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Water Demand Management: A Key Building Block for Sustainable Urban Water Management

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Abstract

It is becoming clearer, even to non-members of the scientific community that the rapidly increasing global population, coupled with the impacts of climatic change are major contributors to the looming water scarcity. Water scarcity is acknowledged to be a key barrier to attainment of MDGs in low-income countries. Currently, about 30 countries are considered to be water stressed, of which 20 are absolutely water scarce. It is projected that by 2050, about one-third of the population in the developing world will face severe shortage The water scarcity situation will get worse in the world's urban areas, which have grown to the extent that since early 2007, urban areas account for over half of the world's population.

The alarming rate of water scarcity, coupled with widespread environmental degradation has brought into focus the need for planned action to manage water resources in a more effective and sustainable manner. The dwindling water resources need to be optimally managed while minimising the negative impact on the environment. The EU-funded SWITCH project was conceived arising out of a realisation that continued application of the conventional urban water management (UWM) concept will not deliver the required results in the future. The main objective of the SWITCH project is "the development, application and demonstration of a range of tested scientific, technological and socio-economic solutions and approaches that contribute to the achievement of the sustainable and effective UWM schemes in 'The City of the future'". The SWITCH project is a multi-disciplinary integrated research project that aims at creating a paradigm shift in urban water management.

This paper highlights limitations of the conventional urban water management, and explains the concepts of the more robust integrated resource planning and demand management (DM) approaches, that need to be adopted to respond to the rapidly changing environmental conditions. DM is a central theme of the SWITCH project. Specific activities contributing to DM include (i) developing and testing holistic demand management tools, in order to reduce water wastage on the side of the service provider and the consumer; and (ii) providing capacity building to service providers on DM. The paper will describe how these activities are being carried out in the City of Zarogoza, Spain, one of the SWITCH Project demonstration cities.

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1 The Looming Water Scarcity Situation

The global population has continued to increase rapidly, despite the fact that the overall growth rate and net additions are decreasing. According to the most recent UN world population prospects report, the world population reached 6.7 billion in July 2007, 5.4 billion of whom will live in the less developed regions (United Nations, 2007). Assuming a declining fertility rate, the world population is projected to increase to 9.2 billion by 2050, which increment will mainly be absorbed by less developed regions (ibid).

Water resources are essential for the existence of the human population and other biodiversity species. The water resources have not only remained constant but have increasingly been polluted by the growing population. Yet the rate of abstraction of freshwater has grown rapidly in tandem with human population growth. For example human water use increased by a factor of six in the past century (Andresen, Lorch & Rosegrant, 1997). It is estimated that global water withdrawals will increase by 35% between 1995 and 2020 (ibid). As a result, per capita water availability is steadily declining. While global freshwater supplies are adequate to meet global demand for the foreseeable future, the world's freshwater is poorly distributed across countries, within countries and between seasons. Hence, practical distribution problems concerned with time, space and affordability lead to a widening gap between demand and supply in many parts of the world.

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, 2007). Shorter precipitation seasons, coupled with overall larger annual precipitations lead to larger runoff volumes generated over shorter time intervals, which in turn creates complications in designing for storage and routing of floods. Furthermore, the opportunity time for groundwater recharge is reduced, which undermines the efficiency of conjunctive utilization of surface water and groundwater. If these climate changes continue at current rates, there is predicted to be a serious reduction in dry-season water availability in many regions of the world within the next few decades. One recent study predicted that a temperature raise of 2°C may result in 1-4 billion people of developing countries experiencing water shortages (Stern, 2007).

The water scarcity situation will get worse in the world's urban areas , which have grown to the extent that since early 2007, urban areas account for over half of the world's population. (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). Parallel with this growth in population, the demand for drinking water has been increasing rapidly in urban areas, in line with raising living standards. Yet the number of viable water resources in any region is limited and has to serve competing requirements such as domestic, industrial, irrigation, fishing, navigation, tourism, recreational, ecological demands and waste disposal/assimilation.

This alarming growth of water scarcity, coupled with widespread environmental degradation has brought into focus the need for planned action to manage water resources in a more effective way. The dwindling water resources need to be optimally managed while minimising negative impacts on the environment. The conventional urban water management concepts cannot cope with the rapidly changing situation. The following section briefly describes key limitations of the conventional urban management framework.

2 Limitations of the conventional Urban Water Management Concept

Much of the material used in this section has been adapted from the SWITCH Project Description of Works (SWITCH, 2006). The current conventional urban water management concept, which was developed in the 19^{th} century mainly to counter epidemics caused by water-born pathogens, cannot adequately respond to the changes enumerated above. Under this conventional system, the design for the urban water infrastructure services was mainly driven by public health considerations, rather than environmental sustainability. Understandably, this did not take due consideration of the rapid population growth rates, high levels of urbanisation, industrial growth and climate change which the world is currently experiencing.

A key limitation is the use of high quality drinking water for all domestic purposes. Yet, there are substantial differences in water quality demanded for different uses in the household. Only drinking and cooking, which consume a small proportion of the total household demand, require high quality treated water. Other uses may be satisfied with poorer quality water, which could permit re-use of water from one application to another. Use of such high quality water for all household chores has implications on the production costs and the unnecessarily higher pollution loads arising out of the treatment processes.

Furthermore, large volumes of drinking water are used to transport excreta over long distances to centralised wastewater treatment plants. Limitations of such a sewerage system are: (i) the capacity of the centralised end-of-pipe treatment processes to absorb large volumes of wastes and effluents are being stretched to their limits, (ii) valuable resources in terms of potable water and nutrients are wasted during the transportation and treatment processes; (iii) extensive sewer networks are costly and difficult to construct and maintain; and (iv) performance of large-scale treatment facilities is reduced under wet weather conditions, when wastewater is heavily diluted.

Another key limitation of the conventional urban water management concept is over-emphasis on managing supply at the expense of considering demand options. The traditional response to the ever increasing water demand is development of new water sources. Such supply management tendencies are neither environmentally sustainable nor economically viable, as they lead to higher rates of depletion of the finite water resources at higher marginal costs.

Under conventional urban water management systems, the institutional setup engenders a highly fragmented division of responsibilities and tasks. In many cases, different organisations do not share information, and activities in the catchment areas are not coordinated. Urban water managers in water supply, sanitation and drainage have largely been working in isolation, focussing on their individual sectors. As a result, many urban water managers do not fully appreciate the impact their operations have on the environment, and environmental sustainability is rarely part of the corporate objectives. Where there are efforts to mitigate against environmental degradation, the efforts are mostly ad-hoc, and often fragmented.

It is clear from the above consideration that application of the conventional urban water management concept to contemporary times will not ensure sustainability. The current environmental management issues call for a change in the way urban water resources are managed. Today's water sector professionals are faced with enormous challenges of effectively managing the ever dwindling water resources to deliver water and sanitation services while minimising the negative impacts on the environment. The 2002 World Summit on Sustainable Development (WSSD) recognised the need to adopt Integrated Water Resources Management (IWRM) for promotion of more sustainable approaches to water development and management. IWRM is an approach that '…promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (Global Water Partnership, 2000, p.22).

However, IWRM principles cannot be transferred wholesale to the urban context, mainly because management boundaries in IWRM are catchment-based, while water supply and wastewater systems in the urban areas are usually demarcated along political boundaries. Integrated urban water resources management (IUWRM) is therefore different from IWRM, mainly because it is operated at a much more local scale. The principal components of IUWRM are supply optimisation; demand management; participatory approaches to ensure equitable distribution; improved policy, regulatory and institutional framework; and intersectoral approach to decision-making (UNEP-International Environmental Technology Centre, 2003).

3 Demand Management (DM): Definition, trends and benefits

As mentioned in the previous section, the usual tendency of urban water managers when faced with increased demand is to plan for increasing the supply capacity to conform with the required service levels. 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, demand management (DM) may be defined as the development and implementation of strategies, policies, measures or other initiatives aimed at influencing demand, so as to achieve efficient and sustainable use of a scarce resource (Savenije and van der Zaag, 2002). Put in another way, DM is any action that modifies the level and/or timing of demand for a particular resource (White and Fane, 2001).

DM involves the adoption of policies and investment by a water utility to achieve efficient water use both within the water distribution network and on the customers' side. Measures in the distribution network include reduction in system losses, including timely leakage detection and repair; efficient operational procedures such as optimum operating pressure and reduced mains flushing or reservoir cleaning; controlling of street water points; institutional capacity building in the utility to raise the importance of DM measures; and ensuring accountability of staff of the water utility.

Other measures that a utility could introduce to enhance water demand management include universal customer metering to encourage economic usage of water; maintaining efficient and informative billing systems; detailed customer feedback systems that provide information on water use; comprehensive information, education, training and advisory services which assist customers who wish to take action to reduce their water use; provision of detailed water use analysis (audits) for water consumers in the various sectors; and financial incentives for purchase and installation of efficient water using equipment.

Apart from changes in the water distribution network and management systems, a utility needs to actively promote water conservation in the customers' properties. Activities that bring about water conservation in the customers' premises fall into two broad categories: those that promote structural/technical changes and those that promoted behavioural changes (Turner and White, 2006). Structural/technical changes are those that influence the efficiency of water use in the fixtures and appliances, such as changing a shower head to a more efficient design. On the other hand, behavioural changes lead to reduction in water use through their actions and practices, such as reduced shower periods. Figure 1 shows typical options available in the residential sector.

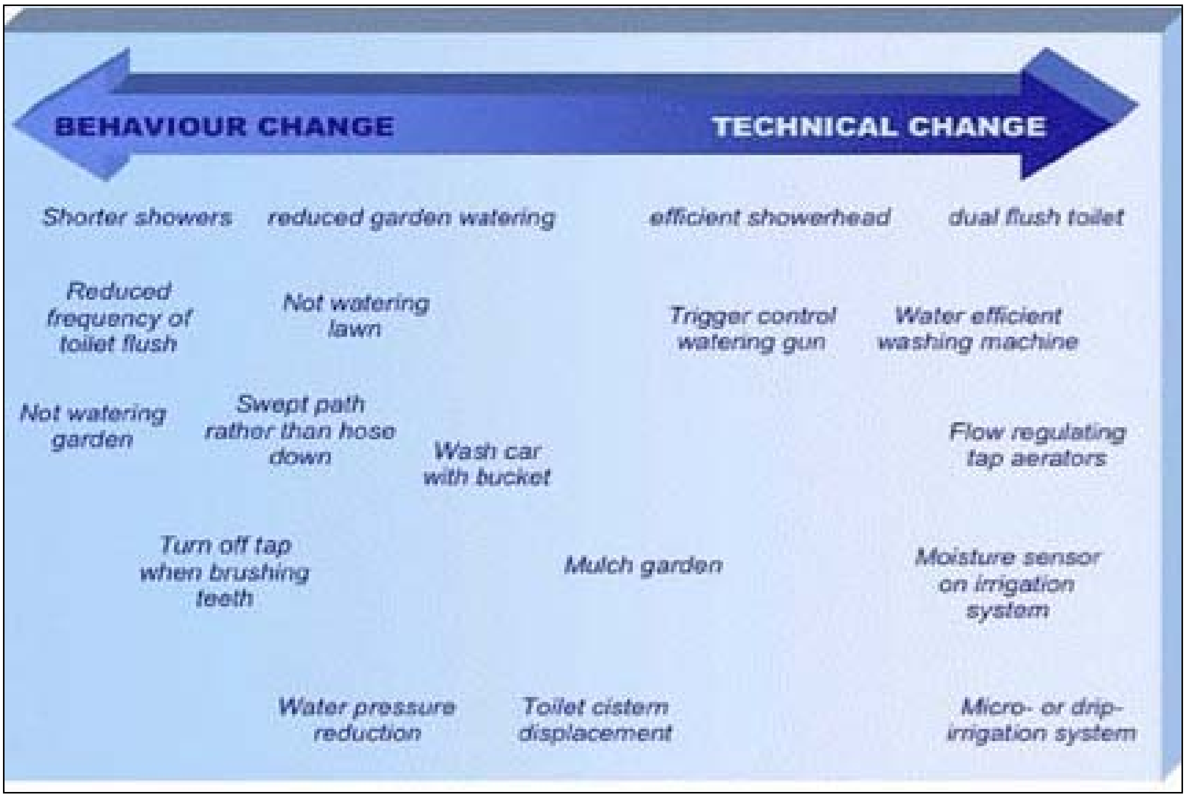

Figure1: Structural/technical and behavioural changes for water conservation (Source: Turner and White, 2006).

For water conservation to be sustainable, utilities need to tap into the conservation potential from both behavioural and technical categories and use a combination of measures and instruments that will achieve the optimum changes. Measures are actions to be taken, e.g. conversion of inefficient to efficient flush toilets. Instruments are how to ensure the chosen measures are taken up by the customers, e.g. through public education, advertising and marketing. Instruments may be (Turner et al, 2006) :

- Economic, i.e. incentives such as rebates and retrofits for efficient fittings and faucets, or cost-reflective tariffs that encourage customers to reduce their water consumption;
- Regulatory, e.g. the use of bye-laws to ensure all new properties are fitted with a specified minimum level of water-efficient fittings and fixtures; or manufacture and/or importation of a specified level of efficient water using equipment.
- Communicative, i.e. investing into public education, marketing tools and advisory services to promote behavioural change.

Water demand management offers a variety of benefits from the point of view of the utility, the customer and society as a whole. Well planned and effectively executed DM measures on the side of the utility can reduce operation and maintenance costs (e.g. water treatment and energy pumping costs), which will result in lower tariff levels for the customers. More importantly, DM measures in utility operations and the customers' end use will reduce the marginal cost of production, through deferring the need for new capital investments. For customers who pay their bills based on volumetric charges, water conservation activities will directly and proportionately result into reduced bills, hence freeing a portion of household income for other requirements. Some empirical data have been reported in the literature, showing how DM has yielded positive results. A few examples are summarised in Table 1.

Table 1: Examples of benefits of DM as reported in the literature (Source: Jalil & Njiru, 2006)

Study Reference	Study setting	Action	Achievement
Martindale & Gleick, 2001	New York, USA	City Council provided rebates for installing low-volume water closets	Reduction in overall household use by 29%
Mkandla et al, 2005	Bulawayo, Zimbabwe	Public education and rationing	Reduction of consumption by 25%
Smith et al, 2001	Millennium Dome London	Use of a combination of poor ground water, grey water and rainwater for toilet flushing	Savings of about 50% of potable water consumption
Ahn & Song, 2000	Lotte World, Seoul, South Korea	Reclamation of wastewater for toilet flushing	18% (900m3/day) of total water supply provided
Christopher et al, 2000	Three UK industries	Installing water-efficient devices & new technology	30% reduction in water consumption
Yeoh et al, 2001	Malaysia	Reusing the spent wash in molasses dilution and fermentation	40% reduction in freshwater consumption
March et al, 2004	Mallorca Island, Spain	Recycling of grey water to flush toilets at a local hotel	23% of water consumption was saved

Apart from the financial benefits highlighted above, water demand management measures have got a positive impact on the environment. Reduced consumption leads to less demand on the stream flows and ground water resources, hence promoting inter-generational equity. Furthermore, there are less carbon emissions as a result of lower treatment and pumping loads, and significant reduction in energy usage for heating water for showers, dish-washing and garment-washing.

Another key benefit of DM is concerned with reduction of wastewater flows. Conservation measures on the side of the customers reduce the wastewater load onto the sewerage system and subsequently the sewage treatment plant, which will not only lead to reduced operation/maintenance costs, but will also defer the augmentation of the plant. Wastewater treatment processes are more capital-intensive than water distribution systems, and such benefits will be significant in developing countries where a big proportion of utility customers do not obtain sewerage services.

4 Integrated Resource Planning: Beyond DM

In the recent past, DM has been placed within a conceptual framework of Integrated Resource Planning (IRP), a process that embraces wider strategic planning principles and fits well within the integrated urban water resources management paradigm. IRP is an approach that was first applied in the energy sector in the United States in the early 1980's, which recognised the limitations of focusing on only construction of power supply infrastructure. In response, the IRP process was adopted, in which a full range of both supply-side and demand-side options are assessed against a common set of planning criteria (Tellus Institute, 2000). The guiding philosophy for IRP is that utility customers do not necessarily demand for a resource itself but rather for the services that the resource provides, often called end uses.

During the 1990's, a significant amount of work has been done by researchers in Australia and the US to adapt the IRP principles to the water sector. IRP is based on the guiding principle that since customers of water utilities require services rather water per se, water supply systems should be designed and managed to satisfy water-related service needs or end-uses. Therefore, IRP shifts the focus of attention from the quantity of water delivered to the quality of service provided (Fane, Turner and Mitchell, 2004). 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).

IRP may be defined as a comprehensive form of planning that uses an open and participatory decision-making process to evaluate least-cost analyses of demand-side and supply side options (Beecher, 1995). It is a process in which water utilities determine the least cost options that they can use to provide their customers with water-related services that they demand rather than the water per se (Howe and White, 1999). Table 2 shows the major differences between IRP and the traditional urban water planning.

As can be seen from Table 2, IRP is a systematic planning process that identifies the most efficient means of achieving the goals, while considering the costs of the project impacts on other societal objectives and environmental management goals (Maddaus and Maddaus, 2001). The table shows that shifting from a conventional urban water planning process to IRP requires a paradigm shift in the way urban water resources are managed. Urban water planners and managers need to appreciate that it may not be always necessary to increase the water supplied in order to satisfy demand: rather, one way to fulfil the demand could be increasing the efficiency of resource use, as it is assumed that providing the same services with less resources makes no difference to the consumer.

The key principles of IRP include (Turner et al, 2006):

1. Water service provision – recognition that it is the service that is required by customers and not the water itself,
2. Detailed demand forecasting – dis-aggregation of demand into end uses such as toilets and showers enables detailed demand forecasting as well as determining the potential of water conservation with respect to various options,
3. Consideration of a broad spectrum of viable options that satisfy service needs,
4. Comparison of options using a common metric, boundary and assumptions,
5. Participatory process, which ensures that diverse groups of stakeholders are involved at different stages of the planning process, and therefore identify and respond to multiple needs and objectives, and

6. Adaptive management – emphasis on iterative, on-going learning process in which initiatives are decided upon, implemented and evaluated in repeated cycles.

Table 2: Comparison of traditional urban planning with IRP (Source: Turner el al, 2006)

Criteria	**Traditional Planning**	**IRP**
	Planning Orientation	
Resource options	Supply options with little diversity	Supply and demand management options; efficiency and diversity are encouraged
Resource ownership and control	Utility-owned and centralised	Some resources owned by other utilities, other producers, customers
Scope of planning	Single objective, usually to add to supply capacity	Multiple objectives determined in the planning process
Assessment criteria	Maximise reliability and minimise costs	Multiple criteria, including cost control, risk management, environmental protection, economic development
Resource selection	Based on a commitment to a specific option	Based on developing a mix of options
	Planning Process	
Nature of the process	Closed, inflexible, internally oriented	Open, flexible, externally oriented
Judgement and preferences	Implicit	Explicit
Conflict management	Conventional dispute resolution	Consensus-building
Stakeholders	Utility staff and its rate-payers	Multiple interests
Role of stakeholders	Disputants	Participants
	Planning Issues	
Supply reliability	Constraint and high priority	A decision variable
Environmental quality	A planning constraint, comply with regulations	A planning objective
Cost considerations	Direct utility system costs	Direct and indirect costs, including environmental & social externalities
Role of pricing	A mechanism to recover costs	An economic signal to guide consumption, and a way for sharing costs and benefits between different stakeholders
Risk and uncertainty	Should be avoided or reduced	Should be analysed and managed

These IRP concepts have been applied in various contexts by water utilities around the world, with significant work done in America and Australia. The Institute of Sustainable Futures (ISF), a research institute of the University of Technology, Sydney has been at the forefront of applying IRP principles in Australia. ISF has worked with various water utilities in Australia to develop a coherent integrated process that brings together essential IRP elements to ' …unlock the potential in DM and compare water conservation options on equal footing with source substitution and supply options' (Mitchell et al, 2004, p.4). Figure 2 shows a process diagram that has been applied for urban water systems in Australia.

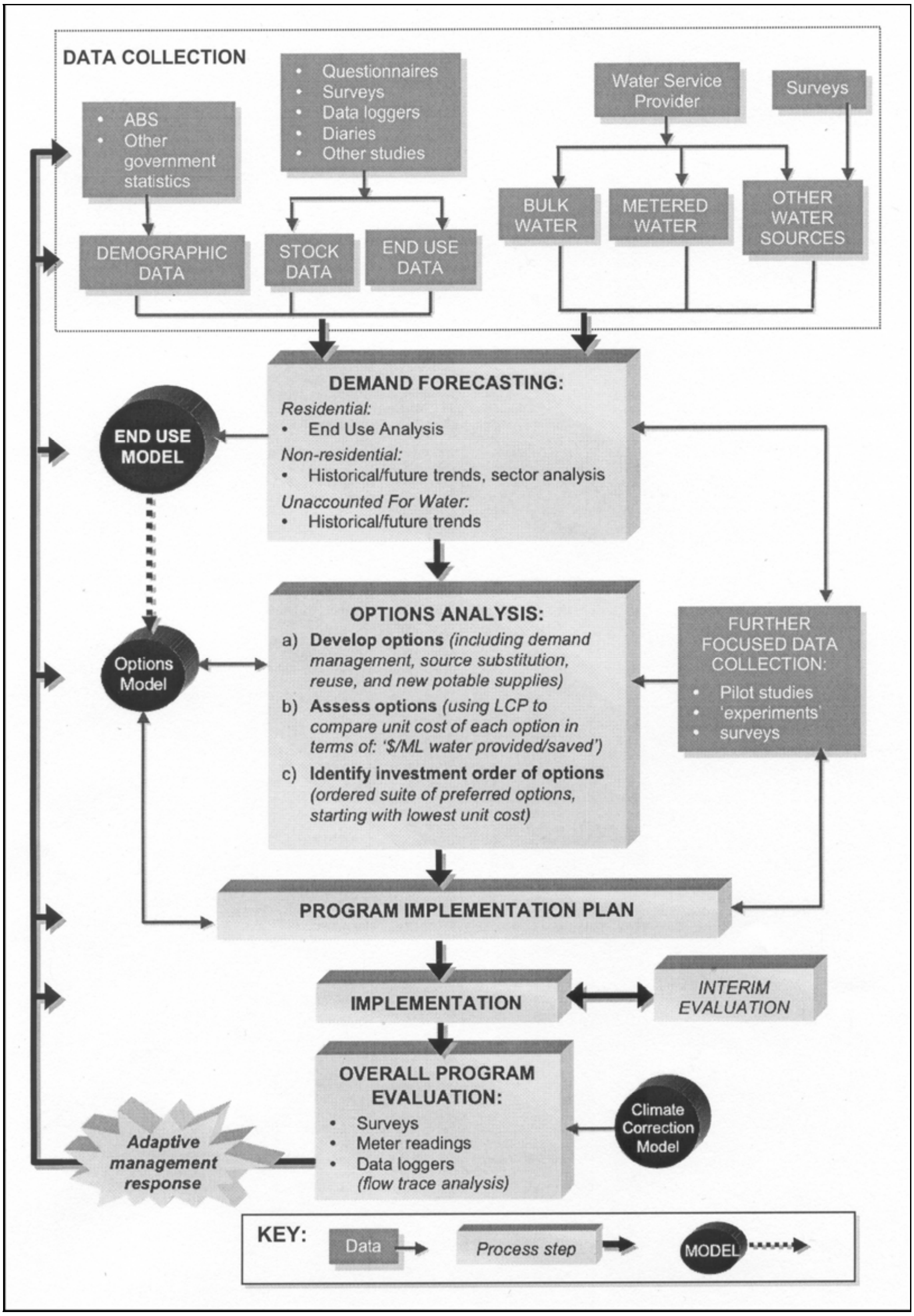

Figure 2: The demand management process being applied in Australia (Source: Mitchell et al, 2004).

Following on the work that has been carried out in Australia, ISF has been championing an international task force that is developing an International Demand Management Framework (IDMF). ISF leads Task Force No 7 that was set up in 2004 by the International Water Association (IWA) Specialist Group on 'Efficient Operation and Management'. The task force was set up in realisation of a need for development of a common framework for water in the context of urban water planning and the supply-demand balance. The major objective of the task force is to develop a consistent framework that harnesses international good practices in water demand management and enhances effective knowledge transfer of the latest research and skills. Work is in advanced stages on adapting the already existing Australian water demand management framework (shown in Figure 2) to international context through the use of various case studies.

To successfully carry out the process shown in Figure 2, it is a prerequisite to identify local drivers and set targets. The drivers could be categorised as direct (such as supply gap due to an increasing population); indirect (such as implications of climate change on catchment runoff); or organisational (e.g. corporate strategy). These drivers will in turn influence the targets set, which may be short-, medium- or long-term. The next step is to collect historical data for demand forecasting, which level of detail varies from context to another, depending on allocated resources. Depending on availability and level of analysis required, data may be collected on the variables that influence demand, shown in Figure 3. The data may include demographics, water using appliance stocks, end use data, bulk supplies, metered water supplies, climate variables etc.

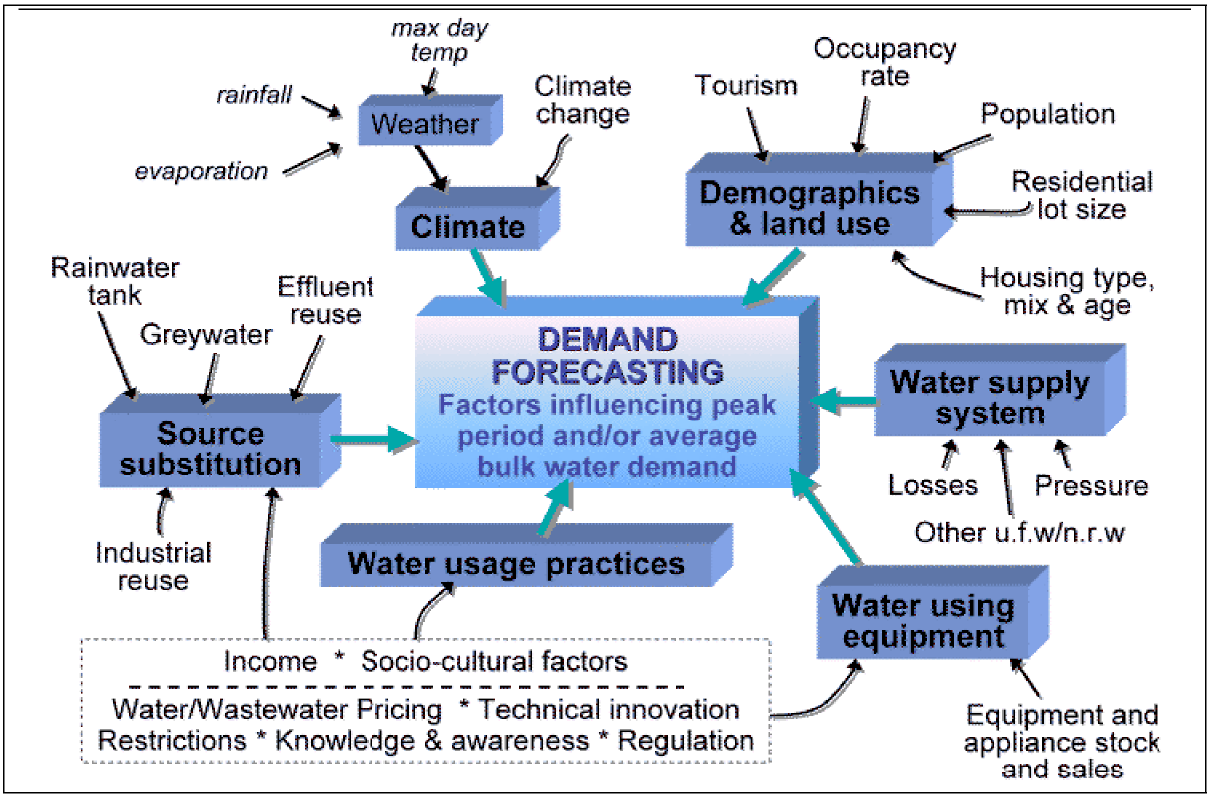

Figure 3: Data required for demand forecasting (Source: Mitchell et al, 2004)

Historically, demand forecasting has been done by taking a snapshot at a given time, calculating or estimating the current per capita usage, and projecting demand by multiplying this figure by the projected population. In this framework, demand is more accurately forecasted using end-use analysis and modelling, whereby demand is disaggregated into individual sectors (e.g. single and multi-residential, commercial, industrial, institutional and non-revenue water) and individual end uses (e.g. for households – toilets, showers, taps, dishwashers, washing machines, outdoor gardens, swimming pools) (Mitchell et al, 2004). This breakdown is facilitated by data collected on the stock of houses and appliances in a specific region and how consumers use the appliances (in terms of frequencies and durations). Each area is different: it is important that region-specific data is obtained in order for the model to accurately reflect the situation on the ground.

The next step of IRP process is to devise and analyse the DM options. As discussed in Section 3, the options may be a combination of various types of measures and instruments, to bring about the required changes, examples of which are shown in Figure 1. Examples of measures include (Mitchell et al, 2004): indoor residential retrofits, subsidised outdoor garden assessments and free giveaways, showerhead and toilet rebates; business audits/retrofits; school programmes; education and community awareness programmes; water pricing reforms to implement cost-reflective tariffs; labelling and water efficiency performance standards; regulations on garden watering practices; short term restrictions; leak detection and pressure reduction in the network.

Each of the chosen options are then individually analysed in terms of economic costs, technical feasibility, political/social acceptability and environmental impact. These options are analysed using present value levelised costs based on total societal perspective, compared with the water saved and supplied. The options are then ordered in terms of the unit costs, and plotted on a supply curve, which also shows the cumulative water saved and supplied. Figure 4 shows a typical curve of a study conducted for the Australian Capital Territory.

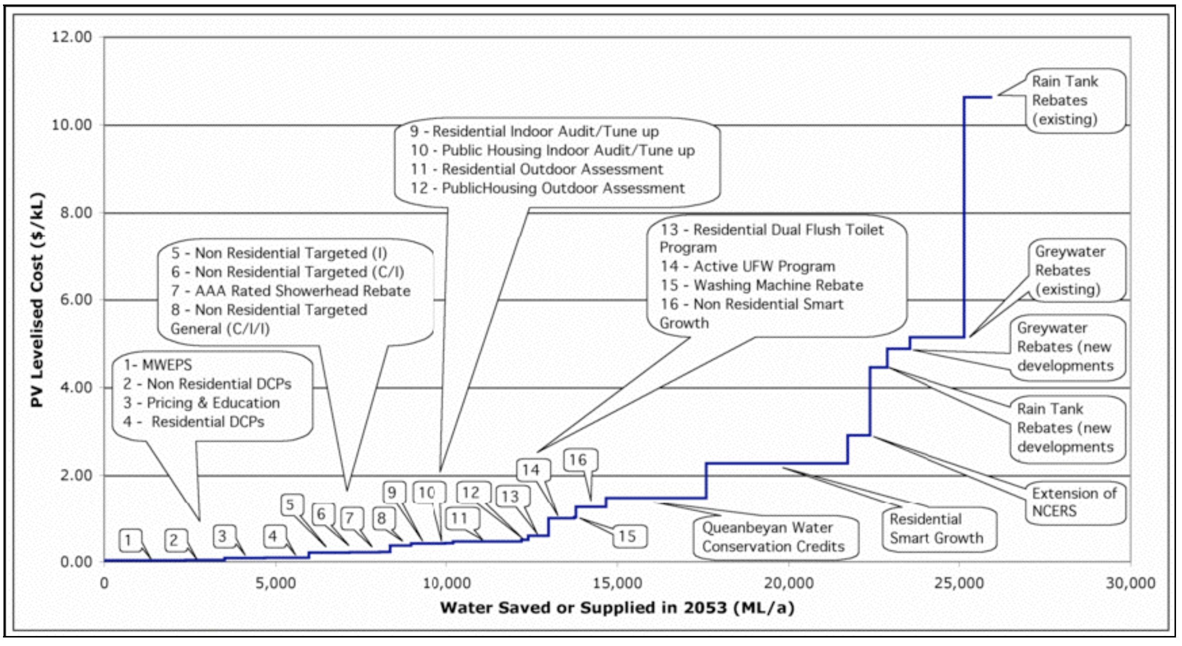

Figure 4: A typical supply curve for DM options (Source: Mitchell et al, 2004).

After obtaining the most viable individual options, these should be allocated to groups of scenarios that meet the set goals. These combinations should further be analysed and compared to come up with the most optimal trade-off of a group of options, putting into consideration the unit cost, flexibility, reduced risks, increased synergy and social/political acceptability. It is recommended that a pilot study be carried out in which the selected group of options is tried out, before going for full-scale implementation. Monitoring and evaluation is carried out during the implementation, to assess the programme processes and outcomes against set objectives, and enable reflective and adaptive learning.

To summarise, the key distinguishing features of the IRP process described above from the conventional urban water planning process are (Mitchell et al, 2004):

1. Rather than projecting demand based on supply-driven design criteria, demand forecasts are built bottom-up using end-use analysis, and based on key changes over time such as stock of water-using appliances.
2. Local drivers are identified as a basis for development of options to meet expressed service demand, taking into consideration DM, source substitution and new supply options.
3. Analysis, assessment and comparison of options are carried out on the basis of levelised unit cost of meeting demand, rather than providing supply.
4. Societal benefits and costs, rather than utility costs/benefits, are used for comparison

5 DM research activities under the EU SWITCH Project

DM is one of the themes being researched under the SWITCH project. SWITCH is an acronym for an EU-funded five-year research project that started in April 2006 on how 'Sustainable Water management Improves Tomorrow's Cities' Health'. SWITCH is an integrated project whose overall goal is to trigger a paradigm shift in current urban water management practices by developing, applying and demonstrating a range of tested scientific, technological and socio-economic solutions and approaches that contribute to the achievement of sustainable and effective urban water management schemes in the 'city of tomorrow (projected 30-50 years from now)'. The specific objectives of SWITCH are:

- To develop an overall strategic approach to achieve sustainable UWM in the city of the future,
- To develop effective storm-water management options in the context of the hydrological cycle at urban and river basin level,
- To explore ways of providing effective water supply services for all at minimum impact for water resources and the environment at large,
- To develop effective sanitation and waste management options based on the principles of 'Cleaner Production',
- To integrate urban water services into the ecological and other productive functions of water at city and river basin level, and
- To develop innovative, effective and interactive institutional arrangements covering the entire urban water cycle in the urban and broader river basin setting.

Activities under the SWITCH Project are being undertaken by a consortium of 32 international partner institutions, led by UNESCO-IHE Institute of Water Education, Delft (The Netherlands) and assisted by other reputable universities, and research institutions. The other project partners are the cities that have signed up to participate in the demonstration activities. The activities are clustered in six themes, corresponding to the research objectives 1-6 above, and each theme is contributed to by several work packages. Figure 5 shows how the activities under each theme interact with each other, in order to have integrated efforts towards the overall goal of the project.

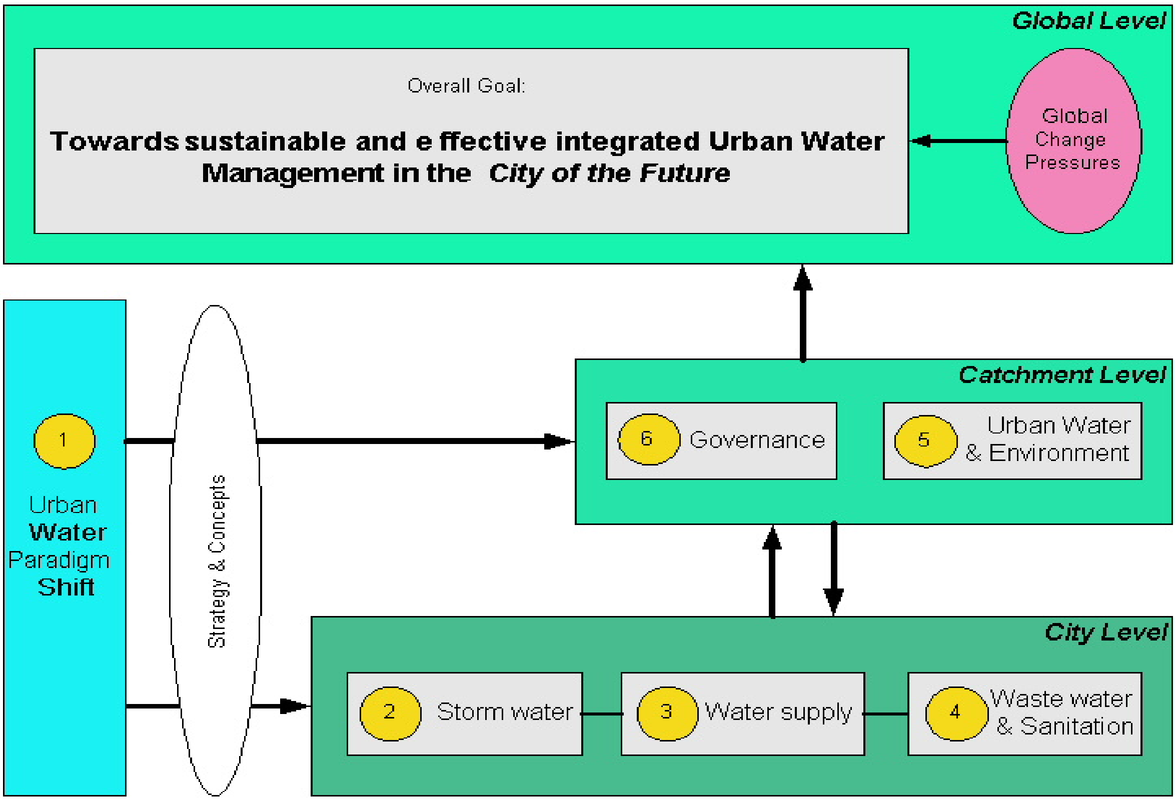

Figure 5: The Integrative nature of the SWITCH Project activities (Source: SWITCH, 2006)

As shown in Figure 5, research activities contributing to themes 2-4 on management of storm-water, urban water supply, and wastewater/sanitation are carried out at the city level, while those contributing to themes 5 and 6 on governance and urban water and environment are conducted at the catchment area level. Being guided by the SWITCH strategic approach to the paradigm shift in urban water management (Theme 1), the results of the research activities will be integrated in an interactive way to contribute to the overall goal of the SWITCH project.

The overall approach and methodology employed by the SWITCH Project is composed of the following methods (SWITCH, 2006):

1. Action research, where users participate in the development, application and demonstration of new approaches of scientific, technological and socio-economic application in the improvement of sustainable integrated urban water management,

2. Multiple-level or integrated approach, in which the research activities recognise the impacts and dependency of urban water systems onto the natural environment in the river basin, which in turn depends and impacts on systems,

3. Training and multiple-way learning, where cities and individuals learn from each other, and

4. Learning alliances, in which stakeholders in the demonstrations cities interact productively and proactively to create win-win solutions to practical problems.

All these methods interact with each other, and are guided by the SWITCH strategic direction. In carrying out the project activities, the participants recognise the varying technological, economic, and socio-cultural environments in different study areas and demonstrations cities, and seek to reap maximum benefits from the diversity.

Water, Engineering and Development Centre (WEDC) of Loughborough University is one of the research consortium partner institutions of the SWITCH Project. WEDC is contributing to the theme on 'efficient water supply and water use for all', and is leading on Work Package 3.1, which deals with water demand management. The objective of Work Package 3.1 is to develop and test holistic demand management tools, encompassing commercial and physical aspects, in order to reduce water wastage and provide educational materials on the two main components for the benefit of service providers. The main activities under Work Package 3.1 are (SWITCH, 2006):

1. Establishment of an international panel of experts on demand management,

2. Development of innovative cost-effective methodologies of reducing non-revenue water, encompassing both physical and commercial losses,

3. Development of innovative methodologies for mainstreaming demand management within utility management, through use of tariffs,

4. Production of innovative educational materials, and training programmes, for selected target groups in various social, economic and geographical contexts, and

5. Facilitation of capacity-building in the area of demand management, by using the tools and materials developed in the project.

The SWITCH demonstration city for DM activities is the Spanish city of Zaragoza, where water conservation has been a priority area for the past ten years. WEDC is currently working with the Zaragoza City Council, the University of Zaragoza and other stakeholders to build on the work already done and to carry out further WD research and demonstration activities in the City. Section 6 describes what DM measures have been applied in the past, and what activities are being carried out under the SWITCH Project.

6 DM Activities in Zaragoza, Spain

6.1 The Study Setting

The city of Zaragoza, situated in the central area of the River Ebro basin, is the capital of Aragón region in North-eastern Spain. Zaragoza, with a mean elevation of 199m above seal level, experiences a hybrid of continental/Mediterranean climates, characterised by long winters (about 121 days with temperatures lower than 10°) and long summers (about 150 days with temperatures higher than 17°). Zaragoza is situated in a semi-arid region with an average annual precipitation of 314 mm, and a potential evapotranspiration rate of 795 mm per year (Arbués and Villanúa, 2006; Arbués, et al, 2004). To mitigate against the widely varying seasonal flow rates of River Ebro, 138 dams have been constructed on the river since the 1930s, providing a total storage capacity of 687,300 m^3 (Penagos, 2007). The 2001 national census put the population of Zaragoza at 614,905 (a 31% increase with respect to the 1970 population), making it the fifth largest city in Spain (Arbués and Villanúa, 2006).

Water and sewerage services to the city residents are provided by Zaragoza City Council, through centralised municipal departments. Raw water for the city supply is abstracted from River Ebro, mainly through the Aragón Imperial Canal. Water is distributed to the consumers through more than 1,100 kilometres' length of a reticulation network. The network is mainly composed of pipes made of the following materials: (i) asbestos cement (34%); (ii) ductile iron (48%); (iii) reinforced concrete (6.5%) and (iv) PVCn (5.5%).

Although there are plentiful groundwater resources in Zaragoza, underground water has not been exploited for the municipal water supply, mainly because it contains high concentrations of minerals such as sulphates, nitrates, sodium and magnesium (Arbués et al, 2004). To respond to the increasing water demand, the city council has until the 1990s focused on supply-side options, namely abstracting surface water further away from Zaragoza, through construction of dams, barrages, aqueducts and canals, the development of the Yesa dam being the most recent such project (Arbués and Villanúa, 2006).

6.2 'Zaragoza, the water-saving city' Project

Following a serious drought in Spain during the period 1991 to 1995, Zaragoza City Council imposed a variety of water restrictions, which prompted displeasure from the customers. The droughts also sparked off disagreements and confrontations between various regions of Spain about mass transfer of water through building dams, tunnels and channels. These incidences motivated Fundación Ecología y Desarrollo (FED), a Spanish environmental Non-Governmental Organisation (NGO) to develop a pilot project that aimed at demonstrating that the water shortage problem could be solved using a cheaper, more environmentally friendly, and socially acceptable approach (Fundación Ecología y Desarrollo, 1998).

Working with various partners, FED initiated the 'Zaragoza: Water Saving City' project in 1996, whose objective was to (i) create awareness of the need for water-saving; (ii) promote information about simple water-saving technologies; (iii) work towards creating a water-saving city, which would be set an example for the outside world; and (iv) save water without sacrificing comfort. With a budget of 0.87 million euros variously contributed by the founding partners, the first phase of the project kicked off in February 1997, for two years, while the second phase run from 2000 to 2002. The first phase, focusing on 'small steps, great solutions', sought to have a systematic focus on all that individually and institutionally determine a water culture such as institutional policy framework, technology, knowledge/information, regulations and consumer habits.

It was recognised right from the project inception that improving a water-saving culture was a collective challenge, and required the full participation of all stakeholders that contribute to the water culture. Based on the principle of shared responsibility, the intervention was therefore designed to create a collective challenge which would bring about participation of all stakeholders in the city, and build on the synergy of these partnerships. Participation in the project was deliberately sought from all key stakeholders such as consumers, plumbers, policy makers, manufacturers, retail outlets, businessmen, building companies, financial institutions and architects. Table 3 shows a summary of actions carried out with the key partners of the project.

Table 3: Main actions targeted at key partners of the 'Zaragoza water-saving City' project.

Key partners	Main actions
Professionals involved in domestic water use	• Project objectives and strategies mailed to builders, property agencies, promoters, architects, etc. • Information sessions arranged for plumbers, distributors and manufacturers • Publicity materials distributed in retail outlets • Competitions organised to reward sales staff promoting water-saving devices • Development & distribution of a catalogue providing water-saving technology • Development & distribution of a catalogue of techniques for planning, design and maintenance of parks/gardens, and planning of water management
Large scale consumers	• Information sent on environmental & economic advantages of saving water • Information sessions arranged on efficient water management • Stickers provided for public washrooms, which identified water-saving equipment; showed users how to use them properly; and remind users on importance of water saving
School children and teachers	Teaching materials were produced for teachers to work through with pupils: • Big Book of Water - with blank pages for pupils to fill in their ideas • Water Card – each pupil designed an image & slogan to persuade others of the need to preserve precious water • Water Savings Book – to keep a record of monthly progressive savings achieved • Experiences Directory - a collection of classroom activities related to water
General Public	• Publicity campaign using TV stations, radios, newspapers, leaflets, posters, billboards, buses, urban installations. • Water help-line – a telephone service to inform the public about water-saving technology and where they could find the devices. • A web-page - to publicise the project on the internet • Water –saving products toolkit – a package including a flow regulator for taps, water-saving shower, water-saving cistern, plus information on their use, distributed free of charge to public personalities

By the end of the first phase of the project, over 150 organisations were actively involved in project activities, such as distribution of information. The active partners included public institutions, NGOs, private companies, trade unions, professional bodies, community-based organisations and business associations. About 90% of the media houses in Zaragoza fully participated in the project. Furthermore, over 140 wholesale and retail establishments selling products related to water consumption, accounting for about 65% of all the traders, collaborated in the campaign. From the educational sector, 474 teachers and about 70,000 pupils from 183 schools collaborated in the educational programme on water-saving culture (Fundación Ecología y Desarrollo, 1998). Clearly, in the two years of the first phase of the project, FED, the leading project partner successfully mobilised partnerships for enhancing water-saving culture in Zaragoza.

Although the first phase of the project aimed at saving at least 1,000 million litres of water in the homes of the city of Zaragoza per year, the project achieved an overall saving of 1.176 billion litres of water, equivalent to 5.6% of annual domestic consumption. (Fundación Ecología y Desarrollo, 2001). To achieve these results, the following actions were actively promoted: (i) change of attitude towards water use and consumption, leading to behavioural change; (ii) provision of information, education, training and advisory services which assist consumers who wish to take action to reduce their water use; (iii) replacement of old equipment with new water-saving devices; (iv) acquisition of new water-saving sanitary fittings (e.g. flushing toilets, taps, showers) and household appliances (e.g. washing machines and dish washers); (v) the introduction of individual household hot water meters; and (vi) other actions that would save water, such as timely repair of leaks in the premises, and recycling of domestic water.

An evaluation survey carried out at the end of the first phase in 1999 showed that the number of people aware of the importance of water-saving measures improved from 40% to 72% of the respondents. However, the same survey showed the water saved was more as a result of behavioural change than adoption of water saving technology (Edo & Soler, 2004, Fundación Ecología y Desarrollo, 2001). Hence, a second phase of the project was initiated in the recognition that there was need to have an integrated strategy encompassing, among other methods, campaigns for behavioural change and adoption of water-saving technology, if the water conservation measures were to be sustainable.

The second phase of the project, entitled 'Zaragoza, water saving city – 50 good practices' was initiated to widen and extend the intervention to non-domestic sectors, and consolidate the achievements realised by emphasising the use of water-saving technology in the households. This phase was implemented from June 1999 to March 2003, and aimed at developing 50 best practices for efficient water use in selected public buildings, industries, and parks/gardens, such that these demonstration centres become a reference and model for others in the respective sub-sectors (Edo & Soler, 2004, Fundación Ecología y Desarrollo, 2001).

By the end of the phase, 30 good practices were achieved in efficient water use in buildings for public use. Typical examples are a shopping mall that achieved 92% water savings through a change in floor cleaning methods and an educational centre that saved 70% through environmental education. Similarly, 13 good examples were established in the parks/gardens sub-sector, mainly through careful consideration of the design of the lawns, selection of the plant species, and water methods. In industries, huge savings were made in at least 9 enterprises through modification of the production and cooling processes, ranging from water recycling, water recirculation and reverse osmosis (Edo & Soler, 2004). Furthermore, practical guidelines for efficient water use in the non-domestic sector were published and widely circulated. These publications include practical eco-audit guidelines for hotels, offices, industries, hospitals and educational institutions; and practical guidelines for dry-land gardening (Garrido et al, 2005).

Similarly, audits were also carried out in selected households, with the aim of promoting water-saving technology. As a result, a practical handbook on efficient water use in the homes was produced, which provided guidelines for householders to evaluate their water consumption rates, and adopt good practices for water use efficiency by installing technological devices and changing their habits. Households were offered subsidised kits of household water-saving devices, such as shower heads, tap devices and double-flush cisterns. These devices were installed in the in the households at a subsided cost. Activities involving use of water-saving technology were carried out in full collaboration with the enterprises concerned with manufacturing, distribution and/or installation of the water-saving devices. Technical staff from firms were continuously sensitised, kept informed of the project activities, and their profiles were widely circulated to the consumers.

The overall outcome of both phases of the project ‘Zaragoza: the water-saving city’ have been quite significant. Average water consumption in the households of Zaragoza reduced from 107 litres per capita per day in 1996 to 99 litres per capita per day in 1999 (Garrido et al, 2005). These figures are well collaborated with operational data for Zaragoza City Council, which show that, with an increase in population of 6.3% between 1996 and 2004, water supplied to the city reduced by 14% during the same period (Zaragoza City Council, 2006). To consolidate these achievements, another phase was launched in November 2006. ‘Zaragaza, a water saving city: 100,000 commitments’ aims to solicit for commitments for achieving efficient use of water by individual consumers.

6.3 Towards Economic Pricing for Water Services in Zaragoza

By the end of the drought in 1995, the water tariffs set by Zaragoza City Council, the service provider, were mainly driven by financial and political considerations, rather than economic considerations. The tariff, which was comprised of a fixed fee and a volumetric-based rate, ensured that revenues cater for a politically acceptable part of the costs of providing water services (Arbués and Villanúa, 2006). The monthly fixed fee was based on the street category where the building was located, and mainly depended on the length/width of the street, and whether there were any commercial enterprises. Not enough quantitative data were collected to determine these rates, and therefore, there were cases where the rates were allocated based on political criteria (Arbués and Villanúa, 2006). On the other hand, the volume-based rates were categorised into four blocks, as shown in Table 4.

Table 4: Zaragoza variable tariff in 1993 (Source: Key informant, Zaragoza Finance Department, 2007).

Monthly Consumption per property	Price in Pesetas* per m^3	Equivalent price in Euros (at 2002 exchange rates)
0 - 6 m3	12	0.07
6.1 – 13 m3	25	0.15
13.1 -35 m3	40	0.24
Over 35 m3	56	0.33

*The Spanish Pesetas was replaced by the Euro in 2002 at an exchange rate of 166.4 pesetas to 1 Euro.

Table 4 shows the variable tariff for the City of Zaragoza was an increasing block tariff even before the drought, which to an extent fostered some economic principles. However, a key shortcoming was that the fixed portion of the tariff, which was based on noneconomic criteria was quite substantial. Other shortcoming were (i) the tariff levels were quite low, and could cover only a fraction of the operating costs, (ii) there were quite a few properties that did not have consumption meters, and were charged on a flat rate; and (iii) there was no differentiation between domestic and non-domestic tariffs, and hence could not foster social equity.

Subsequently, Zaragoza City Council initiated a long-term programme to reform the tariff in 1995, in which price levels were raised to economic levels in a step-wise fashion. As part of the programme, an empirical study was carried out by the University of Zaragoza from 1996 to 1998, to test short-term sensitivity of water demand to changes in price and key socioeconomic variables. This study used a longitudinal survey of a sample of 1596 households, and obtained data on a set of 10 water consumption meter readings, the price paid, daily maximum temperature, educational level and age of head of household, household size and availability of a common hot water facility in each household (Arbués and Villanúa, 2006).

The key findings of study were as follows: (i) the average price elasticity of demand was –0.08; (ii) the average income elasticity of demand was 0.79; (iii) the average elasticity of water consumption with respect to family size was 0.48; and an installed collective hot water storage system leads to an average fall of 15.4% in the consumption registered on the individual household meter (Arbués and Villanúa, 2006). Other key findings were that every household required an average basic minimum amount of 3.5 m^3 per month to maintain the common good in the home, while each resident required additional 2.5 m^3 of water per month, which decreased with household size, along economies of scale.

The results highlighted above were used to inform the design of a tariff that aimed at engendering optimization of economic efficiency; horizontal and vertical equity (i.e. same benefit, same cost, and different benefits, different costs); universal access and transparency. Tariff structures that have operated since 2005 have been designed to match the socioeconomic attributes and consumption habits of the population. The tariff is composed of fixed and variable parts as shown in Table 5.

Table 5: Zaragoza domestic variable tariff by end of 2005 (Source: Key informant, Zaragoza Finance Department, 2007).

Breakdown	Consumption Range (per property per day	Price* (€/m^3)
Fixed consumption (3.5 m^3 per hh) plus 1 person's 2.5 m^3 per month (equals 6 m^3 for one occupant in a month)	0 – 0.2 m^3	0.32
Fixed consumption (3.5 m^3 per hh) plus up to 6 person's consumption at 2.5 m^3 per person per month	0.2 – 0.616 m^3	0.768
Excess consumption	More than 0.616 m^3	1.536

*Price includes sewerage charges

Whereas consumption falling in block 1 and 2 attract some subsidies, the price levels in block 3 cover full supply costs. In order for households with more than six people to benefit from these subsidies as well, there is a provision for them to be charged on a special tariff rate, after their claims have been verified by the responsible utility staff.

Other categories of people that benefit from special tariffs are the unemployed, the sick and the poorest of the poor.

Furthermore, Zaragoza Municipal Council has been offering economic incentives to households that reduce their consumption rates. If households reduced their consumption by at least 40% in 2002, they were entitled to a 10% discount on the bill. After one years' trial, it was realised that 40% reduction in household water consumption was rather unrealistic, as can be seen from the low number of people (1,708) who achieved the target. In subsequent years, the target was reduced to 10% reduction in consumption rate per year. Following this change, more households participated and managed to achieve the target.. Table 6 shows the number of households that have made water savings, and who have benefited from the economic incentives.

Table 6: Number of households benefiting from the economic incentives for water saving (Source: Key informant, Zaragoza Finance Department, 2007).

Start Year	Households with new commitments	Further subsequent savings of 10% in the Year			
		2003	2004	2005	2006
2002	1,708	375	66	2	1
2003	27,741		5,331	487	123
2004	24,331			2,956	721
2005	27,929				4,635
2006	33,274				

Table 6 also shows that some households have the capacity to continuously make savings in subsequent years. For instance, of the 1,708 households that reduced their consumption by 40% in 2002, 375 of these made a further 10% reduction in 2003. A further 10% savings were achieved by 66 households in 2004, two households in 2005 and one household in 2006, respectively. As can be seen from column 2 of the table, the scheme is being embraced by an increasing number of households, which has contributed to overall reduction in water consumption in Zaragoza described in Section 6.2.

6.4 DM Activities under the SWITCH Project

Activities under Work Package 3.1 of the SWITCH Project are building on the great work already done to enhance water demand management in Zaragoza City. A preliminary assessment of the existing situation in Zaragoza showed that little work has been done on the water demand management on the side of the utility. Therefore, the SWITCH project activities in Zaragoza have been designed to supplement ongoing efforts and strengthen demand management in the water distribution network. The following paragraphs briefly describe two key areas on which the SWITCH project is concentrating.

A. Enhanced water loss management

The IWA strategy on water loss management will be applied for efficient operation and maintenance of distribution piped networks in a sample water supply zone in Zaragoza. This strategy, which has been developed by the IWA Specialist Group on 'Efficient Operation and Management of Urban Water Systems', is made up of four components, as shown in Figure 6. Attributes of the network such as pipe material, age of the network, number of consumer connections, length of the network and pressure determine an acceptable level of water leakage, at which point, for a unit of water produced, the marginal costs of repairing the leaks exceeds the cost of producing the unit of water. This point is termed as the Unavoidable Annual Real Losses (UARL). Improving effectiveness of measures under each of the components (i.e. pressure management, speed and quality of repairs, active leakage management and pipeline/asset management) will minimise the potentially recoverable real losses.

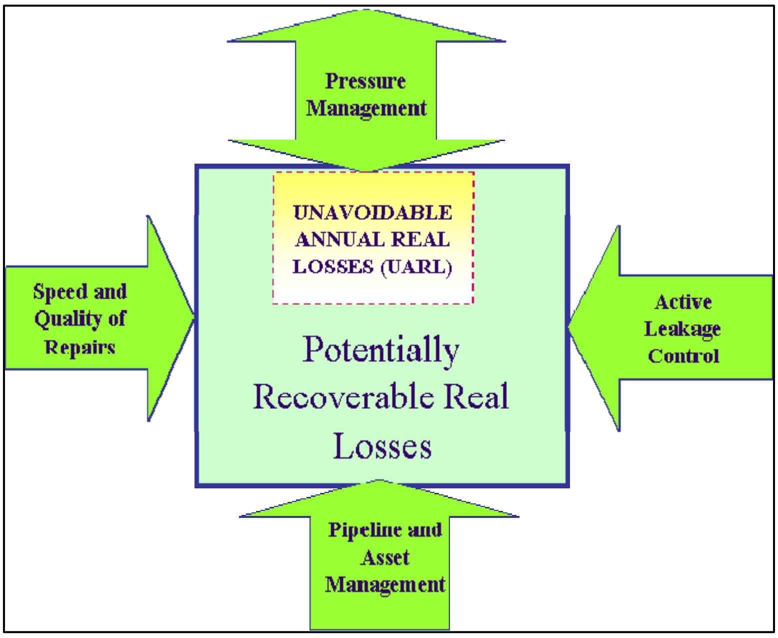

Figure6: Components of water loss management strategy, as developed by IWA (Source: Liemberger and Farley, 2004)

Actur area, with a population of about 60,000 people has been selected to be a case study, and has already been demarcated and isolated using boundary valves. District meters and data loggers have already been fitted, and pressure and flow readings are being obtained through remote sensing. We are currently in the process of carrying out a District Meter Area (DMA) testing to ensure the robustness of the boundary fittings. We shall then determine the average pressure in the DMA, work out UARL, and estimate the minimum night flow. These data will enable us to work out an Infrastructure Leakage Index (ILI) based on the IWA benchmarking system. We shall then apply active leakage and pressure management techniques to optimise leakage rates in the area.

B. Application of Integrated Resource Planning to Zaragoza water systems

SWITCH Work Package 3.1 is adapting the IRP framework developed for water utilities in Australia, a schematic of which is shown in Figure 2, to the water supply systems in Zaragoza. Working in partnership with the University of Zaragoza and the Zaragoza City Council's Environmental Education Department, WEDC has already started applying the IRP framework to urban water systems in the City of Zaragoza. In this planning process, we aim to:

- Treat demand, water substitution and supply options on an equal footing,

- Carry out the steps reflectively and iteratively, adjusting to inevitable change,
- Maximise inclusiveness, taking in account different stakeholders' perspectives, and promoting acceptance and ownership of outcomes,
- Encourage deliberative decision-making, and maximise meaningful engagement of stakeholders, and
- Identify levels of uncertainty at each step

7 Conclusion

The looming water scarcity coupled with serious negative environmental impacts currently being experienced compels water sector policy makers and professionals to rethink the way they manage the water resources. Instead of focusing on supply-side options, urban water managers need to also apply DM tools in the utility distribution systems and at the end-use level. Water professionals could adapt the IRP approach, which has successfully been applied in the energy sector to assess demand, water source substitution and supply options on an equal footing. The IRP approach is based on the concept that consumers could be offered the same or even better service levels by using water more efficiently, and hence achieve the same organisational objectives while consuming less water resources.

IRP is an iterative and participatory process that assesses both the supply and demand options over a long-term horizon, and evaluates suites of options and scenarios for economic, technical, social and environmental sustainability. Advanced water loss management is one of the aspects that is being researched in Zaragoza water supply system under the SWITCH Project, and will be considered in an overall IRP process. Through these research activities, the SWITCH Project will add value to the water-saving culture in Zaragoza that has already been fostered through public action championed by Fundación Ecología y Desarrollo, a local environmental NGO, and the economic tariff structure that has been implemented by Zaragoza City Council, the water utility.

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