018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Deliverable D1.1.2 - B

Formulation of the draft SWITCH strategic approach and testing of the approach in 4 workshops

Due date of deliverable: M22
Actual submission date: M33

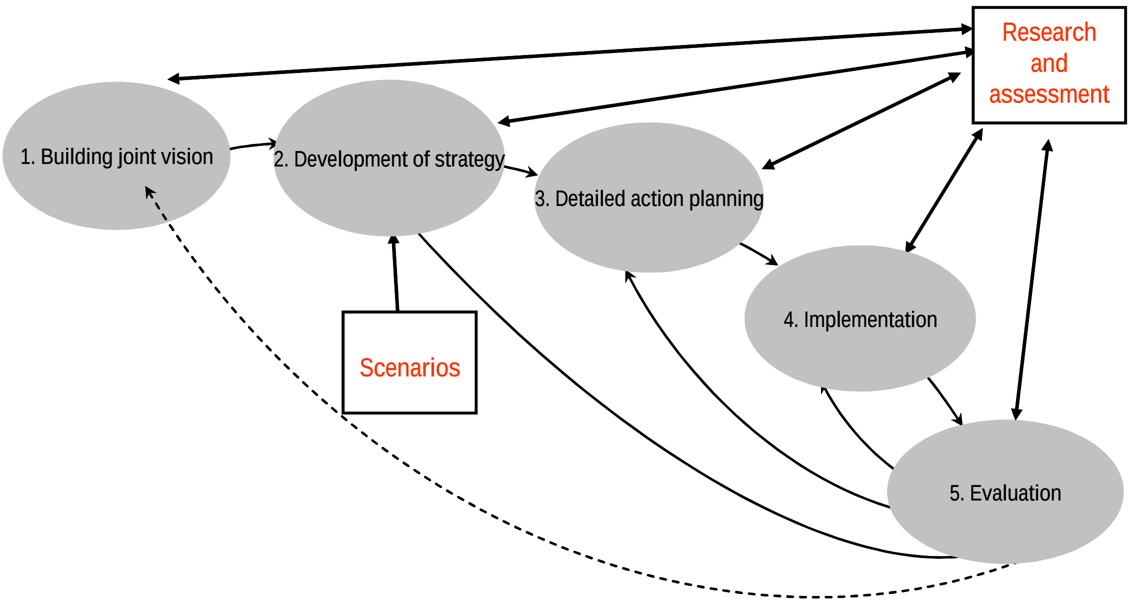
Start date of project: 1 February 2006 Duration: 63 months

UNESCO-IHE Institute for Water Education
Peter van der Steen

Revision [final]

Project co-funded by the European Commission within the Sixth Framework Programme (2006-2011)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SWITCH Approach to Strategic planning for Integrated Urban Water Management (IUWM)



Peter van der Steen, John Butterworth, Heike Langenbach, Adriaan Mels, Diederik Rousseau, Ian Smout, Saroj Sharma and René van Veenhuizen

SWITCH Approach to Strategic planning for Integrated Urban Water Management (IUWM)

Audience

The target audience of this document is the scientific and professional water sector (utilities, universities, private sector) in Europe and major cities in developing countries. Urban water managers are designing and operating the urban water system (or elements of it) according to certain approaches and underlying assumptions. These approaches determine the strategic direction of the cities watermanagement. It is believed that current changes in the urban environment require a rethinking of these approaches. This document contains the results of this process of rethinking urban water management, with an emphasis on the role of strategic planning.

Purpose

To present an overview of the current state of the SWITCH approach to UWM. This approach is aimed at solving the challenge of water management in the city of the future.

The approach consists of the following elements:

- 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 of strategic planning for urban water management under changing conditions and uncertainty.
- 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, the results of which are 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 of these strategies and options.
- Recommendations on the application of a number of innovative (technological) options in future urban water management schemes.

Background

The current approach and methods in urban water management are unlikely to result in a sustainable (finances, environment and society) urban water system. The global change pressures, such as rapid urbanisation, rising energy prices and climate change will make conventional methods of urban water management just not enough. Therefore a new approach is needed, build on strategic planning. This documents reports about the progress SWITCH has made in this respect in the first half of the 5 year project.

Potential Impact

If the SWITCH approach is accepted by decision makers in Europe’s major cities it will result in a new approach to urban water management, characterised by integrated (holistic) rather than piecemeal design and management of the urban water system. The system will be aimed at satisfying simultaneously social, financial and environmental boundary conditions and will use at a wide scale innovate technologies and methods.

Contents

SWITCH Approach to Strategic planning for Integrated Urban Water Management (IUWM)

Urban water management is the activity undertaken by public and private organisations to achieve or to maintain: a) sustainable water supply for a variety of end-users, b) hygienic collection and treatment of (liquid) waste, c) good water quality in surface and groundwater bodies, d) the use of water bodies as an urban amenity to improve the living environment and e) a living environment not endangered by flooding. This task is becoming increasingly difficult due to a number of changes that are on-going in the world in general and especially in its urban centers.

This document describes the response formulated by SWITCH to address these changes. Its response is build on the uptake of technical and non-technical innovations in urban water management through a multi-stakeholder process, named the Learning Alliance process. The aim of the Learning Alliances is to break down barriers for uptake of innovations, to achieve integrated management of the urban water system by breaking down barriers between institutions and to develop a new strategy for urban water management by going through a process of visioning and strategic planning.

1. A changing world, changing cities

In order to take into account the changes while developing strategies for urban water management, one needs to understand the cause-effect relations that are part of today's realities. The changes and the underlying cause-effect relations are best analysed in a systematic way and a proven model for this is 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 (**impacts**) and finally the **responses** of society to mitigate the impacts (see Figure 1). 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, impacts and responses.

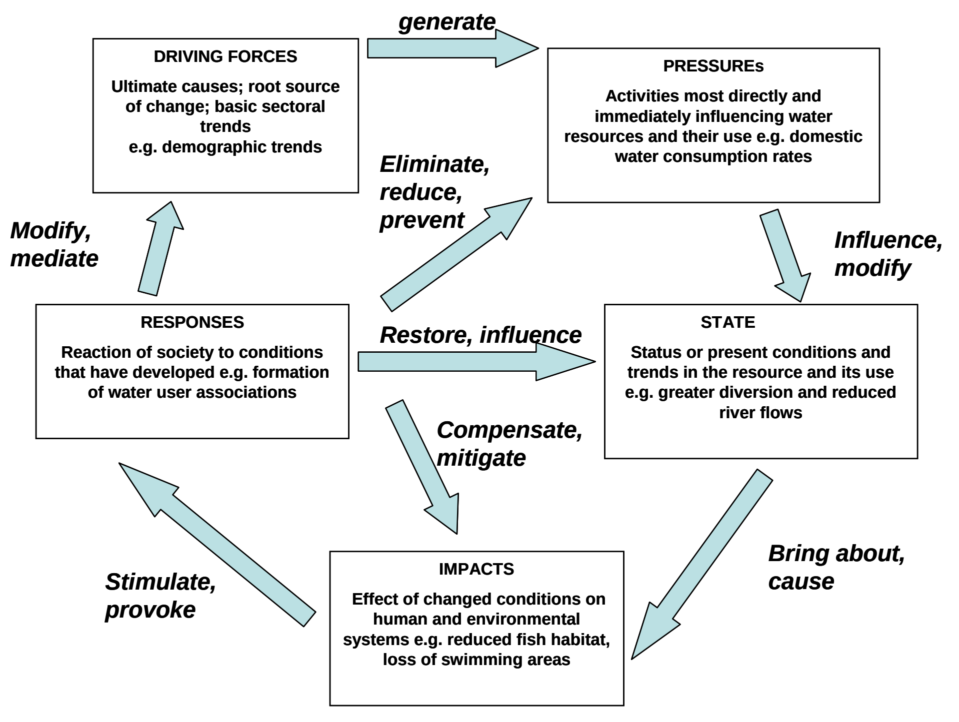


Figure 1. The DPSIR framework (OECD, 2003)

The changes that are currently foreseen, based on the trends, are described below:

Climate change

Climate change is an important driver that affects the pressure on and the state of the urban water system. Changes in precipitation patterns towards more intense storms lead to an increased risk of flooding. Therefore the impacts of flooding, such as economic damage and the spread of diseases, are likely to increase. In the UK the 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 ^{0}C (Stern, 2006). Cities in delta regions may have to cope with significant sea level rises, while at the same time the fluctuations in river discharge are expected to increase. This may lead to extreme high water levels and disastrous flooding, or during low discharge periods to the invasion of saline water. While 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. Cities located in urbanised river basins may need to compete with agriculture for water allocations during the dry periods.

Governance and policies

Another change introduced by the European Water Framework Directive is the increasing involvement of stakeholders in water management, starting right from the planning phases. Decisions and plans are no longer made top-down, but joint decision making involving citizens 'of age' is likely to increase. At the institutional level different forms of cooperation emerge. No longer are only government institutions providing water services to cities. There is a landscape of different models of governance and institutional arrangements. Lack of investment means by governments and the real or perceived inefficiency of public institutions has prompted the participation of the private sector. Currently in Europe 176 million people are receiving water services via private sector participation and it is expected to increase by 75% by 2015. (Kelay *et al.*, 2006). Whether this trend will continue will depend to a large extent on the ability of governments to establish effective regulators.

Population growth and urbanisation

An unprecedented growth of the urban population is a major driver for urban water management, especially in the developing world. Growth rates of up to 4% per year put cities in developing countries for almost impossible challenges. Cities, in principle, are vulnerable because they rely heavily on external resources (water, food, energy, etc.) that need to be imported from outside the city. Planning the cities expansion, providing shelter, energy, water, food and health care is needed (every year!) for numbers of people that equal the population of large towns. Population in urban areas in less developed countries will grow from 1.9 billion in 2000 to 3.9 billion in 2030. On the other hand, in developed countries, the urban population is expected to increase only from 0.9 billion in 2000 to 1 billion in 2030 (UN, 2006). Some European cities are even facing a decrease in the number of its inhabitants or a significant change in the composition of the population (less 'productive' people). Cities that face an increased urban water demand may decide to construct large infrastructural works to transport water from longer and longer distances, creating environmental damage in the cities hinterland. Groundwater table lowering due to overabstraction is already reality in many cities. Rapidly growing cities also generally face major difficulties in providing water services to especially the immigrants within their borders. Informal, unplanned areas generally lack basic water supply and sanitation and form an important target group for reaching the Milennium Development Goals on water and sanitation.

Deterioration of infrastructure systems

In those cities where major water infrastructure was put in place during the previous century, urban water managers will increasingly be confronted with deterioration of infrastructure, especially pipe networks. In many parts of Europe, pipes are over 100 years old and the cost of rehabilitation of water infrastructure system is increasing substantially. European cities are spending in the order of 5-billion Euros per year for wastewater network rehabilitation (Vahala, 2004). The amount spent on asset rehabilitation programmes will further increase over the coming decades due to the synergetic effects of infrastructure ageing, urbanisation and climate change. Infrastructure deterioration will impact on the public health, environment, and institutions in various ways. Higher rate of water leakage means higher water losses and higher chances of in-filtration and ex-filtration of water. This will create higher chances of drinking water contamination and outbreak of water-borne disease.

Changes in public priorities
Increasingly people in Europe express personal identity through the type of food (organic) they consume and the energy supply (green energy or private solar panels) they use. This could also affect the priorities of citizens towards water. It could result in a favourable attitude towards decentralised (therefore more personal) ways of water treatment and wastewater treatment. On a different note, it could also result in a preference for drinking bottled water and the perceived positive health effects or status associated with it.

Emerging technologies
Technological innovation in the water sector is an on-going process which has changed the range of options for urban water management and will continue to do so. The improvement of membrane technologies, especially the reduction in energy requirements and the increasing robustness of these systems has changed already the water and wastewater treatment industry. Application of membrane technologies at decentralised scale in households, shopping centers, universities etc. could completely change the urban water system and open up possibilities for large scale decentralised urban recycling.

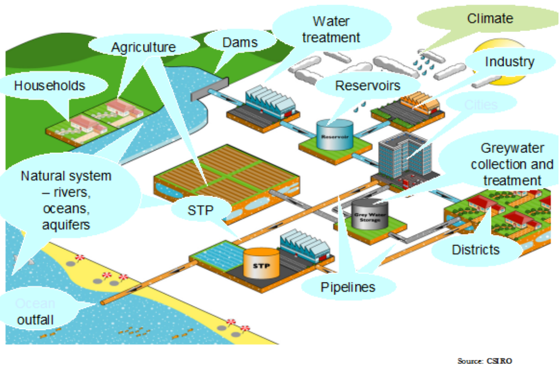


Figure 2. The urban water system

Energy costs
Recently energy costs have surged to unimaginable heights and this will only increase the recognition that the urban water system is a small, but still 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’.

Increasing complexity and risks of infrastructure systems
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 that controls the flood barriers. Similarly, a problem with computers may disturb water or wastewater treatment works. Low flows in rivers may limit the cooling capacity of power plants and therefore power production.

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 (i.e. they need to be more resilient). This uncertainty needs to be included in planning and decision making. The uncertainty also requires strategic thinking, translated into strategic and flexible planning, rather than conventional blue-print planning.

2. The need for strategic planning and an integrated plan

Strategic urban planning is not a one-off undertaking, but a continuous management process, a process of cumulative learning, analysis of issues, repetitive review and updating. Strategic city plans provide decision-makers with a tool that makes it possible for those in the driver-seat to respond effectively to changing circumstances (Municipality of Tel Aviv Yafo, 2006). 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 cities water system. A strategic plan that is jointly developed and accepted by all stakeholders becomes a powerful tool to give direction to yearly plans of municipalities, utilities and waterboards. It may also inspire and invite the private sector to participate in the realisation of the vision.

Strategic plans for the urban water system need to take a long term perspective (15-40 years) because the life span of part of the infrastructure is 40 years or longer and because the changes and pressures also develop over these long time spans. Some changes occur gradually, but some other changes may have the character of step-changes. The plan needs to take into account the uncertainty around the changes and therefore needs to be build on a flexible strategy, using technologies and methods that are flexible and that can be applied under different future scenarios. The nature of a strategic plan is cross-sectoral, it takes a broad view that includes all aspects of the urban water system and even aspects that traditionally are not considered to be the responsibility of the water sector, such as energy issues and urban planning. The plan can only address all aspects, if all stakeholders are involved in its preparation.

Implementation of the plan through the public and private sector will affect the general state of the urban water system. The developments in the state of the urban water system (rather than the performance of organisations) may be monitored in order to evaluate the effectiveness of the strategy and its implementation. A monitoring system based on data collection and the formulation of a number of indicators (such as the total discharge of nutrients from the system, or the total energy use in the system) will help the city evaluate whether it is moving towards its vision for a sustainable urban water system, or not.

It is important to realise that the state of the urban water system and the score of the indicators supersedes the traditional sub-sectors. To achieve the desired state of the urban water system therefore requires an integrated strategy, that acknowledges that the various elements of the urban water system interact (see Figure 2). The changes in the system elements and their effects are all interlinked. It is crucial that system boundaries are wide enough, not to externalize important effects, either in space or time. Too narrow system boundaries will result in 'harmful suboptimization' (Hellström et al., 2000).

3. Major strategic issues facing cities now and in the future

Based on the change pressures one could identify a large number of issues that strategic plans ideally would address. For each of these issues the strategic planners need to make strategic decisions. The strategic issues include the following:

3.1 Governance and institutions

- The European Water Framework Directive stipulates stakeholder involvement (consultation) in the preparation of river basin management plans. In urban water management such a strategic decision has not been made yet. Cities may consider a choice regarding the level of involvement (consultation, joint planning, joint decision making) of individual citizens, NGOs and companies. This involvement is important for several reasons. One example is that involvement and cooperation is required for the introduction of decentralised systems, or, for maintaining the support of the general public for expensive measures for environmental protection.

- Most cities have various institutions that each are responsible for a certain element of the urban water system. This may result in more efficient management of that element, it may also result in harmful sub optimization and a piecemeal approach to an interlinked system. A strategic choice between setting up ‘water-cycle-companies’ (as in Amsterdam for instance) or splitting up responsibilities over various institutions under a regulatory body should be considered.

- A city is subject to national and supra-national (European) legislation concerning urban water management. The objectives embedded in the legislation may or may not be in line with the ambitions of the local stakeholders. Some cities or stakeholders may want to set more ambitious goals (for instance in terms of water quality, or energy consumption). A strategic choice between just satisfying the legislation or give room for ambitious stakeholders may be considered. Ambitious goals may generate enthusiasm and societal support and action.

- Decisions about investments in urban water infrastructure are usually based on a thorough financial analysis of the proposed projects, complemented with Environmental Impact Assessments and consideration of social aspects. In practice the weight of the financial aspects are given priority over environmental and social aspects. A strategic decision is necessary about the weight assigned to each element of the Triple Bottom Line (environment, society, finances).

- Cities that engage in a strategic planning exercise are confronted with uncertainty in predicted scenarios. What approach is taken towards uncertainties and the associated risks? A city could adopt a strategy to be prepared for the worst scenario, but would need to pay a financial price. A strategic choice is needed about what rational to follow when selecting acceptable risks.

- Cities may benefit from innovations in urban water management from the academic world or from other cities. Moreover, by cooperation with academics and peers from other cities, cities may contribute to innovations and be the first to benefit. At the same time, investing in research and implementation of innovations is risky. What kind of investments a city wants to make and what risk is the city willing to take? A strategic decision could be to create an enabling environment in which science and research are able to flourish, and to contribute to innovations in the urban water system.

- Urban planning and urban water management have so-far been separate worlds. However, especially the relation between stormwater management and urban planning is very strong. The design of urban areas determines the quantities, qualities and peak flows of stormwater that are generated, as well as the available storage or buffer capacity. Another area that requires close cooperation between urban planners and the water sector is urban reuse of wastewater in urban agriculture. Therefore, a strategic choice is needed about the level of coordination between the two sectors. Are water aspects considered from the very start of the development of urban plans (Water Sensitive Urban Design) or are water managers supposed to manage water within the boundary conditions created by urban planners?

- Each citizen has the same right to water, sanitation and a safe environment. This statement is supported by almost all government, but practice is often different. Investments made by governments are not always targeted such that equity is encouraged. A strategic decision could be to apply an equity-test for all planned investments.

3.2 Water supply, sanitation and environement

- Most cities face increasing risks of periods of water scarcity, either because the water resources are not sufficient or polluted, or because the capacity to treat and distribute the water is limited. These are exacerbated by the drivers of climate change and increasing populations. Water scarcity could be addressed by developing new water resources at a larger distance from the city or to install extra treatment and transportation capacity. Alternatively, strong Water Demand Management measures in the city could reduce the cities demand for external water resources. In addition, alternative water resources in the city could be developed (rainwater, stormwater, recycled wastewater).

- Public institutions in the water sector see their role as ‘service providers’. However, in the developing world it has become clear that these institutions are often not achieving anything close to full coverage. Therefore a strategic choice should be considered to change the organisations from a service provider to an ‘enabling organisation’, helping private initiatives (commercial and non-commercial) in water supply and sanitation to provide services. Also in the developed world, ‘service providers’ may want to involve companies or citizen groups in water management. This could be especially suited to so-called decentralised infrastructure.

- Consideration of economies of scale have lead to so-called ‘centralised’ water treatment and distribution systems, as well as centralised wastewater collection and treatment systems. The advantages may however be offset by the disadvantages of transportation over large distances. Moreover, centralised systems do not benefit from new options for decentralised water production and decentralised treatment and reuse of household wastewater. Therefore cities should consider a strategic choice about whether the decentralised options are going to be implemented seriously and at a large scale.

- Municipalities and utilities in cities in developing countries have been struggling for decades to increase the percentage coverage for the water distribution network and the wastewater collection system. Some argue that decentralised solutions (rainwater harvesting, septic tanks, ecological sanitation) are better and affordable solutions. A strategic decision should be considered to abandon the idea of full coverage with the networks and instead invest in decentralised solutions (see also above on ‘enabling organisations’)

- Modification of natural water bodies (wetlands, aquifers, river banks) through ecological engineering or the use of waste stabilisation ponds has shown that the natural purification capacity of these natural systems is excellent. In urbanised areas however, one needs to carefully plan these facilities, because they need more area than mechanised and energy intensive compact systems (membrane reactors, activated sludge). Careful urban planning and making multiple use of the same space may overcome these limitations. A strategic choice should be considered whether a city would prefer to rely on compact and energy intensive systems or on natural systems with larger land requirements.

- Increasingly strict discharge standards on heavy metals and endocrine-disruptors and some pharmaceutical for effluents from municipal wastewater treatment plants may require quaternary treatment steps. Alternatively one may design strategies to prevent pollution of the wastewater with these compounds. A strategic choice between further improvement of end of-pipe wastewater treatment and the alternative of pollution prevention, reuse and recycling should be considered.

- In many countries the recycling of treated wastewater for agricultural purposes is common practice, although other countries hesitate to officially allow this practice. With increasing scarcity and increasing urban demand, it is likely that urban non-potable reuse or even potable reuse will be more and more considered seriously. The introduction of urban reuse requires an extensive network for distribution (for centralised options). The inclusion of infrastructure like that is best done in the construction phase of new neighbourhoods, even though the reuse practice may only start some time in the future. In cities where water scarcity is pressing and there are possibilities for urban reuse, a strategic decision is therefore needed now.

3.3 Stormwater management

- The expected increased frequency and intensity of storm events requires rethinking of the strategy towards stormwater management. A strategy could either be to increase the capacity of the centralised stormwater drainage system or instead to invest in various forms of stormwater retention, infiltration or use. Or a balanced combination of the two approaches.

- The current trend in sewerage is to install separate sewer systems in new developments, while in many cities stormwater is disconnected from the foul sewer in existing neighbourhoods. The overall cost benefit of the latter is often not clear. In the foreseeable future sufficient data will become available in order to evaluate the disconnection projects. Based on those results the strategy towards disconnection of stormwater could be reconsidered.

- Climate change will increase the danger of flooding, either from high water levels in rivers or from sea level rise. The response of cities (and regions) could be to increase heights of dikes and other protective measures. Alternatively one may decide to adopt other measures ‘to live with water’, such as the use of flood resilient buildings, floating cities or overtopable dikes and other flexible solutions. Such an approach would have major consequences and is of strategic importance.

4. Strategic planning and management of urban water systems under uncertainty

Based on the recognition that global change pressures are real now and will continue to affect the urban water systems in the future and based on the urgency of the above described strategic choices, the SWITCH project embarked on a strategic planning exercise in 9 global cities. The objective of this exercise was not to develop detailed plans, but to develop new strategic directions for urban water management, which would lead to a truly sustainable urban water system. The process in the 9 global cities resulted in a proposed new strategy for urban water management. In the following paragraphs the various phases of the strategy development process in the cities is described. The actors in this process were all part of a multi-stakeholder platform, named Learning Alliance.

4.1 Learning Alliances

One of the features of strategic planning is that it is carried out together with all stakeholders rather than by the municipality or other government authorities alone. The Learning Alliance is a platform where these stakeholders come together and together go through a strategic planning exercise. Only a shared vision for the future of the city and a broadly supported strategic plan can drive the city towards sustainability. The Learning Alliance approach was developed by staff from the International Reference Center on Sanitation IRC (EMPOWER project).

The LA consists of members that come together for meetings with a frequency of 2-6 times per year. The objective of these meetings is to go through the various stages of strategic planning (see below) and finally come up with a new strategy for urban water management. The whole process may take between 2-5 years to go through and requires also studies and research in between the meetings. The new strategy will need to address the global change pressures and it is believed that such strategies cannot do without innovations. Technological innovations are needed, as well as innovative ways of governance and institutional arrangements. The LA is meant to stir the development of such innovations. Firstly by defining the needs for academic research, and subsequently also by giving feed-back on the interim research results. This cycle of needs assessment, discussing research results and adjusting research activities is the basis for the joint learning experience. This approach makes the likelihood of the upscaling of innovations from the academic world to the city, the national or international level much more likely.

Achieving a truly sustainable urban water system is only possible when this system is designed, planned and managed in an integrated way. This statement has been the key hypothesis of the SWITCH research project and has been confirmed by the research outcomes. For the Learning Alliance, it means that all the institutions or organisations involved or responsible for an element in the urban water system should be represented. This is what is named horizontal integration. Only by a representation that covers the entire urban water system, an integrated strategy can be developed. The strategy development process, using the LA methodology, is geared to break down the barriers between the various organisations.

In addition to horizontal integration, the LA is also meant to achieve vertical integration. Vertical integration refers to the involvement of various levels of government (local, municipal, national, regional) and of NGOs, companies and citizen groups. The vertical character of the LA corresponds to the joint development of strategic plans by all stakeholders. It makes the flow of information between the various levels more easy and allows for the top level to know the real challenges of practice.

The strategic planning process has three subsequent phases (see Figure 3). It starts with the **Visioning**, i.e. the development of a shared vision of the future organisation of the urban water system. After that the LA develops a number of plausible **Scenarios**, i.e. a qualitative and quantitative description of the future external situation that the city and its inhabitants will face. Finally, **Strategies** are developed which describe the various general strategic approaches which could be followed under certain scenarios to achieve the vision. The three phases are described in more detail in the following sections.

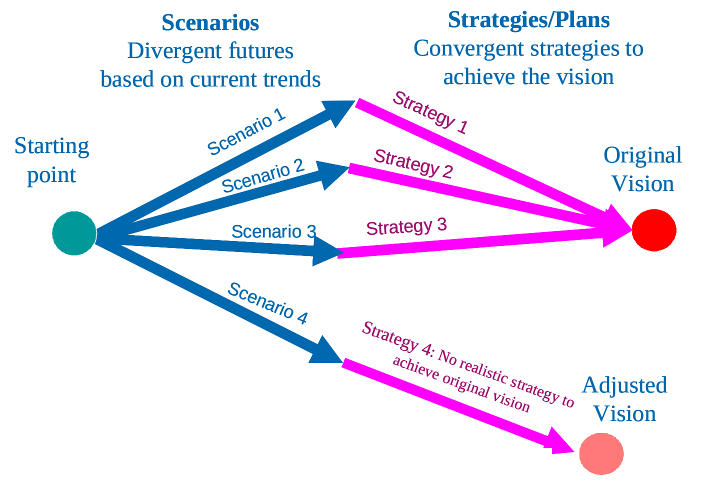


Figure 3. Proposed LA planning process in SWITCH demonstration cities: visioning, scenario analysis and strategy development (Moriarty, pc)

4.2 Visioning[1]

Having a shared vision may provide the drive to a society or a city to move forward. The absence of it may result in stagnation and deadlock. A vision is a picture of a desired future, in this case for the water system of the city. A vision is a narrative description, which is shared by most or preferably all stakeholders. It 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 decisionmakers have a clear vision of what they would like to achieve through the development and implementation of strategies and plans. 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 amongst such a group and a shared commitment to work constructively towards the achievement of a vision. Visioning is often used to promote stakeholder dialogue during the early stages of forming a LA. This is because visioning provides stakeholders with an opportunity to exchange and debate opinions and aspirations for future water services and the urban environment. If it is facilitated well visioning can also be empowering, inclusive, highly participatory and fun.

[1]This section is from SWITCH LA Briefing note no. 9 (Batchelor and Butterworth)

Visioning helps stakeholders to think beyond the day-today reality of problem solving, and to imagine an achievable medium to long-term future for which they can plan – typically 5-15 years ahead at the community level; and 10-30 years ahead at the city level. To be useful as part of a wider planning process, a vision must be realistic and achievable and grounded in the realities of trends in water supply and demand and the successes (and, where appropriate) of ongoing water management initiatives. 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 in a vision. This said, it is often easier to get consensus amongst a diverse group of stakeholders on the components of vision than it is on the strategies and plans for achieving a vision. Or put another way, strategies and plans are often more politically contentious than visions. Visioning gives stakeholders an opportunity to discuss their concerns and fears with other stakeholders and/or members of a learning alliance. In this context, visioning can create a focus for discussions between specialists and non-specialists. It is important, however, that specialists recognise that their role in visioning should be one of supporting rather than leading discussions. Facilitation is often needed to ensure that specialists present information in a form that can be understood by non-specialists. Visioning is not to be carried out as a one-off activity but is part of the wider strategic planning process. Visioning is often necessary and a number of different levels from the community up to the national level. Ideally, community and city level visions should inform, and be informed by national polices and strategies. It is also important that there is consistency across visions created at different spatial and temporal scales. For example, a city level vision should be mutually consistent with a vision that has been developed for the district or governorate in which the city is located and a vision developed for a time horizon of 10 years should be mutually consistent with a vision created for a time horizon of 30 years. in summary, visioning helps to:

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 indepth ecological awareness contributes to exceptional quality of life. Our city is a leading centre for innovation, education and implementation in Poland.

Developed by the Lodz Learning Alliance in January 2008

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

4.3 Scenario development[2]

"Nothing is more obvious than the unpredictability of the future". In planning processes, we just 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, if not counterproductive, planning processes that are based on probabilities and extrapolation of current trends. Or put another way, unique forecasts of factors influencing water supply and demand can and should not be relied upon. So, what can we do? One

[2] This section is from SWITCH LA Briefing note no. 11 (Batchelor and Butterworth)

option is to use scenarios and scenario building as an integral part of the strategic planning process. In the context of integrated urban water management, the main purpose of scenario building is to enable a LA 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, 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 throughout the fields of industry, commerce and government, its use in the water sector and urban planning is still relatively limited. In these other sectors, scenario building is no longer regarded as gimmick but as a methodology is taken very seriously. The result being that, scenario building is an integral part of planning processes and time and other resources are routinely allocated to develop the skills required to construct and use scenarios effectively. Scenario building can be a very creative and enjoyable process that inspires stakeholders into identifying and discussing uncertainty and risk. Whilst a scenario process should not ignore lessons learnt from early projects and programmes, it is important that stakeholders recognise that the future rarely resembles the past. Adaptation to change is feasible if the change processes are slow and predictable (i.e. based on current trends or frequencies of occurrence). Problems really start to kick in when change is rapid and unpredictable. This is when scenario building shows its real worth as part of a planning process.

Scenarios are developed in workshops (and worked out in more detail after the workshops). The workshops are facilitated by experienced scenario planners and the participants are provided with relevant information (assessment results). Some specialist support is necessary to support the process with expert knowledge to check consistency of the scenarios. In order to include all viewpoints, it is important to maintain the vertical character of the LA. Social groups from the margins of society should also be represented.

The scenario development starts with the identification of most important and at the same time uncertain factors. These factors are combined (n factors; n! potential scenarios) into narrative scenarios. The scenarios 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. Good scenarios have a logical structure and are internally consistent, take full account of existing information and are a mix of narrative and numerical information. Good scenarios will also challenge and surprise rather than confirm current conceptions and have the ownership of the stakeholders.

4.4 Strategy development

After the development of a number of plausible scenarios, the LA is ready to think about a response. Which strategy should 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 most likely to be different under different scenarios. This problem is illustrated in figure 4, where 3 possible strategies and 3 potential scenarios result in 9 different outcomes. Each outcome could be scored based on the extent to which it achieves the vision, for instance by applying a cost-benefit methodology, some other assessment method or an evaluation based on the use of sustainability indicators (see next Chapter). Whatever method is used, an important consideration is the flexibility of the strategy and the flexibility of the measures (infrastructure or institutional arrangements) that will be the result of the strategy. An ideal strategy would be able to achieve the vision not only under one scenario, but under as many scenarios as possible. If one would assign likelihoods of occurrence to the scenarios and one could quantify the outcomes, then one could apply an optimisation algorithm of the Bayesian type to find the optimal strategy.

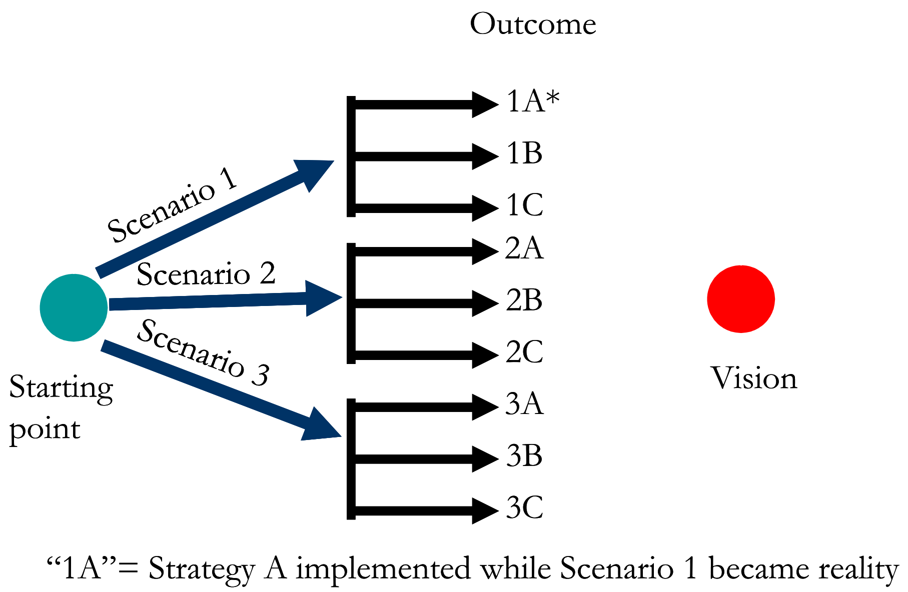


Figure 4. Strategic planing; 3 strategies (A, B and C) under 3 possible scenarios result in 9 possible outcomes.

Although this approach is valid one must also realise that a strategy is not so much a set of technical measures, but more an approach. And it will therefore be extremely difficult to quantify the outcomes of the strategies under different scenarios (Yong Liu et al., 2007). A strategy is more about 'how' to achieve the vision, what 'type' of measures are to be implemented and what are the strategic choices to be made (see Chapter 3). It will therefore not be possible to fully quantify the outcomes, neither to select the optimum strategy based on some optimisation algorithm. Moreover, such an approach would deny the fact that decisions are usually not based on a purely rational analysis, but decisions are the outcome of a discussion amongst stakeholders. In this discussion interests, mandates and power play a significant role. The assessment of the various outcomes and strategies is therefore not so much to find the optimal solution, but rather to provide the stakeholders with information about all options. The stakeholders can use this information in the discussion and come to a decision.

Although 100% quantification of the outcomes and Bayesian optimisation is probably not feasible, it still may make sense to present information about the outcomes of strategies to stakeholders in a (semi) quantified way. One way to present this information to stakeholders is the use of so-called 'sustainability indicators'.

5. Use of sustainability indicators for monitoring the state of the urban water system and for strategy adjustment

When a city has decided to adopt strategic planning it starts an iterative process, with a cycle of 3-10, typically 5 years. After the first strategic plan has been finalised and has been translated into operational plans for the various water sector organisations (see next Chapter) one may expect that this response (DPSIR) is going to affect the state of the urban water system. It therefore makes sense to set up a monitoring system that will measure the state of the urban water system in terms of sustainability indicators (SIs). The score of the indicators in time will indicate the effectiveness of the strategy and the sum of all activities and projects undertaken by the water sector, as well as the effects of external factors. SIs are therefore different from performance indicators, since these are used to measure the performance of organisations, rather than the state of the urban water system. SIs are tools that aim to measure sustainability and to address the key question: is the city moving towards the sustainability vision, or not? The aim of SIs is to guide decision makers, so they can make decisions that direct the city towards the sustainability vision (Lundin, 2002). SI's indicate to what extent the vision has been reached.

Assuming that the LA agreed on a vision for the urban water system that is characterised by 'sustainability' then it makes sense to name the indicators as "sustainability indicators". It is generally agreed that sustainability has financial, social and environmental aspects. The set of indicators that is used to monitor the system therefore ideally includes an equal number of indicators for these three aspects.

Examples of SIs are:

- % of citizens having access to appropriate water supply and sanitation
- number of citizens attracting a water related disease from the urban water system
- total costs of the urban water system
- pollution loads excreted from the water system
- electricity and chemical consumption in the urban water system
- frequency of flooding events in the city

5.1 Indicators and DPSIR

There are different frameworks to use indicators. The simplest framework is lists of a variety of indicators in the categories 'social', 'environmental' and 'financial'. Although these lists can be useful, they fail to increase the understanding of the functioning of the urban water system. Indicators integrated into the DPSIR model (see Figure 1) do increase this understanding. The DPSIR is sometimes simplified to a PSR system. The PSR system applied to the problem of eutrophication results in the following indicators:

Eutrophication	**Pressure**	**Nutrient balance**
		Emissions of N and P in water and soil
		N and P from fertilizer use and from livestock
	State	BOD/DO in inland water, in marine waters
		Concentration of N&P in inland waters, in marine waters
	Responses	Population connected to biological and/or chemical sewage treatment plants
		Population connected to sewage treatment plants
		User charges for waste water treatment

SIs can be formulated at different levels of aggregation (see Figure 5). Where the general public would generally prefer to receive information in the form of Index-indicators, water sector specialists would like to have access to the underlying data. The right level of aggregation for strategic planning purposes is probably the 'headline indicator', for instance formulated as 'degree of eutrophication'. The calculation of the score for the headline indicators is not a trivial exercise (see Figure 6). First of all, one would need to give certain weights to the lower-level indicators and different stakeholders may give different weights to different indicators. In general one may state that the more aggregation is used, the more subjective preferences are included in the headline indicator. Therefore one should prevent unnecessary aggregation. Secondly, some indicators may only be scored in a qualitative way or its value is uncertain (fuzzy). The uncertainties in basic indicators will propagate into the headline indicators (see Figure 6). The resulting uncertainty may be presented to the stakeholders so that they can take uncertainty into account in their decision making.

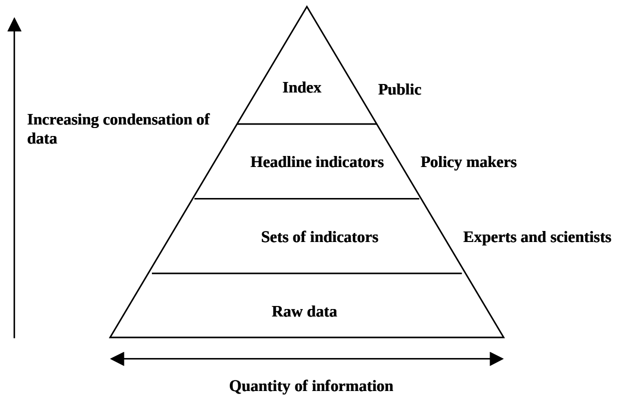


Figure 5. Level of indicator aggregation

5.2 Reporting on indicator scores and data collection

A yearly or bi-annual report on the scores of the agreed set of indicators may be presented to the decision makers, the LA and the general public. Decision makers can then see whether the responses (DPSIR) that they decided on in the strategy have resulted in the desired outcome or not. If the outcome is not satisfactory, the strategy could be adjusted. Once the Learning Alliance (or a post-SWITCH new organisation responsible for IUWM coordination) has decided on the indicators that will be used for monitoring, agreement is also needed on the collection, sharing and making accessible of the required data.

The discussion on sustainability indicators has until now focussed on their use in monitoring and evaluation of the effects of a strategy. However, indicators can also be used to evaluate future plans. In that case there is no historic data available and one needs to rely on predicted data, for instance by using modelling and decision support tools. One such a tool is SWITCH City Water, which is especially developed to evaluate different strategies (down to the level of technical options and innovative financing methods) under certain defined scenarios, in terms of their effect on overall urban water system sustainability. Chapter 8 gives an overview of these 'more sustainable' options. Chapter 9 various methods for integrated assessment of strategies and options can be used for decision making.

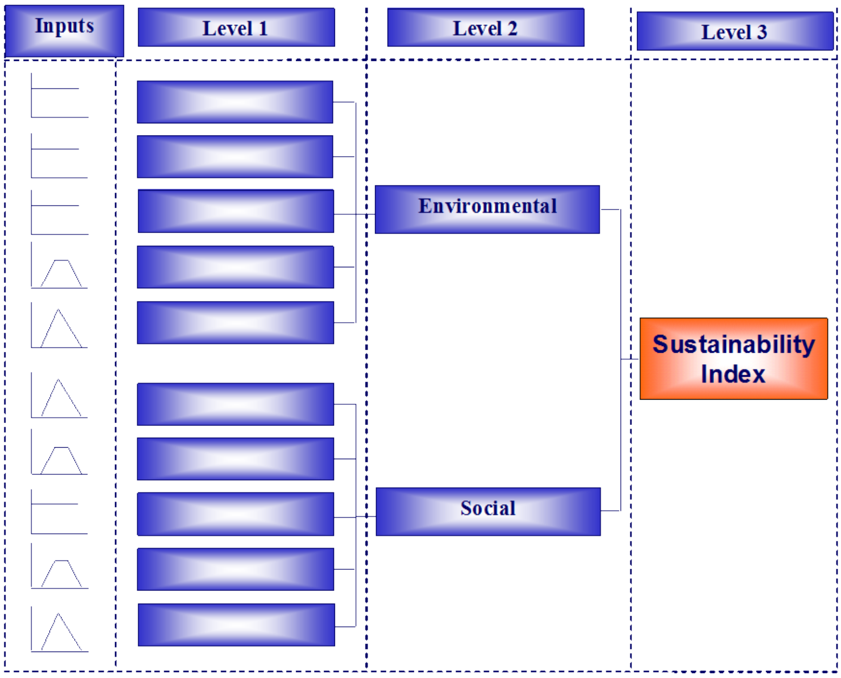


Figure 6. Aggregation of basic indicators into higher level indicators. Uncertainty in input variables for the calculation of indicator values propagates to the higher level indicators.

6. Strategy implementation

Once the water sector in a particular city has gone through the entire process of strategy development (see figure 7), the translation of the strategy into action is needed. Unfortunately this is often a weak point and many plans are gathering dust. Therefore a good implementation plan is necessary, with the roles of all key players defined. It is important to realise that strategic plans cannot be implemented by one organisation alone, due to its integrated nature. Therefore all water sector organisations have a role to play in the implementation, both from the government sector, but also from the private sector (commercial and non-commercial). For the latter, the government organisations could play an enabling role. For the government sector, the strategy is to be translated every year into operational plans for municipalities, waterboards, utilities, etc. Subsequently, for each department annual objectives, targets and workplans are formulated in line with the operational plans and therefore in line with the city strategy. The implementation of these workplans is monitored by using performance indicators. This is the small evaluation loop in Figure 8. In addition to the small evaluation loop, sustainability indicators are used to monitor the state of the city. This long loop evaluation is used to monitor the state of the city in order to evaluate whether all actions together have the desired effect, i.e. moving towards sustainability. Based on the results of the long loop monitoring, the vision, scenarios and strategies are adjusted once every 3-5 years.

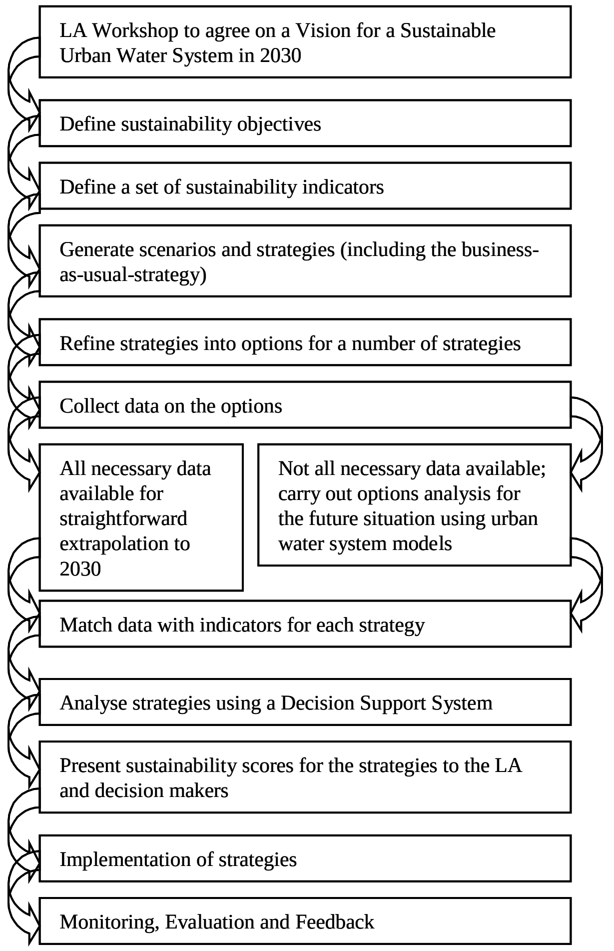


Figure 7. The role of sustainability indicators in the planning process. (Adapted from Foxon et al, 2002)

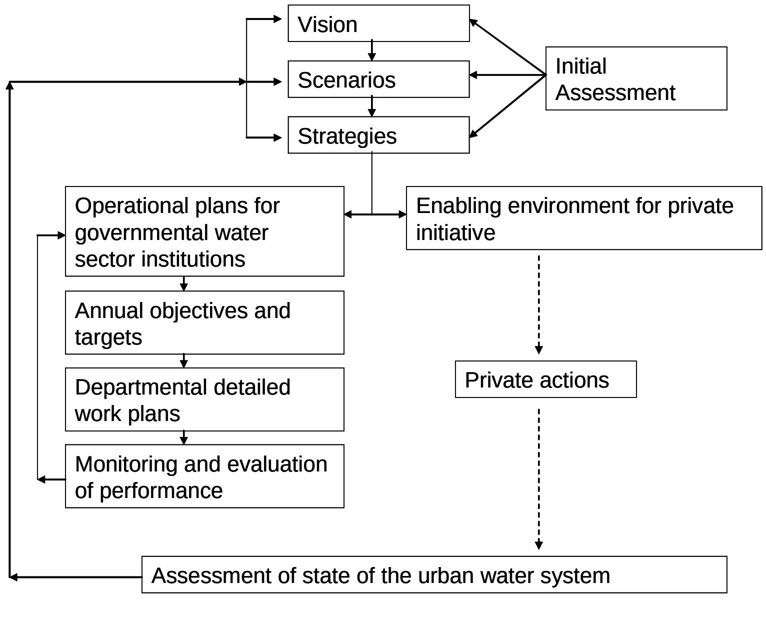


Figure 8. Implementation phase of the strategic planning process

7. SWITCH vision and strategic approach for IUWM

During the SWITCH project the LAs in the demonstration-cities are going through a strategic planning exercise as described above. The products from this exercise are the visions, a set of narrative scenarios and a number of worked out strategies for each city. The 9 global cities are very different in terms of climate and average income and it is therefore logic that the visions, scenarios and strategies are also very much different. Still, a number of communalities emerged and these were merged into the "SWITCH Vision and Strategy for Integrated Urban Water Management". The SWITCH vision for 2035 for a truly sustainable urban water system was formulated in the form of a set of sustainability objectives. A city that wishes to achieve sustainability for its urban water system should set itself the following objectives:

General

1. To have citizens that are aware of 'water and sustainability' and where the authorities will involve the public in decision making
2. To manage its urban water system in an integrated way; integrating aspects of water supply, stormwater management, wastewater collection, wastewater treatment and wastewater reuse .
3. To use a set of sustainability indicators for decision making, strategy development and planning.
4. To have a strong scientific basis for decision making concerning the management of its Urban Water System.To ensure equity in the access to water, as well as to irrigated green areas.
6. To minimise the energy consumption in the urban water system

Water supply and Sanitation

7. To supply water of good quality to its citizens and other stakeholders (industry, companies, agriculture) in sufficient qualities, at the lowest possible costs
8. To give priority to Water Demand Management over development of new water resources
9. To provide all its citizens with proper sanitation, at the lowest possible costs
10. To give priority to pollution prevention over end-of-pipe treatment
11. To reduce the net waste output from the city ot the environment to below the carrying capacity of the receiving environment. Furthermore it will enhance the self-purification capacity of the the receiving environment by ecohydrology

Stormwater management and reuse

12. To reduce the risk of flooding in vulnerable areas to levels acceptable to all stakeholders, even under future climate change scenarios
13. To protect and enhance the water quality and ecological status of urban receiving waters, both surface and ground waters
14. To apply source control techniques to enable stormwater to contribute to the quality of life in the urban environment.
15. To harvest rainwater and stormwater for non-potable reuse purposes.
16. To utilise stormwater to re-establish a balanced natural water cycle (in conjunction with landscape development).

In order to achieve this general vision, one would need to formulate a strategy, which consists basically of the answers to the strategic issues raised in Chapter 3. However, these answers would be very much city specific. An in-depth analysis of a particular city is necessary to arrive at the best strategy. Still, on a more general level one could formulate strategic directions which are valid for basically all cities in the world. These strategic directions are the following:

- UWM strategies need to be aimed at increasing overall sustainability, which means simultaneously satisfying social, environmental and economic boundary conditions.

- UWM strategies need to aim at increasing the sustainability of the overall urban water system (See Figure 2). Optimisation of the entire system will result in more sustainable systems than optimisation of separate elements (sub-systems).
- UWM has the highest chance of success, when based on a learning process in which all water sector institutions are taking part. The City Learning Alliance (LA) is a multi-stakeholder platform that is meant to steer the city towards sustainability or to advise the responsible organisations on how to achieve sustainability. The steps undertaken in this process include a) to agree on a vision for a sustainable urban water system, b) to guide demand-led research to develop innovations that are required to achieve the vision, and c) to upscale successful innovations to the city level.
- The vision for a sustainable urban water system needs to be translated into SMART sustainability objectives, the achievement of which should be measured by using indicators. Monitoring (and publication) of the indicators can be used in evaluation of policies, planning and decision making.
- UWM is providing services to citizens; it needs to provide equity in terms of equal access to water, sanitation, and irrigated green areas, as well as equal protection from floods and other water related services for each citizen.

8. More sustainable options

After a city has decided on the overall strategic directions, more or less in agreement with the general SWITCH approach, it needs to implement the strategy into its working plans (see Chapter 6). The translation of the strategy into working plans will often include choices with regard to which technologies or which methods for urban water management to use. In this Chapter a number of more sustainable options are described, with an emphasis on their potential within the new strategic directions.

8.1 Water Sensitive Urban Design (WSUD)

WSUD as a response to change pressures

'Water Sensitive Urban Design' (WSUD) is the interdisciplinary cooperation of water management, urban design and landscape planning which considers all parts of the urban water cycle, combines water management function and urban design approaches and facilitates synergies for the ecological, economical, social and cultural sustainability. WSUD addresses the change pressures listed in Chapter x, and in addition addresses changes related to cultural aspects. There is an increasing need of an appropriate urban and landscape design of water management solutions, which creates locations with an unique identity. A wide understanding of sustainability is required which includes ecological, economical, social and cultural demands. This can only be achieved in the cities of the future when the isolation in different specialities will be overcome. The possibilities of the different specialities to solve the current and future problems of water management are often exhausted. The combination of urban design, landscape architecture and water management should develop new solutions. Objective of 'Water Sensitive Urban Design' is the functional, sustainable and aesthetical handling of water.

Strategic issues relevant for WSUD

From a WSUD perspective, two strategic issues have to be highlighted. Firstly, the interdisciplinary cooperation between water management, urban planning and landscape design should be improved. Synergies are expected from the interdisciplinary cooperation: improved acceptance of water management measures, economisation by joint planning and sharing realisation expenses, development of attractive locations near water bodies, etc. The integrated cooperation requires several organisational measures, in particular an adequate communication between the several institutions involved. Essential measures are the coordination of the planning activities and the development of a common terminology for communication.

Secondly, the uncertainty of future developments have to be considered. Because of the long lifespan of urban infrastructure, it is conceivable that the basic conditions for the design of the infrastructure will change during its life time. Two types of changes should be considered. On the one hand the change of external factors e.g. consequences of climate change for flood protection or changes in legislation. On the other hand local changes at the planning site and the consequences for the design of the WSUD-solutions have to be considered. Fortunately, WSUD-solutions tend to be more adaptable and flexible, for instance because it is making use of open space in the city, and open space is more flexible for redevelopment than the built up areas. Open space contributes greatly to the adaptability of infrastructure. WSUD-solutions are also required to be robust against changes and robustness does not mean the over-sizing of the infrastructure. Over-sizing could actually negatively affect the operability of infrastructure in the case of declining volumes of water. There is a danger that flexible measures lead to a trivial urban and landscape design without any possibilities of identification. Because of this reason flexible WSUD-solutions need an ambitions urban design, which combines a characteristic design with high adaptability and flexibility.

The way forward

'Water Sensitive Urban Design' (WSUD) aspires to integrate the parameters of sustainable water management in the planning system of modern town planning and urban design. This objective requires planning instruments which are able to improve water qualities as well as qualities of urban design, under the conditions of future development. A design manual was developed that presents sustainable solutions for water management and the urban and landscape design of the city of the future. The manual presents WSUD-solutions for runoff, retention, infiltration, treatment etc. The case studies also illustrate how the single elements of WSUD are combined into sustainable concepts. The following planing principles were identified:

- *WSUD-solutions require the combination of function and design*
- *WSUD-solutions require an interdisciplinary cooperation of urban design, landscape architecture and water management*
- *WSUD-solutions need to be integrated in city-wide or regional planning*
- *WSUD-solutions should consider all parts of the urban water cycle*
- *WSUD-solutions should facilitate social, ecological, economical and cultural synergies*
- *WSUD-solutions should consider the requirements of a fair planning process*
- *WSUD-solutions should consider the temporal aspect of spatial planning*
- *WSUD-solutions have to be adapted to the local basic conditions*

Objective of WSUD is to use the potentials of water management measures as basis for the urban and landscape design. It is improper to separate the functional design (dimensioning, technical principles etc.) from aspects of the urban and landscape design. The functional, sustainable and aesthetical dealing with water management solutions should facilitate the development of attractive locations with a unique identity.

Objective of WSUD is the turning away from engineering standard solutions and to develop solutions which are customised to the local basic conditions. The general objectives of WSUD should be customised for the local basic conditions.

8.2Demand management and sustainable water supply

Water demand management as a response to global change pressures.

According to UN-HABITAT, 2007 was a historical year in which the proportion of people living in the urban areas of the world passed the 50% mark (UN-HABITAT, 2006). Between 2000 and 2030, it is projected that there will be an increase of urban population of 2.12 billion, with over 95% of this increase expected to be in low-income countries (UN-HABITAT, 2004). Yet water resources have remained constant, culminating in a declining per capita water availability. The water scarcity situation is compounded by the major impacts of climate change on the water resources, namely shorter duration of the precipitation seasons and an increase in hydrological extremes (Stern, 2006). Furthermore, these water sources are increasingly getting polluted by rising population. There is no doubt, therefore, that urban water managers need to rethink the way they manage the urban water resources. Conventional urban water planning, which involves fulfing growing demand by mainly considering supply options, is not sustainable.

Urban water managers need to adopt Integrated Resource Planning (IRP), an approach that assesses both supply and demand-side options, and treats them equally when determining how to close the supply-demand gap. Supply planning involves consideration of a wide range of water supply sources such as distant surface water, groundwater, desalination; as well as various sites and sizes of conventional storage, treatment and transfer options. On the other hand, Water Demand Management (WDM) may be defined as the development and implementation of strategies, policies, measures or other initiatives aimed at influencing water demand, so as to achieve efficient and sustainable use of a scarce resource (Savenije and van der Zaag, 2002). Put in another way, WDM is any action that modifies the level and/or timing of demand for water (White and Fane, 2001).

Reducing the demand for water will mitigate the effects of the pressures described above, from population growth and climate change.

Strategic issues relevant for WDM

The research on water demand management will provide tools which urban water planners and managers can use for long term planning, for managing water demand over the long term, and for balancing demand and supply. It will focus attention on strategic indicators for non-revenue water, leakage and consumption by end users, which will enable cities to measure progress towards sustainability. It will put these within a holistic process of Integrated Resource Planning (IRP) which addresses the strategic issues by:

- using a long term planning horizon
- using multiple criteria, including cost control, risk management, environmental protection and consumer preferences.
- encouraging an open process, that is flexible and externally oriented.
- considering environmental and social externalities
- considering price as a signal to guide consumption, and as a way to share costs and benefits between different stakeholders.
- considering risk and uncertainity as factors to be analysed and managed.
- considering stakeholders as participants.

Potential of WDM

WDM options include improving the utility's system efficiency (e.g. through active leakage management, or through pressure management), improving residential water use efficiency, improving non-residential water use efficiency, and substituting potable water use (e.g. with rainwater, storm water, greywater , effluent re-use). The options need are to be assessed and compared for cost-effectiveness and other criteria, and IRP provides a way to do this through an open and participatory decision-making process to evaluate demand-side and supply side options. IRP shifts the focus of attention from the quantity of water delivered to the quality of service provided. As such, consumers are perceived to generate demand for the end uses, such as clothes washing or toilet flushing, rather than a demand for litres of water (White and Fane, 2001). Dis-aggregation of demand into end uses such as toilets and showers enables detailed demand forecasting as well as determination of the the potential for water conservation with respect to various options. IRP compares both demand-side options and supply side options, using a common metric, boundary and assumptions.

The way forward

The research on WDM will contribute to the realisation of the sustainability objectives of the SWITCH vision (as set out in Chapter 7) in various ways. Through educational campaigns on saving water and meter/tariff strategies it will increase the awareness of citizens on 'water and sustainability'.The IRP approach will help cities to manage its urban water system in an integrated way; integrating aspects of water supply, stormwater management and whenever possible, wastewater management. IRP is also using indicators to improve the rational of decision making and the IRP approach provides a framework for comparing reuse with other options. Energy consumption is expected to decrease as a result of WDM, because reducing water consumption reduces the demand for energy to treat and pump the water. Reducing water consumption has also a direct positive effect on the volumes of wastewater.

8.3 Decentralised wastewater management

Decentralised wastewater management as a response to change pressures

Conventionally, wastewater from households and large parts of industrial areas in cities is collected through gravity sewers and transported to central treatment facilities. This way of collection and treatment is based on mixed discharge of concentrated and diluted flows. Although centralised urban wastewater management systems may function well with respect to the protection of public health and the environment - provided treatment facilities are in place and operating - they have several weak points, such as i) removal of an important source of water out of the urban area; ii) destruction of valuable nutrients; iii) frequent storm water overflows that result in uncontrolled discharge of wastewater to urban water systems; vi) production of polluted municipal sludge at wastewater treatment plants; v) emissions of micropollutants to water systems, both in the city and downstream.

The objective of SWITCH research on decentralised wastewater management is to develop and demonstrate pollution prevention-based approaches to wastewater handling in urban areas in which concentrated waste flows are separately collected and treated. A number of research and demonstration initiatives in and outside Europe have already shown that these approaches can result in promising new and cost effective options for wastewater management, preventing emission of pollutants to the urban environment and facilitating new local sources of water and the use of valuable nutrients in agriculture. The dissemination of these approaches is however still limited and various aspects need more development for wider application at city scale.

Systems that separate grey water, black water and / or urine offer new solutions to urban sanitation shifting the paradigms in wastewater treatment from an approach with centralised mixed systems to decentralised systems based on source control and separate treatment of concentrated and diluted household wastewater flows. Potential advantages compared to the 'central paradigm' are: avoiding environmental pollution, enabling the nutrient recovery for agricultural use and preserving water for groundwater recharge, irrigation and other purposes.

The research conducted anticipates on several of the change pressures that are mentioned under chapter 2, i.e.

- Climate change: One major issue of climate change is more intensive precipitation. Mixed sewers that transport both rain water and wastewater are likely to have more overflow events. Most of the decentralised wastewater management systems under research are designed with separate solutions for storm water management. This avoids mixing up of rain water and wastewater and avoids sewer overflows.
- Population growth and urbanisation: decentralised wastewater management linked to local recycling may reduce water scarcity. A combination with urban agriculture could be a response to increased demand for food.
- Overloading of existing infrastructure: development of options to renovate and modify existing sewers by creating hybride systems of centralised-decentralised nature.
- Governance and policies: decentralised wastewater management systems require new institutional / entrepreneurial arrangements.
- Emerging technologies: decentralised wastewater management may benefit from emerging technologies, such as various membrane systems.
- Energy costs: one of the drivers to research decentralised wastewater management systems is to reduce costs or recover energy (biogas).

Strategic issues relevant for Decentralised Wastewater Management

- European Framework Directive: one of the objectives is to make citizens more aware of what is done with their wastewater. Decentralised wastewater management systems bring treatment closer to people.
- Installation of separate sewer systems for storm water: Most of the decentralised wastewater management systems under research are designed with separate solutions for storm water management. Decentralised wastewater management therefore seems to fit in this trend.
- Increasingly strict standards on heavy metals, endocrine-disruptors and some pharmaceuticals: part of the research work is dedicated to develop combined treatment techniques to remove endocrine-disruptors and pharmaceuticals from concentrated (urine, black water) and diluted flow (mixed household wastewater). This may prevent surging costs for quaternary end-of-pipe treatment of combined wastewater for the removal of endocrine-disruptors and pharmaceuticals.
- Urban water reuse systems: options to recycle grey water for landscaping or second quality household water fit in a city-wide strategy for reducing overall water demand.
- Wastewater reuse for agriculture: especially the recycling of nutrients for agriculture use is under investigation, since it may partly solve the expected shortage of phosphate and reduce the high energy consumption in fertiliser production.
- Sanitation as a basic right including: the poor: new – decentralised – systems with high potential for reuse that may (partially) cover the operational expenditures could be a strategic tool to improve equity in access to sanitation.

Potential of Decentralised Wastewater Management

There are a number of innovations currently under investigation in SWITCH. Basically the approach is to separate concentrated and diluted wastewater flows to maximize the reuse potential. Black water is digested for biogas production and later used in agriculture. Urine is separated to be a potential fertilizer. Grey water is treated and can be locally recycled.

The various options under investigation are:

- Decentralised treatment of grey water in constructed wetland with subsequent use in pond systems (with a demonstration in China). From the pond systems the water may be used as second quality water for e.g. car washing or toilet flush water. One of the main objectives is to investigate the potential of water bodies to give extra value to the built environment.
- Vacuum collection of black wastewater followed by anaerobic digestion (demonstration in Sneek, a Dutch town)
- The use of (processed) urine as a fertilizer for urban agriculture (with a demonstration in Accra). Urine could provide a fertilizer with a similar nutrient value as chemical fertilizers. As such it will raise the agricultural yields of poor urban farmers that often have insufficient budget to buy chemical fertilizers. The use of urine will also decrease the discharge of nutrients to wastewater treatment plants or to the environment (as is the case in Accra).
- Treatment techniques to remove pharmaceutical and hormones from urine and other concentrated (demonstration in Sleen, a Dutch village)

The way forward

Decentralised wastewater management strategies have the potential to save and even produce energy. Decentralised treatment will reduce transport energy and has large potential to save water (and thus save energy during water production). The decentralised treatment of grey water by constructed wetlands does not require forced aeration and as such is saving energy. Black water can be a source of biogas. The use of urine as a fertilizer saves mineral fertilizer and will thus save (large amounts of) energy in the production of mineral fertilizer.

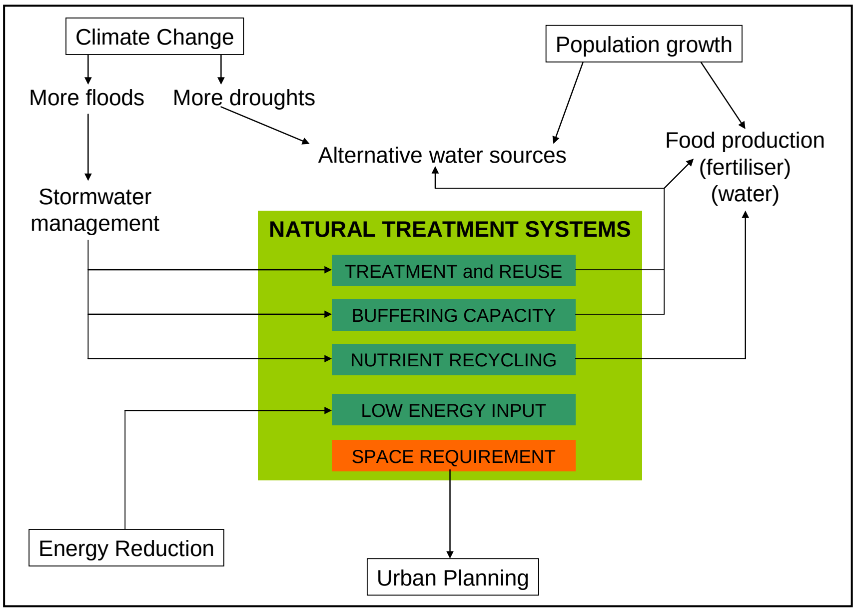


Figure 9: Main advantages (green) and disadvantages (red) of natural treatment systems and how these relate to driving forces and pressures.

8.4 Natural systems for water treatment and non-potable reuse

Introduction

Aquatic systems such as rivers, lakes, ponds and wetlands, provide a number of important ecosystem services and benefits to society including clean water, protection of human health from waterborne diseases and pollutants, protection of urban areas from flooding, and the maintenance of aesthetic and recreational ecosystem services.

One of the technologies studied in SWITCH are man-made aquatic ecosystems created for the purpose of storm- and wastewater treatment. These systems are characterised by the use of naturally occurring energies such as solar and wind energy, as opposed to conventional treatment technologies which are highly dependent on non-renewable fossil fuel energies, and on added chemicals.

The different types correspond with different ecosystems along the land-water gradient, i.e. starting from the land side: high rate infiltration and overland flow, constructed wetlands (CW) and waste stabilization pond (WSP). In addition to treating wastewater, natural treatment systems (NTS) have a number of ancillary benefits which are discussed in more detail in the following sections.

Natural treatment systems as a response to change pressures

No given technology can solve all of the current (and future) problems in urban water management, but many of the pressures and strategic issues mentioned before in this paper can at least be partly addressed by introducing NTS. Their only major disadvantage is that they require large surface areas, and land is in many cases scarce in cities. An overview of main advantages and disadvantages of NTS and their relation with pressures is given in Figure 9.

Wastewater treatment and reuse. Both CW and WSP typically have BOD/COD removals in excess of 80% and coliform removals of 3-4 log units but nutrient removal efficiencies (N/P) are lower and usually do not exceed 50%. This makes them especially suitable technologies for water reuse, as their effluents contain acceptably low numbers of pathogens from a human health point of view; but enough nutrients for stimulating plant growth. Examples of NTS reuse applications are: irrigation of agricultural crops, watering of golf courses and public parks, flushing toilets, cleaning, cooling water, groundwater replenishment, and as a reliable water supply for nature reserve areas.

Nutrient recovery. The macrophytes (plants) and microphytes (algae) grown in CW and WSP take up nutrients from the wastewater and can later on be harvested for nutrient recovery. Certain plant species have commercial value, some as ornamental plants and others as raw material. Mulching and composting of harvested plants can for instance yield soil additives; pulping of plants provides fibers; and silaging produces livestock fodder. Another option is to integrate wastewater reclamation with aquaculture. Nutrients in the wastewater are converted into algal or plant biomass and are then passed on via the food chain to fish or even ducks, which can then be used for human consumption.

Energy reduction and greenhouse gas balance. CW and WSP only make use of solar and wind energy; typically no fossil fuel energy is needed (except in cases where the local topography requires pumping). On top of that, the micro- and macrophytes sequester carbon during their growth. This advantage is however partially offset by the release of greenhouse gases (CH_4 and N_2O) from these systems. In fact until now, there is hardly any information on the net carbon and greenhouse gas balance of NTS; a PhD study on this topic has therefore been initiated within SWITCH.

Economic advantages**.** NTS are reputed for their low investment and maintenance costs in comparison with conventional treatment technologies. As such they are a viable option for developing countries but also an attractive alternative for economically stronger societies. In addition, costs can be partially recovered via effluent reuse and nutrient recovery.

Decentralised treatment. In most cases NTS are used as decentralised treatment (not withstanding a few exceptions such as the Western Treatment Plant in Melbourne, Australia, treating the wastewater of some 1.5 million inhabitants in WSP with a surface of 100 km^2). They are very suitable for local treatment (and reuse) of small to medium-high volumes of wastewater. Although they are reliable and stabile systems, there is very often a "build-and-forget" attitude towards NTS resulting on the long term in system failures. Proper management schemes should therefore be established, with or without help of local residents.

Public acceptance**.** Opinions on this are mixed. The green image, landscape integration, habitat function and combination with park and nature functions are clear pros of these systems. On the other hand, there are many (not always justified) fears of odour problems and mosquito (and malaria) proliferation. Adequate planning, design and operation can in most cases counteract these problems and stakeholders should be properly informed about this.

Strategic issues relevant for Natural Treatment Systems

The main strategic decisions that are relevant for NTS are (1) the decision to go for decentralised systems with local treatment and reuse, and (2) the decision to make the link between urban planning and urban water management. Other decisions would almost automatically follow from that.

Indeed, accepting that NTS can have ancillary benefits such as providing habitat for flora and fauna and adding green zones to the urban environment implicates that the necessary space will be allocated for these systems. By working in a decentralized way, it is easier to involve local stakeholders in maintaining or even building these systems, obviously with the help of public institutions which would in this case function as service providers. By reusing the effluent locally, less transport infrastructure is needed and alternative water sources are provided to the residents and/or companies and/or urban farmers.

The way forward

The main innovations that are needed are related to the major drawback of NTS, i.e. the large area demand. To reduce the required space, new technologies are being studied (not exclusively in SWITCH) such as hybrid wetlands (combinations of different wetland types), tertiary treatment wetlands (preceded by another less space-demanding technology), aerated wetlands (for better nitrogen removal) and Wastewater Storage and Treatment Reservoirs and High Rate ponds as alternatives to conventional pond systems. Along the same lines, research efforts are ongoing to develop better models of some of these systems which will be of great assistance in optimizing design and operation of NTS.

Other research is more related to the issues of energy consumption and greenhouse gas emissions. A PhD study is ongoing about greenhouse gas emissions from NTS and will finally result in an LCA of several technologies in which greenhouse gas emissions, CO_2 storage as biomass and reduced energy consumption will allow a more objective comparison with conventional wastewater treatment technologies.

Box 1 Soil Aquifer Treatment (SAT – A Natural system for wastewater treatment and resue

SAT as a strategic response to change pressures

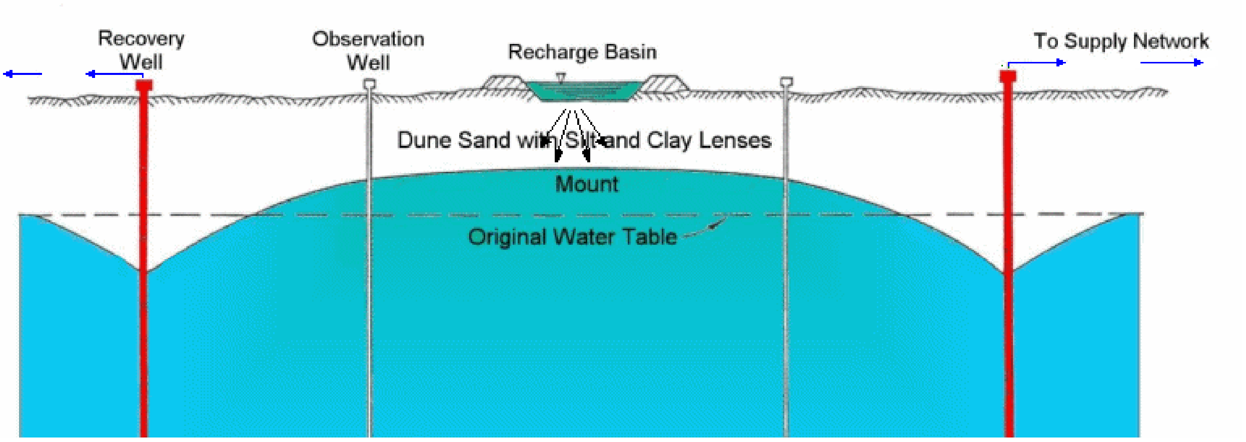
The challenge is to identify and provide safe, reliable and sustainable sources of water for different uses. Wastewater treatment and reuse is one of the strategies for water resources development and management that also ensures sustainability and environmental integrity. Furthermore more water reuse is favourable due to increasingly stringent treatment requirements for discharge of sewage effluent into surface waters. Artificial recharge for augmentation and storage of fresh water underground either as part of integrated water management or conjunctive use of surface water and groundwater, or for underground storage and soil-aquifer treatment (SAT) of wastewater effluent for water reuse, is still rapidly increasing and appears to be a promising acceptable solution.

Potential of Soil Aquifer Treatment

Soil aquifer treatment is a managed aquifer recharge (MAR) as well as wastewater treatment technology which, in combination with other available wastewater treatment technologies, can produce effluent of acceptable quality for indirect potable reuse. This technology uses physical, chemical and biological processes in the soil matrix and aquifer for wastewater treatment. It is a low cost and appropriate option for wastewater reclamation in developing countries as well as developed countries. It is also considered appropriate for replenishment of underground water to avoid exhaustion of groundwater resources and lowering of groundwater tables, particularly in arid and semi arid regions of the world. Thus, artificial recharge of groundwater basins with SAT effluent contributes to the sustainability of surface water and groundwater resources within the context of integrated water resources management

SWITCH activities on SAT for safe water reuse

SAT is an attractive option for indirect potable reuse and helps to close the urban water cycle locally to a large extent. However, there are still some concerns regarding the fate of some organic micropollutants during wastewater treatment and subsequent SAT. The genotoxicity and carcinogenicity of organic micropollutants present in effluent organic matter (EfOM) and their fate during SAT have not been adequately established. Within this context the SWITCH project is focused on (i) analysis of the mechanism of removal of different contaminants during soil passage and (ii) comparison of different pre-treatment and post treatment options for SAT for sustainable indirect potable reuse. Furthermore, a framework for analysis of the performance and design of SAT system is being developed for pre-feasibility assessment of SAT under given conditions (water quality, process conditions, local regulations and financial consideration). As water reuse is inevitable in the cities of the future, it is expected that the knowledge and skills developed under this research will help to better design and operate SAT systems (and related pre- and post-treatment) for sustainable indirect potable water reuse.



Box 2 River bank filtration (RBF)

RBF as a strategic response to change pressures

As the world population is increasing, provision of clean drinking water has become an important global environmental problem around the world, especially in major cites in developing countries or those cities where major water infrastructure was constructed in the previous century. Many water utilities in developed countries have been employing advanced water treatment methods like membrane filtration after pretreatment or followed by advanced oxidation. But in developing countries and cities with an older water infrastructure system, most water utilities have conventional treatment processes or less, and there is a lack of financial resources and manpower for advanced treatment technologies. Many developing countries discharge their sewage into the receiving aquatic environment without any treatment or after primary treatment. Therefore, the contaminant loadings are higher than those of developed countries; thus, advanced methods (e.g., membrane filtration and advanced oxidation) may not remove all the contaminants as designed.

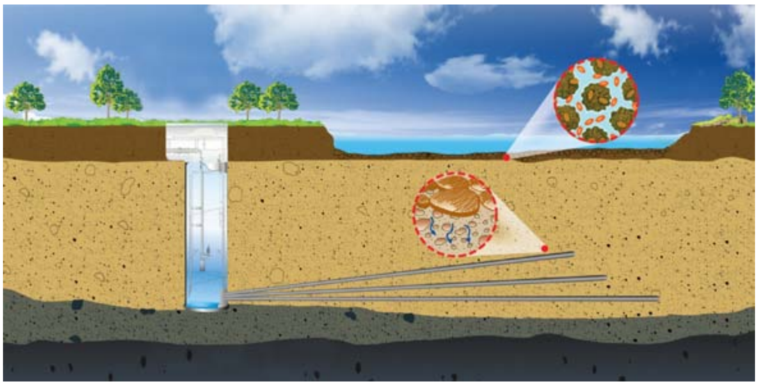
Potential of RBF

Riverbank filtration (RBF) is a natural treatment process for drinking water; it is also applicable to wastewater-impacted drinking water sources. RBF systems induce surface water to flow in response to a hydraulic gradient through intake facilities such as a vertical, horizontal or angle well types by lowering the water table. It is a relatively robust and multi-objective barrier that has sufficient buffer capacity to chemical shock loads or temperature changes. RBF has been recognized as a proven process for drinking water treatment in Europe. Many cities along the River Rhine have been successfully supplied with drinking water through RBF for many years. RBF is also an attractive water treatment process for developing countries because it is a low cost and robust technology.

SWITCH activities on RBF

The work within SWITCH on RBF consists of collection and analysis of data on hydraulics and water quality from the published literature on laboratory and field-based studies of RBF throughout the world as well as laboratory-scale experiment. The reported removals of dissolved organic carbon - DOC (organic matter) and selected trace organic compounds during RBF are being analyzed using statistical techniques such as multiple regression and principal component analysis in order to delineate removal trends as a function of site characteristics and operating conditions.

A framework or guidelines for the assessment or prediction of water quality from a riverbank filtration system will be a very important tool for quick screening of candidate RBF project sites for the professional water sector (utilities and private water sector) and to compare its costs with other conventional treatment systems. The use of this framework will facilitate the increased application of RBF technology for water treatment.



Typical River Bank Filtration scheme

8.5 Water use in urban agriculture

Urban agricuulture as a response to change Pressures

Some of the challenges that go with urbanisation are insufficient access to water and sanitation, rising world food prices, and poor local governance. In addition, climate change will also affect the urban water system and thereby the water supply for urban agriculture. As a great number of urban dwellers lack access to improved domestic water supply, the possibility that this limited water resource will be used for productive activities such as agriculture in and around cities is minimal. Many municipal authorities actually forbid the use of domestic water for irrigated agriculture even at the lowest scale. As a greater proportion of economic activity is concentrated in space-confined urban areas, and competition for scare natural resources increases, the development of new (re)sources of water will be needed. Alternative water resources that could be put to productive use in the city are rainwater or stormwater and wastewater.

Global food demand is increasing and the current food crisis is hitting the urban areas, thereby seriously impacting the urban poor in particular. This has also pushed agriculture higher on the political agenda in recent times with requests for more applicable, diverse and flexible food systems. Farming in and around urban agglomerations is a way of providing some of this food as well as serving other urban functions. Increasingly it is realised that urban agriculture may contribute to resolving urban problems related to water and waste/wastewater management as well as poverty, social exclusion, and the environment.

The link with water is obvious not only for food production but also for greening the cities, among other services. These water uses could become much more efficient if stormwater and wastewater were reused for agriculture. The reuse of wastewater for agricultural purposes is common practice, although not always regulated. Farmers fall back on using wastewater as water sources become scarcer. This appears to be an efficient way to save fresh water which could be used for other purposes, and at the same time protect water sources from uncontrolled pollution. However, there are related health risks. The introduction of urban water reuse requires changes in policy and infrastructure that would affect various stakeholders. Experiments with such reuse are ongoing in a number of cities.

Strategic Issues relevant for urban agriculture.

Water, sanitation and food problems affect people directly. Maintaining a healthy environment calls for sustainable management of urban resources. Cities need a longer-term and broader vision of the use of urban space to reduce poverty and promote sustainability. Access to affordable water, good sanitation and food is essential.

Achieving these goals will require integrated approaches and multi-stakeholder participation in the development of service provision and facilitation, and in the management of urban water. In most cases urban planning, urban water and urban sanitation are managed separately. Consultation, joint planning, and joint decision making will be needed to adapt existing policies or develop new ones. New institutions may also need to be created as most cities have various institutions that are independently responsible for certain elements of the urban water and food system. Urban agriculture is often not recognised as an urban livelihood strategy, often due to perceived and real health risks in the use of wastewater. This constrains the reuse of urban water for agriculture.

Potential of Urban Agriculture

Urban producers apply various strategies, including the enhancement of access to existing water sources or using these more efficiently, and using other water sources (e.g. rainwater collection, wastewater). In semi-arid and arid areas it is often the only source of water available and it is available year-round. It is also an inexpensive source, not just of water but also of nutrients. Irrigated urban agriculture produces very competitive profits, and flourishes and spreads without any external initiative or support. It takes advantage of market proximity, the demand for perishable cash crops, and the common lack of refrigerated transport as well as access to wastewater resources. These farmers could be assisted through (training in) safer and more efficient water use management. In

addition a constructive dialogue among urban farmers' and their organisations with local authorities should be facilitated. Management options to reduce risk where comprehensive wastewater treatment is too expensive and not feasible in the near future are being undertaken in action research.
To link the urban agriculture multi-stakeholder platforms already established by RUAF and the SWITCH city learning alliances on integrated urban water management, working groups have been set up in these three cities with the task of developing improvements in agricultural production, and other livelihood activities, using freshwater, rainwater and wastewater. These working groups guide and are involved in research, training and demonstration activities regarding technical and institutional innovations. These innovations involve techniques like cooperative horticulture and agro-tourism using rainwater harvesting (Beijing), improvements in water storage, on-farm treatment of poor-quality water and its use for agriculture (Accra and Lima) and parks and gardens (Lima). The intention is also to increase awareness of health risks along the farm-to-fork pathway (as in Accra). Changes sought in the three cities include more integrated planning and development of policies (Accra and Lima), organisational innovations (cooperatives in Beijing and urban producer organisations in Accra) and action to reduce risks to the environment and health of producers and consumers.

The way forward

With the increase in urban poverty, food insecurity and malnutrition shifting from rural to urban areas, renewed interest arises in alternative strategies for improving urban livelihoods, local governance, urban design, local economic development and waste management, as well as for urban food security and nutrition. Many citizens have turned to urban agriculture as a livelihood strategy and it is an important source of income for a substantial number of urban households. To a large extent, urban agriculture complements rural agriculture and increases the efficiency of the national food system.
Increasingly, urban agriculture is seen as part of sustainable urban development. Many national and local authorities have come to understand the role urban farmers can play in various urban policy areas such as local economic development (production, employment and income generation, enterprise development); health (food security and nutrition, food safety); urban environmental management (urban greening, climate and biodiversity; waste recycling; reducing ecological footprint of the city and CO2 emission); and social development (poverty alleviation, social inclusion of disadvantaged groups, HIV-AIDS mitigation, recreation and education). However, urban agriculture may have risks for health and the urban environment. Of course, as in the rural areas, agriculture in the city needs proper management and support to minimize health and environmental risks. In addition, urban farmers often lack tenure security, critical information on the best farming practices and available support services. While political support for urban agriculture has been steadily increasing, financial support for urban growers has been more limited.
Urban challenges related to the water-sanitation-agriculture nexus call for a number of initiatives or interventions, advocacy, multi-stakeholder dialogue and joint action planning. New forms of governance, institutions and policies are needed which are constructed through the synergy created by initiatives, such as RUAF and SWITCH.
Urban agriculture faces common challenges as well as city-specific ones. The role and importance of water for urban agriculture and livelihoods varies across the cities. However, there are similarities in terms of water management, water scarcity and the need for new and innovative systems that allow for the use of different sources of water (rainwater and wastewater). Access to water and irrigation is a crucial requirement for farmers to earn sufficient revenues to pull them up and over the poverty line. Sufficient profits with niche products may also allow them to innovate and adopt improved technologies that will improve the complementary role of urban agriculture in the city. While market proximity supports urban farming, urban expansion and environmental pollution constrain its sustainability. Based on proper analysis of farming under urban conditions, the actual role of farming in urban livelihoods, and current opportunities and constraints for its development, ongoing action research in these areas is important to inform city planning and policy making. The process of developing joint action within a multi-stakeholder context requires time and has to be adapted to the particular institutional arrangements and research and planning cultures of the different countries.

9. Integrated assessment of sustainability and uncertainty for planning and decision making

In Chapter 5 was described how SIs can be used to monitor the state of the urban water system, i.e. the combined effect of the response (DPSIR) and external factors. This Chapter describes the assessment of the planned introduction of new technologies and methodologies into the urban water system, i.e. assessment of not yet existing structures.

While assessing the sustainability of proposed innovations, for instance those described in Chapter 8, it is important not to evaluate the isolated-performance of the innovation, but its effect on the overall urban water system. This is in line with the basic hypothesis of the SWITCH project: *'Design and management of the urban water system based on an analysis and optimisation of the entire urban water system will lead to more sustainable solutions than optimisation of elements of the system'*. Therefore we need tools for integrated assessment, which measures somehow the overall sustainability of the system including the innovation, rather than for one innovative element only. The assessment is therefore a complex exercise, but this approach also prevents a piecemeal approach or even 'harmful suboptimization' (Hellström et al., 2000).

Assessment tools that are fit to be used for total system assessment include cost-benefit analysis, functional risk analysis, quantitative microbial risk analysis (QMRA), life-cycle assessment (LCA), sensitivity analysis, material flow analysis, behaviour/attitude investigations based on interviews and action research (Hellstrom et al., 2007), various financial assessments, embodied energy assessment, ecological footprint and multi criteria assessment (see Kenway et al, 2007 for overview). The integrated assessment methods (especially the LCA and QMRA) require specialist knowledge to be fully understood. Although the general principles of these tools could be communicated to decision makers, ultimately they need to rely on interpretations by specialists. LCA and QMRA results still need to be translated in a small set of key indicators, that summarise the results and provide the necessary information to decision makers.

SWITCH City Water is a 'decision support system' (see Box 3) to assess the effect of innovations in the urban water system on its overall sustainability, through the quantification of a set of headline sustainability indicators. In figure 10 is illustrated how the use of a decision support system can be integrated with the strategic planning process and the LA process. Within the strategic planning process a set of SIs is identified and agreed. Since the proper aggregation level is at the 'headline indicator' some form of grouping basic indicators and some weighted addition can hardly be avoided.

The strategic planning process is not only concerned with monitoring the state of the urban water system, but also with selecting the right strategies for implementation. For proper evaluation of strategies it is necessary to downscale the strategies to tangible actions, which in the case of the city of the future are necessary innovations. Or 'more sustainable options' such as described in the previous chapter. Before testing the effect of these innovations it is necessary to have baseline information about the city, fully or partially encompassed in models and other information sharing tools. The City Water tool has been designed to do this. Subsequently, the models in City Water are used to simulate the effect of a particular innovation on the SIs, assuming a particular scenario to become reality. This results in the production of a SI scorecard. The SI scorecard does not give the 'ultimate answer' on which innovation is considered the best. It does however give factual information to the LA or the decision makers forum that can be used in the decision making process. The question the LA needs to answer is which innovation gives the best result in overall sustainability and this innovation is recommended for implementation.

For decision makers to make well informed decisions, it is necessary to inform them about the uncertainty in the predicted effect of the innovations. Therefore City Water will be able to include uncertainties in both the baseline definition as well as in the simulation stage. The SI score card will therefore not only present crisp values, but also indicate for each SI the uncertainty.

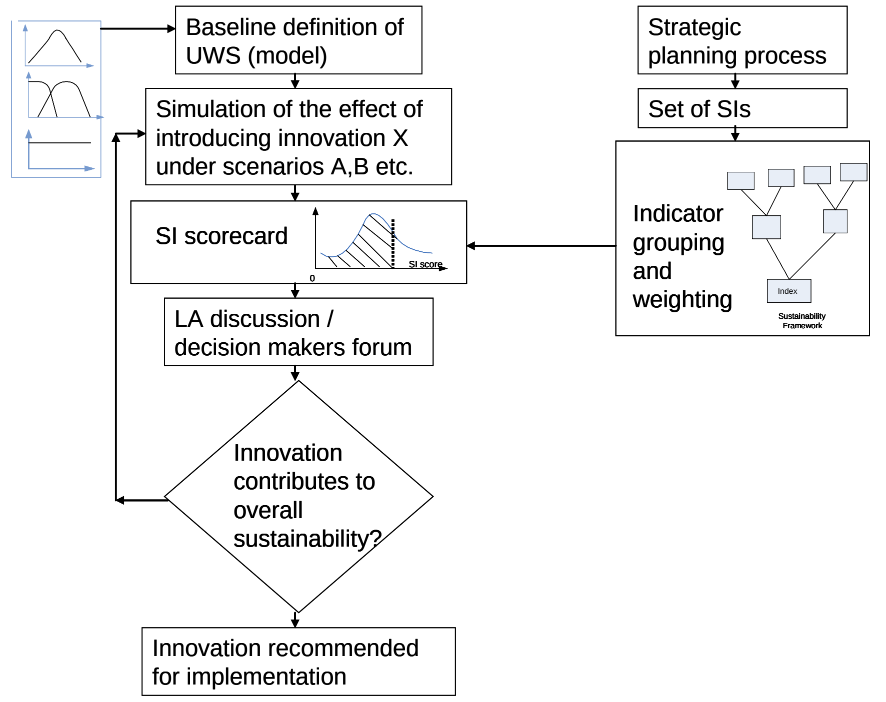


Figure 10. General framework for sustainability assessment of innovations for the urban water system and the link to decision making based on SIs.

Box 3. City Water: The Information Sharing and Decision Support tool developed in SWITCH

City Water Tools:
The ***Combined Water Information System*** is the interface used to link the***Common Database,*** , and the different tools and models within ***CITY WATER.*** The ***Common Database*** organizes, hosts and provides the data required by the tools and models and enhances compatibility and interoperability by the use of a common format . It is organized along three main axes:

- System elements (e.g. actual objects and groups, interrelations).
- Information (e.g. values, textual descriptions, documents), and.
- Uncertainty (e.g. meta-information regarding origin, degree of reliability, basic values, confidence interval).

The ***CWIS***, as a knowledge management system,also provides a set of interlinked data viewing tools:

The ***System viewer*** provides water stakeholders in cities with an information system about their water system and contributing knowledge and displays this system through schematics of the water-related components (e.g. rivers, wastewater treatment plants, energy resources, regulations, , standards and policies, etc.) and their interrelations (e.g. influences between components, water / pollutant / energy fluxes, monetary or data flows and stakeholder relationships).

The ***GIS Viewer*** offers non-specialist access to the spatial dimensions of a city and its thematic elements. It can be used to visualize the spatial distribution of model inputs and outputs. Outputs are typically presented as spatial indicators (for either sustainability or performance). The GIS viewer complements the output capability of the Indicator viewer and by the systemic vision tool, the ***System viewer***.

The ***Indicators Viewer*** allows users to view indicator results and any numerical data stored in the database. It offers easy access to information such as performance assessment results, time series values/indicators or confidence intervals by displaying graphs, charts and tables. It also allows the creation of new indicators by combining existing data and data export in image or excel formats.

City Water Models:

CITY WATER Balance is a scoping model for assessing the dynamic balances of water, energy and pollutants at the city scale It works on a daily timestep over decadal periods and can explore water and wastewater stresses in response to climate change, changing urban populations under a range of strategic technical options for improved IUWM. Six indicators locally or globally are derived for output: Water demand/supply ratios,

- Surcharge magnitudes,
- Wastewater production,
- water quality,
- life cycle energy and
- life cycle cost.

CITY WATER Drain provides decision makers with information on the performance of the existing urban drainage system, its impact on the receiving water, and how this performance would be affected by different strategic options and scenarios including climate change and increasing urban population. The model assesses the performance of the urban drainage system with indicators such as overflow volume and frequency from combined overflow structures, flood volume and water quality.

CITY WATER Economics explores the potential economic implications of future strategies on urban water management by analysing scenarios for cost recovery & economic drivers for change (financing, pricing and subsidies). Cost allocation and pricing schemes can be formulated for the entire range of water services provided, or for specific ones such as stormwater management or wastewater collection and treatment, for the entire urban catchment or for specific geographic areas (clusters).

CITY WATER Futures allows evaluation of stakeholder responses to alternative strategies for coping with different scenarios. This system uses an Agent-Based Model (ABM), adopting concepts from artificial intelligent technology. A complex urban water system is modelled as a collection of autonomous decision-making entities called agents. The model simulates the simultaneous operations of the multiple agents in an attempt to re-create and predict the actions of complex phenomena.

CITY WATER Risk permits users to explore the consequences of uncertainties in either knowledge about the city water network or future conditions and to determine the risks to the system in terms of a likelihood of failure of the system. This model can be used to explore the robustness of decision making based on the scoping strategies identified by a stakeholder community.

10. Outlook; City of the Future

The previous chapters are the outline of the strategic approach that has been developed during the first half of the 5-year SWITCH project. While still under development the approach was implemented in the 9 demonstration cities, with various degrees of progress till date. The progress could be summarised as follows:

> *Learning Alliances have been established and have succeeded to bring a wide spectrum of water sector stakeholders together. The alliances have to some extent been exposed to the innovations that are developed in SWITCH and have been invited to communicate feedback to the research community. The LAs also have started a strategic planning exercise, in which a vision for the future urban water system was created. Innovations that are produced within SWITCH are included to a limited extent in the strategies that have been identified to reach the vision.*

Major objectives for the remaining part of the project are (apart from the continuation of the research, the strategic planning process and the general LA process):

- To facilitate more interaction between the city professionals and the academic researchers in the LA framework. The interaction includes more feedback from the city professionals to the researchers, and as a result adjustment of the remaining research activities such that it fits better to the research needs.
- To translate the research results to the strategic level, such that the new strategies make use of the latest academic research results.

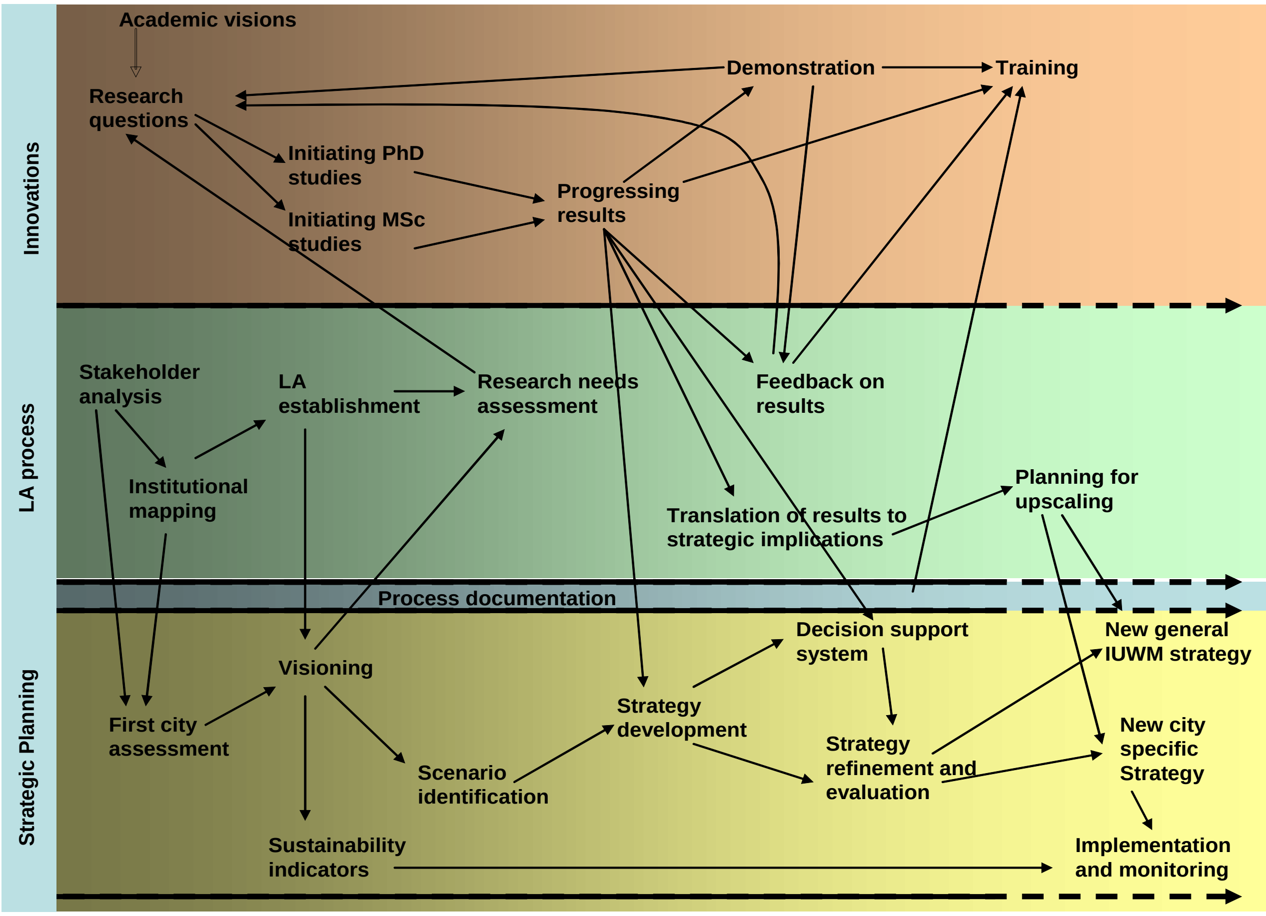


Figure 11. The SWITCH process: Integration of Innovations, the Learning Alliance process and Strategic

The experience of the SWITCH demonstration projects may be valuable for other cities that would like to start a strategic planning process for the urban water system, with the collaboration of academic researchers and city professional. The general layout of such a process is given in Figure 11, it consists of thee sub-processes: the LA process, the development of Innovations and finally the Strategic Planning process itself. In the figure the major links between the various elements are indicated.
The three process are interlinked. It is important that the research questions are both build on existing academic visions as well as the research needs of the city professionals (formulated by the LA). The facilitation of the interactions between the researchers and the city professionals will be documented during the second half of the project and will be included in the Manual for Strategic Plannig for IUWM, which will be made available towards the end of the project and will be subject of open training activites. The set-up and facilitation of the LA process is documented in some detail in a series of briefing notes (SWITCH, 2008).

Obviously, the duration of SWITCH is not sufficient to go through a complete strategic planning cycle (Fig 12). Only steps 1 and 2 can be done within the framework of this project. In real life the strategic plan obviously needs to be translated into operational plans, detailed action plans, be implemented and evaluated. Research and assessment plays an important role during each step in the process.

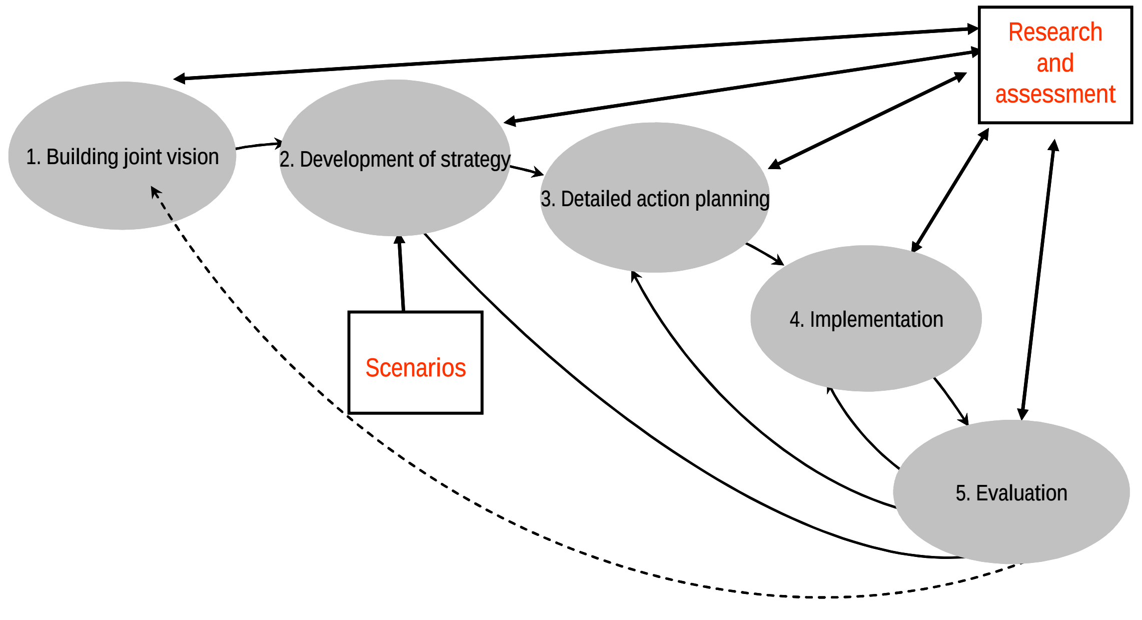


Figure 12. An integrated urban water management cycle

City of the Future

What can we say about the urban water system in a city of the future, in for instance 2030, based on the results of the project so far? The SWITCH Vision and Strategy (as described in Chapter 7) can be maintained; the research results and the feedback received during various international workshops confirmed that we are heading in the right direction. Using scientific innovations to design strategies and solutions that satisfy environmental, cultural, financial and social boundary conditions seems to be the right approach. The cross-fertilisation between academic research and city professionals seem to start paying off, and leads to more creative solutions. Holistic management of the urban water system prevents wasting resources on sub-optimisation of system elements. Holistic management and strategic planning seem to be natural partners. The implementation of the strategies in the demonstration cities will result in the realisation of the more-sustainable-options described in Chapter 8.

Walking through a City of the Future, after the sustainable options were implemented, one would discover that water is visible in the city in many ways. It seems that roads and buildings have been designed such that water has been taken into account. Stormwater is captured and stored in ponds and wetlands, or nicely designed storage reservoirs, and used for various purposes inside and outside of the buildings. Wastewater is produced in only small quantities and usually treated in the basins of buildings in compact and sophisticated membrane treatment systems. In other places wastewater, or grey-water, is treated in subsurface flow wetlands, that one does not easily recognise as treatment plants. One would rather think that these green areas in the cities were designed to attract birds and to create a pleasant atmosphere. Towards the edge of the city there are larger green areas, having the size of metropolitan parks, that are used to infiltrate clean water, originating from stormwater or wastewater. In this way the park is irrigated and the aquifer is recharged. Some other parks, especially those adjacent to surface waters are used to produce drinking water, through various forms of bank filtration. These natural systems do use much less energy and chemicals than the old-fashioned water treatment plants. Moreover, these are just beautifull parks. Speaking about pollution, various technologies have been implemented to reduce the discharge of pollutants from the city into the environment. A major step forward was made when the city council adopted a strategy of pollution prevention, almost to the extreme. Most of the city now has various forms of urine separation. Most of the fertilisers used in and around the city are actually a product based on urine products, from wich any farmaceuticals or other pollutants were removed beforehand. Especially since the phosphate and energy prices surged, urine fertiliser became completely accepted by the urban and regular farmers. Speaking about farmers, almost everyone is a farmer nowadays. At the edge of the city and along the larger parks there are special gardens where urban farmers grow niche products, using urine fertiliser and recycled wastewater.

The citizens of the city are well aware of how important water is for maintaining a sustainable situation in and around their city. They pay to the municipal authorities for water management, but in essence they know that each citizen bears responsibility. Not long ago each citizen had the opportunity to contribute to workshops on visions, scenarios and strategies for the city. And, surprisingly to some, the outcome of the workshops were taken into account when the city council defined regulations and actions regarding water management. The roles and tasks of the various municipal departments and other water sector organisations had been redefined to some extent and there was now much better coordination. It does not happen often anymore that one day the water company opens up the pavement of a major street, completes the job and repairs the road, while the next week the wastewater company seems to repeat the whole operation. Also at the more strategic planning level more coordination has become apparent, to that level that plans were not only aligned, but, where necessary, even integrated. Joint planning procedures were the basis of these successful changes. It seems that a ‘SimCity’ like planning tool plays a major role in planning and decision making.

All in all, water was now much more visible in the city and in the life’s of its citizens, a real amenity.

References

Foxon, T.J., McIlkenny, G., Gilmour, D., Oltean-Dumbrava, C., Souter, N., Ashley, R., Butler, D., Pearson, P., Jowitt, P., Moir, J. (2002), "Sustainability criteria for decision support in the UK water industry", *Journal of Environmental Planning and Management*, Vol. 45 No.2, pp.285-301

Hellström, D, Hjerpe, M. and van Moeffaert, D. (2004)
Indicators to assess ecological sustainability in the Urban Water sector. Chalmers University of Technology, Gothenburg, Sweden, pp. 54

Kadlec R.H. and Wallace S.D. (2008). Treatment wetlands: second edition. CRC Press, Boca Raton, FL, pp. 1016. ISBN 9781566705264

Kelay, T., Chenoweth, J. & Fife-Schaw, C. (2006). Report on Consumer Trends Cross-cutting issues across Europe: TECHNEAU, pp. 46.

Kenway S., Howe C. and Maheepala S. (2007) Triple Bottom Line Reporting of Sustainable Water Utility Performance. American Water Works Association and IWA Publishing, pp. 147.

Lundin M. and Morisson G.M. (2002) A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems. *Urban Water* **4**, 145-152.

Malmqvist P., Heinicke G., Kärrman E., Stenström T.A. and Svensson G. (2006) Strategic Planning of Sustainable Urban Water Management. IWA publishing, London, pp.264.

Mitchell V.G. (2004) Integrated Urban Water Management. A review of Australian practice. CSIRO and AWA report CMIT-2004-075, pp. 56. *http://www.clw.csiro.au/awcrrp/stage1files/AWCRRP_9_Final_27Apr2004.pdf*

Moriarty (2007, personal communication) Handout Visioning and Scenario Planning workshop.

Municipality of Tel Aviv Yafo (2006) City; Strategic Plan for Tel Aviv Yafo.

OECD (2003) OECD Indicators; Development, measurement and use. Environment Directorate Environmental Performance and Information Division, Paris, pp. 48.

Savenije, H. and van der Zaag, P. (2002) Water as an economic good and demand management: paradigms with pitfalls,. *Water International*, 27 (1), 98-104.

Shilton A. (2006). Pond treatment technology. IWA Publishing, London, pp. 496. ISBN 9781843390206

Stern, N (2006). Review of the Economics of Climate Change. Cambridge University Press, Cambridge, UK. (ISBN 0-521-70080-9).

United Nations (UN). (2006). World Population Prospects The 2004 Revision (Analytical Report, Volume III No. ST/ESA/SER.A/246): Department of Economic and Social Affairs Population Division, New York

SWITCH (2008) Briefing notes Learning Alliances. http://www.switchurbanwater.eu/page/1789 [October 2008]

UN-HABITAT (2004) *State of the world's cities, 2004/05*, UN-HABITAT Report, Nairobi, Kenya.

UN-HABITAT (2006) *State of the world's cities, 2006/7*, UN-HABITAT , Nairobi, Kenya.

Vahala, R. (2004). European Vision for Water Supply and Sanitation in 2030. Water Supply and Sanitation Technology Platform.
http://www.wsstp.org/Shared%20Documents/WSSTP%20presentation%20by%20Riku%20Vahala%20(Bratislava).pdf [March 2007]

Yong Liu, Huaicheng Guo, Zhenxing Zhang, Lijing Wang, Yongli Dai and Yingying Fan (2007) An optimization method based on scenario analysis for watershed management under uncertainty. Environmental Management **39**, 678-690.

White, S.B. and Fane, S.A. (2001) Designing Cost Effective Water Demand Management Programs in Australia, *Water Science and Technology* Vol. 46, No 6-7, pp.225-232.

Appendix 1

Set of SWITCH sustainability indicators

The general SWITCH vision was presented in Chapter 7 as a set of sustainability objectives. For each objective one or more indicators can be formulated. The indicators are:

- qualified as either Pressure, State or Response
- mainly meant for reporting purposes (a) and/or for planning purposes(b)
- aimed at the general public (c), at water sector professionals/institutions/NGOs (d) and/or at researchers (e)
- the source of the data is most like the SWITCH city partner (f), another SWITCH partner (g) or a city LA member (h).

The overall aim of using the indicators is to asses to what extent the Vision has been achieved (i.e. reporting) or to what extent the Vision will be achieved by certain plans (i.e. planning).

After the LA has agreed on the indicators, agreement is also necessary on who is collecting the data that is required to score the indicators on, for instance, a yearly basis. Publication of this data will help evaluate the effectiveness of strategies and policies.

Within the SWITCH project there will be models developed to forecast the score of the various indicators under different future scenario's and strategies. This Decision Support System (named City Water) will allow decision makers to make decisions based on the best available information. The DSS will be able to predict a number of indicators for future conditions and under different strategies/measures. These indicators are underlined.

The indicator list in the table below is a general list. Each city LA would need to select a sub-set of indicators that are most relevant for them.

Draft SWITCH indicator list:

	Pressures		State		Response	
Sustainability objectives	**Subject matter**	**Indicator**	**Subject matter**	**Indicator**	**Subject matter**	**Indicators**
General						
1. have citizens that are aware of 'water and sustainability' and where the authorities will involve the public in decision making	Average citizen lacks awareness on water and environment issues and is not involved in decision making on the urban water system		The level of awareness and the extent to which individual citizens and NGOs are involved in decision making		Awareness raising activities and public meetings as integral part of the decision making process	The number of awareness raising activities (c,d,e,h) The number of public meetings organised, the number of citizens and NGOs participating (c,d,e,h)
2. manage its urban water system in an integrated way; integrating aspects of water supply, stormwater management, wastewater collection, wastewater treatment and			Management of the urban water system is done at the level of sub-systems and therefore non-optimal		The ideas of integrated urban water management are incorporated in new policies and (master)plans of the water sector institutions	The number of new documents/plans that do follow an IUWM approach, versus the number of documents that do not. (d,e,f)

wastewater reuse .						
3. use a set of sustainability indicators for decision making and planning.			Decision making processes are non-transparent and the rational of decisions is not always clear		Sustainability indicators are used for decision making processes and planning	The number of decisions on new projects/policies concerning water and environment by the authorities (like city parliaments/governments) that include in the decision-document a reference to sustainability indicators and the effect of the plan on the score of the indicators. (d,e,f)
4. have a strong scientific basis for decision making concerning the management of its Urban Water System.			Decision makers do not always use the latest scientific results (new technologies and methods).		Decision making in the water sector is based on scientific research.	Investments in academic research on topics directly relevant for urban water management (euro/capita/year) (d,e,f,h)
5. ensure equity in the access to water, as well as to irrigated green areas.			The investments made per citizen for water supply and sanitation provision are unequal.		Each citizen is equally served by the municipal institutions in terms of water supply and irrigated green areas.	1)% of citizens that spent more than x% of their income on water and sanitation. (c,d,e,h) 2) the irrigated green area per citizen is equally spread over the city (c,d,e,h)
6. minimise the energy	Use of fossil fuels for		Increasing CO_2		The total amount of	Energy consumed in kWh/capita/year (c,d,e,h)

consumption in the urban water system and greenhouse gas (GHG) emissions from the system	electricity production contributes to CO_2 emissions (greenhouse effect)		concentrations in the atmosphere		energy spent to construct, operate and maintain the urban water system is reduced by energy efficiency measures	GHG emissions in kgCO2/capita/year (c,d,e,h)
Water supply and Sanitation						
7. supply water of good quality to its citizens, in sufficient qualities, at the lowest possible costs	Water availability for water supply schemes is decreasing, both in terms of quantity and quality. Water supply schemes suffer from shortcomings in infrastructure design, operation and maintenance		a) Not sufficient water available for domestic purposes. b)Poor water quality requires extensive and expensive water treatment. c) Inefficient drinking water production and delivery.	a) M3 renewable fresh water / capita /year (c,d,e,h) b) Raw water quality.(d,e,h) Treatment costs euro/m3 (d,e,h) %Drinking water quality samples not satisfying standards (c,d,e,h) c) %UFW (d,e,h) % population having access to proper water supply (c,d,e,h) % cost recovery (d,e,h) Etc.	a) WDM measures and/or development of new resources b) Source protection actions. Application of new/better treatment technologies. c) various	a) total water demand m3/capita/year and availability of renewable fresh water m3/cap/year (c,d,e,h) b) Investment in source protection. (d,e,h) Availability of yearly technology assessment report for technologies currently in operation and technologies for future replacement. (d,e,h) c) various (key indicators to be determined at the city level)

8. will give priority to Water Demand Management over development of new water resources.	High leakage rates; high per capita water demand	% UAF (physical losses) (d,e,h) Water demand m3/capita/year (d,e,h)	Water shortage; low pressure, etc.	Frequency and duration of low pressure events (c,d,e,h)	WDM programs	Investment euro/capita/year in WDM measures (d,e,h)
9. provide all its citizens with proper sanitation, at the lowest possible cost	Not all citizens having access to proper sanitation	% of citizens having access (c,d,e,h)	a)Health impacts b) Polluted surface waters c)Polluted groundwater	a)Disease incidence (or calculated risk) (c,d,e,h) b)/c) Surface and groundwater quality (d,e,h)	On-site sanitation Wastewater and sludge collection Wastewater and sludge treatment	% of population that is planned to get on-site sanitation that does have on-site sanitation (c,d,e,h) % of population connected to sewer (c,d,e,h) Operational wastewater treatment capacity (d,e,h) Operational sludge treatment capacity. (d,e,h) Treatment plant performance (d,e,h)
10. will give priority to pollution prevention over end-of-pipe treatment	High pollution loads are generated in the urban (industrial) area	Kg pollutant/product/year (d,e,h)	Poor receiving water quality	Concentration pollutants (c,d,e,h)	Pollution prevention programs	Investment euro/capita/year in pollution prevention programs (d,e,h)
11. reduce the net waste	High pollution	Kg pollutant/capita/year	Poor receiving	Concentration pollutants (c,d,e,	Studies to determine the	Availability of studies that determine carrying

output from the city to the environment to below the carrying capacity of the receiving environment. Furthermore it will enhance the self-purification capacity of the receiving environment by eco-hydrology	loads are generated in the urban area	(d,e,h)	water quality	h)	carrying capacity of receiving waters and measures to increase the capacity for self-purification. Projects to recycle nutrients to agriculture.	capacity. (d,e,h) Investment euro/capita/year in eco-hydrology measures. (d,e,h) % of nutrients generated in the urban water system that is recycled to agriculture
Stormwater management and reuse						
12. reduce the risk of flooding in vulnerable areas to levels acceptable to all stakeholders, even under future climate change			Vulnerable areas within the city are flooded with an unacceptable frequency, causing unacceptable socio-economic damage.	Flooding frequency and depth Economic damage (euro/capita/year)	Flood risk mitigation measures	Decrease in flood frequency (return period in years) and damage cost function (euro/land use area/year)

scenarios						
13. protect and enhance the water quality and ecological status of urban receiving waters, both surface and ground waters			Urban water quality and ecology suppressed by wet weather diffuse pollution.	Good chemical (e.g.expressed by GQA for surface waters in UK) and ecological status (e.g. expressed by RE classification for surface waters in UK)	Surface and ground waters typical of good chemical and ecological status.	Percentage of waters meeting the requirements of the Water Framework Directive and the Groundwater Directive.
14. apply source control techniques to enable stormwater to contribute to the quality of life in the urban environment.			Poor aesthetic and amenity values for urban water bodies.	Level of community awareness of local water bodies and scope for recreational use.	Create new water systems and improve (in terms of aesthetic and amenity value) those which currently exist.	Percentage of local population valuing local water bodies for amenity purposes.
15. harvest rainwater and stormwater for non-potable reuse purposes.			Rainwater and stormwater are rarely collected and mainly drained directly from urban areas.		Rainwater and stormwater harvesting projects.	<u>% of total urban water demand satisfied by rainwater and stormwater harvesting projects.</u>
16. utilise stormwater to re-establish a			Increased overland flows and evaporation	Imbalance between runoff, infiltration, evaporation,	Re-establish pre-development water	Water movements match the Greenfield situation in terms of ratios of recharge : evaporation :

balanced natural water cycle (in conjunction with landscape development).			losses compared to reductions in groundwater recharge.	transpiration and storage.	balance.	storage : runoff.