-Boczek J., Zbigniew K., Godowska M. and Zalewski M.	Ecohydrology and Hydrobiology 11
2011	Effect of substrate depth on green roof vegetation: An initial experimental assessment of the influence of substrate depth on floral assemblage for extensive green roofs	Olly L.M., Bates A.J., Sadler J.P. and Mackay R.	Urban Forestry & Urban Greening (Paper submitted and due for publication 2011)
2011	Urban groundwater baseflow influence upon inorganic riverwater quality: the River Tame headwaters catchment in the City of Birmingham, UK.	Rivett M.O., Ellis P.A. and Mackay R.	Journal of Hydrology 400, 206-222
2011	Removal of estrone, 17α-ethinylestradiol, and 17ß-estradiol in algae and duckweed-based wastewater treatment systems	Shi W, Wang L., Rousseau D.P.L. and Lens P.N.L.	Environmental Science and Pollution Research 17, 4, 824-833
2011	Learning alliances for integrated and sustainable innovations in urban water management	Verhagen J., Butterworth J. and Morris M.	Waterlines 27, 2, © Practical Action Publishing
2011	Stabilizing the performance of ultrafiltration in filtering tertiary effluent-Technical choices and economic comparisons	Zheng X., Ernst M. and Jekel M.	Journal of Membrane Science 366, 1-2, 82-91

Notes

Colophon

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SWITCH Sustainable Water Management *in the City of the Future*

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