Environmental issue report | No 19

Sustainable water use in Europe

Part 2: Demand management

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Printed in

Printed on recycled and chlorine-free bleached paper.

ISBN

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Preface

This is the second report from the European Environment Agency on sustainable water use in Europe and focuses on how the demand side of water management is being approached across Europe. It has been produced by the European Topic Centre on Inland Waters on behalf of the European Environment Agency. The project was led by the Centre de Estudios y Experimentación de Obras Públicas (CEDEX, Spain), with the assistance of the Water Research Centre (United Kingdom), the International Office for Water (IOW) and the Agences de l'Eau (France) and the Institute of Hydrology (United Kingdom).

Information has been obtained from available sources such as reports from international organisations (e.g. Eurostat, FAO), and national sources such as state of the environment reports. Extensive use was made of the EIONET network of contacts developed by the European Environment Agency. The focus is primarily on the countries of western Europe, but the Phare Topic Link on Inland Waters (led by Vituki Consult Rt. in Hungary) also contributed data and information on central and east European countries.

This report is also a source document for *Europe's Environment: The Second Assessment* published by the European Environment Agency in June 1998 and *Environment in the European Union at the turn of the century* published in June 1999.

The report aims to inform and provide information for policy- and decision-makers at the national and European levels. It will also be of interest to NGOs, educational establishments and interested members of the public.

The report is concerned mainly with measures which aim to achieve increases in the efficiency of use of water over the medium to long term. A distinction is made between urban, industrial and agricultural uses since these vary considerably and water demand management programmes need to be designed specifically for each sector. In addition to sectoral differences, there are considerable differences between and within countries depending on socioeconomic, geographical and climatological factors.

The management of water demand is an important issue in Europe and a number of policies and mechanisms are being used or are being formulated to ensure sustainable use of water. It is intended that this report will act as a source of comparative data to support the assessment of policies in place and a source of information for those developing new policies.

Contents

Executive summary

The European Environment Agency (EEA) and its European Topic Centre on Inland Waters (ETC/IW) are undertaking an assessment of the sustainable use of water in Europe. This report describes the second part of that assessment and looks at, in particular, the demand-side management of water across Europe. There are many pressures on water resources including those arising from agriculture, industry, urban areas, households and tourism. These driving forces on the need for water are intimately linked with national and international social and economic policies. Additional driving forces arise from natural variability in water availability (rainfall) and changes in Europe's climate. Recent history has demonstrated that extreme hydrological events such as floods and drought can create additional stress on water supplies essential for human and ecosystem health. The prudent and efficient use of water is thus an important issue in Europe and a number of policies and mechanisms are being used or are being formulated to ensure sustainable use of water in the long term. Information for this report has largely been collected from western Europe, though some information has also been obtained from some east European countries.

In the past, efforts to satisfy increasing demand have often been expended principally on increasing the supply of resources, which were available abundantly and at relatively low cost. However, the relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that the investigation of sustainable water use is concentrating increasingly on the possibilities of influencing water demand in a way which is favourable for the water environment. The present report continues the work undertaken by the EEA under its study 'Sustainable water use in Europe – Part 1: Sectoral use of water' (EEA, 1999). Part 3 of the work on sustainable water use investigates the importance and significance of extreme hydrological events such as droughts and floods.

This report seeks to identify the key aspects and factors of water demand management as they relate to the different economic sectors. The information is largely gained from case studies which are summarised in the Appendix to the main report.

Most of the water used in households is for toilet flushing (33 %) and bathing and showering (20–32 %). The lowest percentage of domestic use is for drinking and cooking (3 %). The use of water-saving devices, such as reduced volume toilet flushes, in households can achieve savings of around 50 %. The overall savings of water would depend on the proportion of household water demand in total urban demand and on how widespread was the use of such devices. However, at present, their use is not very widespread perhaps because of the lack of information on them and/or because of their relatively high price.

The impact of introducing metering on water use is difficult to separate from other factors, in particular the water charges applied. However, the immediate savings from the introduction of revenue-neutral metering are estimated to be about 10–25 % of consumption. The introduction of metering is usually accompanied by a revised charging system and regulations on leakage. Generally, water meters have been used to determine water used, but, in some areas (Denmark), meter readings will be used to calculate a pollution tax, on the basis that the amount of water used indicates the discharge to the sewage treatment plant.

Losses in water distribution networks can reach high percentages of the volume introduced. Thus leakage reduction through preventive maintenance and network renewal is one of the main elements of any efficient water management policy. Leakage figures from different countries indicate the different states of the networks and also the different components of leakage included in the calculations (e.g. Albania up to 75 %, Croatia 30–60 %, Czech Republic 20–30 %, France 30 %, and Spain 24–34 %).

Tracing and repairing leakage can be very expensive. Increasing water production to feed leaks may prove cheaper in some systems. The consequence is that some local authorities may decide not to trace leakage, despite low efficiency ratios, but continue their wasteful use of water.

The substitution of water (reduction in volume) in industrial processes can give rise to immediate savings particularly if the control of the process conditions is improved at the same time as a reduction of water consumption by about 50 % is achieved. Processes in 'closed circuits' can also reduce water use by about 90 %.

The main water use within the agricultural sector is for irrigation, with minor use by livestock-farming and fish-farming. In the Mediterranean countries, there are national policies to encourage the modernisation or substitution of traditional irrigation methods. These include plans to increase the size of properties to allow the introduction of modern irrigation techniques. The cost of modernisation of existing irrigation methods (gravity) into pressurised systems depends on several factors, but is often in excess of the resultant economic benefits. Thus, governments often offer financial incentives or direct subsidies to farmers for changing irrigation equipment.

The tariff structure has a high impact on the final water price and creates sectoral (industry, agriculture, urban) and geographical (local, regional, national level) differences. Over recent years, the development of water policies in Europe has had an important impact on water bill composition. Information to users is essential in any process of water tariff changes (structure and price increases).

Price structures within the urban sector are generally fixed at municipal level and can vary widely within a country. The differences, in general, take into account different types of users (domestic, industry, agriculture) and tend to reflect differences in cost structures. Experience has, however, shown that an increase in water prices reduces water use.

Block tariffs, which include a connection charge independent of the water use, are widespread: this is the case in Denmark, Finland, France, Greece, the Netherlands, Norway, Spain and the UK. For a family living in a house using 200 m^3 of water per year, Germany has the highest water charges in Europe (EUR 350.16), followed by the Netherlands (EUR 344.35) and Denmark (EUR 303.57). Italy (EUR 49.62) and Norway (EUR 84.83) have the lowest.

The industrial sector faces two different ranges of prices depending on the water source: direct abstraction or from public water supply. Abstraction charges can take the form of a nominal licence fee linked to an abstraction permit regime or they can vary depending on the quantity used. Abstraction charges for industrial water uses are not in place in countries where water is deemed to be abundant (e.g. Sweden). It is usually cheaper for industrial users to invest in water abstraction and treatment facilities than to pay for supplied water, although information is often difficult to obtain.

In most countries, little information is available on tariff structures for industrial users because companies tend to enter into special contracts with water suppliers (e.g. the Czech Republic, Finland, France and Germany). In other countries, such as the UK, standard charges are available to all customers in similar circumstances. In some countries, subsidies can be available for industrial users when they are willing to improve their water abstraction or treatment capacities (e.g. Austria).

The main motive to implement water conservation programmes in companies tends to be economic incentives, normally in the form of abstraction charges and wastewater fees. Other factors can be legislative requirements for cleaner technologies, environmental image and concern for the reliability of water supply.

The situation regarding water tariffs for irrigation is very different from other sectors. The main reason for this is the different role irrigation plays in relation to the different hydrological and climatic conditions across Europe. Irrigation tariffs can be extremely low and there is significant pressure to resist any increase. The use of water for irrigation responds moderately to water price levels, but is more influenced by other factors such as climate variations, agricultural policies and product prices. The most common system for irrigation charges is based on the irrigated surface, followed by a combination of per unit area and volume used.

The general education of and provision of information for water users are important parts of initiatives encouraging more rational water use and changing habits. It is, however, difficult to quantify the effect of a public educational campaign because it is always part of a wider water-saving programme which includes other measures.

In agriculture, the aim of the education programmes is to help farmers optimise irrigation. This can be achieved through training (on irrigation techniques), and through regular information on climatic conditions, irrigation volume advice for different crops, and advice on when to start/stop the irrigation period adjusting irrigation volumes according to rainfall and type of soil.

In Mediterranean countries, the importance of the direct reuse of wastewater is increasing and there is a trend towards considering treated wastewater as an economic good. The technical aspects of reuse are generally in place, but there is a lack of standards and national regulations for the reuse of water. Standards and guidelines are urgently needed. There is also a need for economic incentives to establish new programmes for uses of water which do not require high quality.

1. Introduction

In Europe, there is wide recognition that there is a need for strategies for the sustainable use of water resources. For example, the European Commission has put forward a proposal for a key action on sustainable management and quality of water in the fifth framework programme for research (started in 1999). The aim of the key action is to 'produce the knowledge and technologies needed for the rational management of water resources for domestic needs and those of industry and agriculture' (European Commission, 1998). Also, the purpose of the proposed water framework directive is to establish a framework which will 'promote sustainable water use based on a long-term protection of available water resources'. The directive lists measures that should be applied to achieve this, including the recovery of costs for water services and controls over the abstraction of fresh surface water and groundwater.

As part of the process of improving information and knowledge at the European level, the European Environment Agency (EEA) and its European Topic Centre on Inland Waters (ETC/IW) are undertaking an assessment of the sustainable use of water in Europe. This report describes the second part of that assessment and looks at, in particular, the demand-side management of water across Europe. Information for this report has largely been collected from western Europe, though some information has also been obtained from some east European countries.

Reliable water supply and the protection of aquatic resources through adequate water management are essential to support all aspects of human life and dependent aquatic and terrestrial ecosystems. The use of water across Europe is as varied as the respective countries, because of different climates, cultures, habits, economies and natural conditions. Common to all European countries is the need to satisfy the water demand of households, industry and agriculture. Also common to many countries is a limitation on water resources, both in terms of quantity and quality.

Increasing human demand for resources such as water, energy and land for waste disposal can be met either by expanding supply or by managing demand. Water demand management seeks to ensure that the right balance of demand- and supply-side options is achieved (EEA, 1999e).

In the past, efforts to satisfy increasing demand have often been expended principally on increasing the supply of resources, which were available abundantly and at relatively low cost. However, the relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that the investigation of sustainable water use is concentrating increasingly on the possibilities of influencing water demand in a way which is favourable for the water environment. The present report continues the work undertaken by the EEA under its study 'Sustainable water use in Europe – Part 1: Sectoral use of water' (EEA, 1999). Part 3 of the work on sustainable water use investigates the importance and significance of extreme hydrological events such as droughts and floods.

Sustainability [1] must seek to balance the water available at any particular point in time and space with the demand for water for various 'uses', and the need for enough water to safeguard human health and the aquatic ecosystem. Underpinning this, the water available must be of sufficient quality to satisfy the different users of water including again safeguarding human and other life. Measures may be used to increase availability of water (e.g. construction of reservoirs and leakage control) and/or control and decrease the demand for water (e.g. charging for water and metering).

This report seeks to identify the key aspects and factors of water demand management as they relate to the different economic sectors. The information is largely gained from a number of case studies which are summarised in the Appendix to the main report.

[1] The Brundtland definition of sustainable development: 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'.

2. General considerations

2.1. Definitions

The concept of water demand management generally refers to initiatives, which have the objective of satisfying existing needs for water with a smaller amount of available resources, normally through increasing the efficiency of water use. Water demand management can be considered a part of water conservation policies, which tend to be a more general concept, describing initiatives with the aim of protecting the aquatic environment and making a more rational use of water resources.

The term 'water demand management' can be defined in many different ways. In this report, demand management refers to 'the implementation of policies or measures which serve to control or influence the amount of water used' (UKWIR/EA, 1996).

2.2. Demand-side management in other economic sectors

In other sectors, such as the energy industries (electricity, gas, oil), customer-side management has a long history and is often referred to as 'demand-side management'.

This may involve efficiency standards, product labelling, energy service centres providing advice for users, financing of R & D for energy-saving technologies, subsidies for energy-efficient products, and public awareness, education and training.

Financial instruments include regulatory price controls (which act as incentives or disincentives for energy utilities to adopt demand reduction policies) and price incentives for customers (payment related to consumption and also, in some cases, to level of demand).

Useful experience has been gathered in the energy sector, for example, regarding the dilemma that the successful implementation of a demand management programme through a supply company may have a negative impact on the company's economic result through the reduction of sales and turnover. It is, therefore, obvious that adequate mechanisms have to be foreseen to compensate for this effect.

When a public sector utility company is operating at its maximum capacity, it may be reasonable to look for ways to reduce demand instead of undergoing substantial costs and operational difficulties caused by the construction of a new plant. For example, more than 60 electricity companies in the United States, which supply approximately half the country's population, already have programmes which promote the sale of energy-saving systems (Cairncross, 1993, quoted in López Camacho, 1996). To be really effective, these programmes have to find a way to subsidise those companies which are able to reduce the demand for their product. This intuitively contradictory idea probably can only be put into practice by increasing tariffs for those consumers who do not invest in demand management, applying once again the 'polluter pays' principle.

The electricity sector can provide some useful experiences regarding 'shared savings' and economic incentives for supply companies to reduce demand.

Catalogue of measures

There are many different water demand management measures. These can be categorised:

- *by type of incentive*:
  - legal obligation (e.g. compulsory use of certain technologies, quota for water use);
  - economic incentives (e.g. tariff systems, progressive pricing, subsidies for water-saving investments);
  - information, motivation (e.g. information campaigns, user education, programmes to increase environmental awareness, concern for public image);

- *by kind of tools used*:
  - infrastructure improvement (network improvement, repair leaks, etc.);
  - non-structural measures (information, education, pricing) which may,

however, finally lead to infrastructure improvements being implemented normally through end-users as a consequence of the measures adopted;

- *by time horizon*:
  - emergency measures;
  - medium- and long-term measures;

- *by location of the water supply system, where measures are implemented*:
  - abstraction facilities;
  - storage facilities;
  - conveyance and distribution network;
  - end-users' facilities;

- *by entity bound to carry out measures*:
  - agencies and public authorities (e.g. initiatives within water supply companies);
  - end-users (households, industries, farmers);

- *by entity promoting demand management initiatives*:
  - international treaties and conventions;
  - EU legislation and policies;
  - national legislation;
  - local and regional initiatives;

- *by sector in which measures are applied*:
  - urban use (households, small commerce, etc.);
  - industry;
  - agriculture.

Because water use and consequently water demand management measures vary considerably between sectors, the distinction between urban use, industry and agriculture has been maintained throughout this report.

To avoid ambiguity, it is useful to consider water demand management in the context of an overall water management policy, comprising water supply and demand. Within this policy, four different fields can be distinguished (UKWIR/EA, 1996):

- resource management: policies which affect yield;
- production management: policies targeted at activities between abstraction and distribution input;
- distribution management: policies targeted at activities between distribution input point and consumption;
- customer-side management: policies targeted at customers' consumption (e.g. plumbing losses and water-saving devices in households).

Examples of types of measures within each of these fields are given in Table 2.1.

Table 2.1. Water resource management in the context of total water supply/demand management

Source: UKWIR/EA, 1996

Process	Options	Examples of measures
Resource management (infrastructure + supply)	*Exploitation of additional water resource*	• *Increase supply yield* • *New boreholes or abstraction points*
	Construction of increased storage or transport capacity	• *Reservoirs* • *Aqueducts*
	Management schemes	• *Conjunctive use* • *Artificial recharge*
	Alternative sources to freshwater	• **Use of seawater for cooling systems**
Production management	**Production technology**	• **Technology for improving water treatment such as desalinisation**
	Recycling treated wastewater	• **Recycling for a variety of uses** • **Reduction of production requirements**
Distribution management	*Capacity of mains distribution network*	• *Increase mains capacity*
	Efficiency of mains distribution network	• **Localisation and repair of leaks** • **Pressure reduction**
Customer-side management	**Water-saving equipment**	• **R & D of water-saving devices** • **Encouraging use of devices by individual users and collective users** • **Efficient irrigation material** • **Alternative industrial processes**
	Meter installation	• **Assessment of volumes used**
	Leakage reduction	• **For individual usersFor collective users**
	Tariffs	• **Adjustment of consumption-related tariffs** • **Use of permits for sprinklers** • **Penalties for exceeding irrigation volume ceiling**
	Reuse	• **Rainwater for watering garden** • **Recycling of used water for other uses**
	Education and information	• **General advice and information on conservation** • **Tactical irrigation advice** • **Advice on leakage**

NB: Measures that are part of a water demand strategy are indicated in **bold**.
Measures which are not part of a water demand strategy are indicated in *italics.*

2.3. Reasons and instruments for demand management

2.3.1. Instruments and motivating factors

There is a range of environmental, social and financial factors that motivate water managers, suppliers and users to initiate and implement demand management policies:

- financial: water costs may be an incentive to reduce demand;
- regulatory: legislation, particularly in the industrial sector, can require best available technology to reduce environmental impacts;
- environmental image for competitiveness: this is particularly a factor in the industrial sector, where a competitive edge can be gained by investing in environmental management;
- environmental responsibility: users may feel a responsibility to improve/safeguard the environment;
- sustainability: environmental balance of supply/demand.

2.3.2. Economic viability

The concept of water demand management was first elaborated in the late 1970s and throughout the 1980s when the (physical or financial) limits of infrastructure solutions became apparent. In particular, economic theories concerning pricing, metering and customer-side management were developed in the 1980s. Despite increasing interest in this subject in the 1990s, few published studies on the economic viability of large-scale policies exist.

On the scale of a particular distribution network, the economic viability of reducing, for example, leakage may be difficult to assess, given the fact that many case studies lack economic appraisal.

On the scale of an individual house, collective building or industrial site, the economic viability of saving significant quantities water can be easy to demonstrate, even when pricing policies are not implemented (several case studies are presented in this report).

2.3.3. Organisational framework

In many of the case studies presented in this report, the importance of developing sound partnerships between authorities, users and suppliers is evident. In some cases, this may be encouraged through defining standard structures, where there may, in addition, be a statutory obligation to consult all partners. The importance of including all concerned parties is illustrated by the Local Agenda 21 strategy implemented in the UK (see case study in the box below) and the development of good catchment management in the Charente (France) water resources management protocol (see Appendix, case study 51).

Local initiatives can be encouraged and then assisted by a central coordinating or advisory body. In particular, such organisations can assist in the exchange of experience and carry out research work of common interest. An example of such an organisation on a national scale is the National Water Demand Management Centre in the UK (see case study in the box below). Other local organisations set up by several partners are frequently observed, such as, for example, the advice centre in Copenhagen (see Appendix, case study 34).

Through these types of organisation, widely accepted guidelines for good practice can be drawn up. An example of this is the best practice framework developed by the UK water industry and the regulators (Environment Agency) for forecasting demand and studying the economics of demand management (UKWIR/EA, 1996).

Case studies

Sustainable water management in Local Agenda 21, UK

Local authorities in the UK are being encouraged to develop Local Agenda 21 (LA21) strategies by the year 2000, through defining LA21 comprehensive action plans (EA and LGMB, 1998). By 1998, around 70 % of the authorities were engaged in this process. Water is one of the key issues in sustainable development, and, in particular, with the prospect of an extra 4.4 million new households due to be built between 1996 and 2016 and the uncertainty of climate change, promotion of water efficiency is viewed as an important element.
A large number of partners in sustainable water management need to be consulted in developing LA21 strategies:
- water users;
- government regulators;
- water suppliers;
- facilitators (manufacturers, housebuilders);
- opinion-shapers (lobbies, associations, federations, etc.).

As well as encouraging the development of LA21 strategies, local authorities can provide a lead on water efficiency through their own way of operating; for example, through water conservation within their own premises, giving advice to tenants in authority housing, and also through their responsibility for new development plans, building regulations, etc.

National Water Demand Management Centre, UK

In 1997, the UK Environment Agency (EA) upgraded the National Water Demand Management Centre (NWDMC) in the UK, initially established in 1993 in order to reinforce its commitment to sustainable water management through the provision of specialist services. The NWDMC contributes to the EA strategy through promotion, advice, technical assistance and research.
In particular, promotion actions by the NWDMC include:
- a monthly bulletin containing discussion articles and case studies (currently at a circulation of 1 500);
- consultation reports;
- support for the regulators' contribution to the water industry's strategic business plans;
- publication of case studies;
- a web site;
- roadshow activities, for example at home exhibitions;
- research and development activities, for example on how to establish effective methods for communicating means of water conservation.

2.4. Water management: a public or a private matter?

Traditionally, the public sector has been heavily involved in the allocation and management of water, as a result of several specific characteristics of the water sector:

- water projects often involve large investments which cannot easily be provided by private companies;
- it is often necessary to impose regulations to meet the expectations of all the different users (different sectors of water use);
- public initiative is frequently necessary to face extreme events such as droughts and floods;
- water is allocated by governments to promote social redistribution;
- water, especially in regions of scarcity, has a strategic importance (regional development, national security).

Over recent years, economic considerations have become more and more important in water policies, giving more relevance to the private sector in this field (water supply and water demand management). Therefore, it is necessary to make economic decisions compatible with social objectives (efficiency and equity considerations).

Different forms of water allocation schemes attempt to combine both efficiency and equity principles. While economic efficiency is concerned with the amount of wealth that can be generated by a given resource base, equity deals with the distribution of the total wealth among the sectors and individuals of a society (Dinar et al., 1997, quoted in World Bank, 1997).

A World Bank study on water allocation mechanisms identifies several forms of water allocation, together with their major advantages and disadvantages (see Table 2.2).

Water allocation mechanisms Table 2.2.

Source: World Bank, 1997

Allocation mechanism	Definition	Advantages	Disadvantages	Example
Marginal cost pricing	Targets a price for water equal to the marginal cost of supplying the last unit of that water. Water supply charges typically include collection, transport to a treatment plant, water treatment to meet quality standards, distribution to customers and monitoring and enforcement. Water charges may also include any social costs (or benefits), although they may be more difficult to calculate.	• Avoids the tendency to underprice water • Could avert overuse because prices would rise to reflect the relative scarcity of water supplied • Can also be combined with pollution charges or taxes	• Difficulties in defining marginal cost itself as a result of problems in collecting sufficient information to estimate benefits and costs • Tends to neglect equity issues • Requires volumetric monitoring which is not always in place	IrrigationIn France, water is sold on the 'binomial tariff' basis. The Societé du Canal de Provence designs tariffs with the objective that they reflect long-run marginal capital costs and operating costs in the peak period, operating costs only in the off-peak period, and possible discharge reduction in the form of pollution fees. Thus the State subsidises 50 % of all elements of the tariff.
Public/ admini- strative allocation	The government decides which water resources can be used by the system as a whole, and allocates and distributes water within different parts of that system. The State's role is particularly strong in intersectoral allocation, as it is often the only institution that includes all users of water resources, and has jurisdiction over all sectors of water use.	• Tends to promote equity objectives, ensuring water supply to areas of insufficient quantity; the physical allocation of water among the users is independent of the charge	Prices do not represent either the cost of water supply or its value to the user Often leads to waste and misallocation of water Often does not support user participation The dominant incentive to comply is enforcement by law The structures or fees for water often do not create incentives for users to save and use it more efficiently	

Allocation mechanism	Definition	Advantages	Disadvantages	Example
Water markets	The allocation of water is referred to as an exchange of water use rights, compared to a temporary exchange of a given quantity of water between neighbouring users. Sometimes it requires the intervention of government to create the conditions necessary for markets to operate (defining water rights, creating the institutional and legal framework, investing in infrastructure to allow water transfers).	• The seller has the opportunity to increase profitability • The buyer benefits because the water market encourages increasing water availability • Empowerment of water users by requiring their consent to any reallocation of water and compensation for any water transferred • Provision of water rights tenure to the water users • Induces a shift towards improved water management and efficiency in agriculture	• Difficulties for establishing the market: measuring water, defining water rights when flows are variable, enforcing withdrawal rules, investing in conveyance systems, environmental degradation • Third-party effects have to be identified and quantified to take into account the associated costs in the exchange process (pollution, overdraft of water tables, etc.)	
User-based allocation	Irrigation: farmer-managed irrigation (by time rotation, depth of water, area of land, shares of the flow).Domestic-water supply: community wells and hand-pump systems.User-based allocation requires collective action institutions with authority to make decisions on water rights. The effect of user-based allocation depends on the content of local norms and the strength of local institutions.	• Potential flexibility to adapt water delivery patterns to meet local needs • Administrative feasibility, sustainability and political acceptability	• Requires a very transparent institutional structure • Local user-based institutions can be limited in their effectiveness for intersectoral allocation of water because they do not include all sectors of users	*Communal irrigation system* In Portugal (Vila Cova village), issues such as beginning and ending of the irrigation period, losses in canals, travel time of water, user sequence, and night turns are addressed via various arrangements that involve different community institutions.

The study highlights that no single type of allocation is optimal for all situations, and that, in practice, most countries have some combination of water allocation mechanisms.

2.5. The influence of EU policies

Compliance with EU water directives, in particular with the urban wastewater treatment directive, requires high levels of investment in EU countries.

Water systems when first installed, at the beginning of the century, were for health and welfare reasons, and the States provided subsidies to cover the necessary investment for equipment and installation. Once the initial investment phase was completed, the trend was for governments to stop subsidies to the water services sector, and to pass the costs onto the water consumers via water bills.

The proposed water framework directive takes the river basin as the basic unit for integrated water management. The directive incorporates the recovery of the costs for water services (costs of water services including environmental and resource costs). It opens the possibility to Member States to establish their priorities, taking into account the social, environmental and economic effects of the recovery, as well as the geographic and climatic conditions of the region or regions affected.

2.6. Methodology applied

Obviously, the appropriateness of measures is very much dependent on the kind of water use and the specific conditions of the water supply system. Normally, demand management programmes are a combination of various measures, comprising, for example, structural and non-structural measures or targeting various entities within the water supply system simultaneously (e.g. supply agency and end-users).

This report is concerned mainly with measures which aim to achieve efficiency increases in the medium and long run, and leaves emergency drought management programmes as a separate issue.

Throughout the report, the distinction between urban, industrial and agricultural use has been maintained, considering that water use in these three sectors varies considerably, and that water demand management programmes consequently have to be designed specifically for each sector.

Following this general introduction, the report concentrates on case studies which illustrate the different types of demand management measures available. The objective is to evaluate the potential impact of different measures in order to elaborate general guidelines for designing demand management programmes.

3. Technological approaches

3.1. Water-saving devices

3.1.1. Introduction

Higher standards of living are changing water demand patterns. This is reflected mainly in increased domestic water use, especially for personal hygiene. Most of the European population have indoor toilets, showers and/or baths for daily use. The result is that most of the urban water consumption is for domestic use.

For instance, in Spain, the urban water consumption is apportioned as follows: 70 % for household consumption, 24 % for small industries and services, and 6 % for public services (MMA, 1998).

Most of the water use in households is for toilet flushing, bathing and showering, and for washing machines and dishwashing. The proportion of water for cooking and drinking, compared with the rest of the uses, is minimal. Table 3.1 gives the patterns of water use by households in England and Wales, Finland and Switzerland.

Typical water consumption figures for 'traditional' domestic appliances are given in Table 3.2 for England and Wales, Finland, France and Germany.

Statistics show that there is a potential to improve the water efficiency of common household appliances such as toilets, taps and washing machines. Some appliances are

Table 3.1. **Patterns of water use by households in England and Wales, Finland and Switzerland**

Sources: UK Department of the Environment, 1997; Etelämäki, 1999; Swiss Organisation for Gas and Water Supply, web page.

Household uses	England and Wales (%)	Finland (%)	Switzerland (%)
Toilet flushing	33	14	33
Bathing and showering	20	29	32
Washing machines and dishwashing	14	30	16
Drinking and cooking	3	4	3
Miscellaneous	27	21	14
External use	3	2	2

Table 3.2. **Average appliance consumption in England and Wales, Finland, France and Germany**

Source: OFWAT, 1997; Etelämäki, 1999

Appliance	England and Wales	Finland	France	Germany
Toilet	9.5 l/flush	6 l/flush	9 l/flush	9 l/flush
Washing machine	80 l/cycle	74-117 l/cycle	75 l/cycle	72-90 l/cycle
Dishwasher	35 l/cycle	25 l/cycle	24 l/cycle	27-47 l/cycle
Shower	35 l/shower	60 l/shower	16 l/minute	30-50 l/shower
Bath	80 l/bath	150-200 l/bath	100 l/bath	120-150 l/bath
Water-saving appliances	No incentive for the majority of households to conserve water, but commerce and industry have invested in flush controllers for urinals, push operation taps, low-volume shower heads and devices to limit toilet flush volume	The amount of water per flush in toilets depends mainly on the construction year of the building: prior to 1976, 9 l/flush; 1976-93, 6 l/flush; 1993-96, 4 l/flush; since 1996, 2-4 l/flush	Domestic water-saving appliances are not widespread	Some municipalities have invested heavily in installing water-saving devices and increasing public awareness

Typical water-saving devices in households Table 3.3.

Sources: Fundación Ecología y Desarrollo, 1999

Equipment	Description	Water saving
Taps		
Taps with air devices	Introduction of air bubbles into the water, increasing its volume Less flow and same effect	Flow reduction of around 50 %
Taps with thermostats	They keep the selected temperature	Reduction of around 50 % of water and energy
Taps with infrared sensors	Water is available when an object is underneath	Reduction of between 70 and 80 %
Electronic taps, or taps with buttons for a timed length of flow	Water running for a limited time	
Toilets Double-command toilets	Command for 6 l/flush, command for 3 l/flush	
Water-saving devices for old equipment		
Device to mix water and air for taps	Increases the volume of water (reduction of flow)	Reduction of around 40 %
Button to interrupt toilet flush		Reduction of around 70 %
Device to limit shower flow		Reduction of between 10 and 40 %

best adapted to collective buildings such as public toilets (taps which turn off automatically); nevertheless, most are not widely used because they are expensive. Further research and development in recent years has refined these appliances and made them more accessible to the public. Some typical water-saving devices, which can be used in the home, are described in Table 3.3.

Over recent years, the EU has established conditions required for the 'ecological labelling' of dishwashers (*Official Journal of the European Communities,* 7 August 1993) and of washing machines (*Official Journal of the European Communities,* 1 August 1996). Amongst other conditions, dishwashers cannot use more than 1.85 l of water per cutlery item. Washing machines cannot use more than 15 l/kg of clothes in a cycle of 60 °C, and both types of machine must give clear instructions about water and energy saving.

In addition to regulations, new technologies also have a positive impact on the use of water by these domestic appliances, and have achieved important reductions over the last 20 years (see Figures 3.1 and 3.2).

Evolution of water used for washing machines (1970-98) Figure 3.1.

Source: Water Efficiency in Cities, International Conference, 1999.

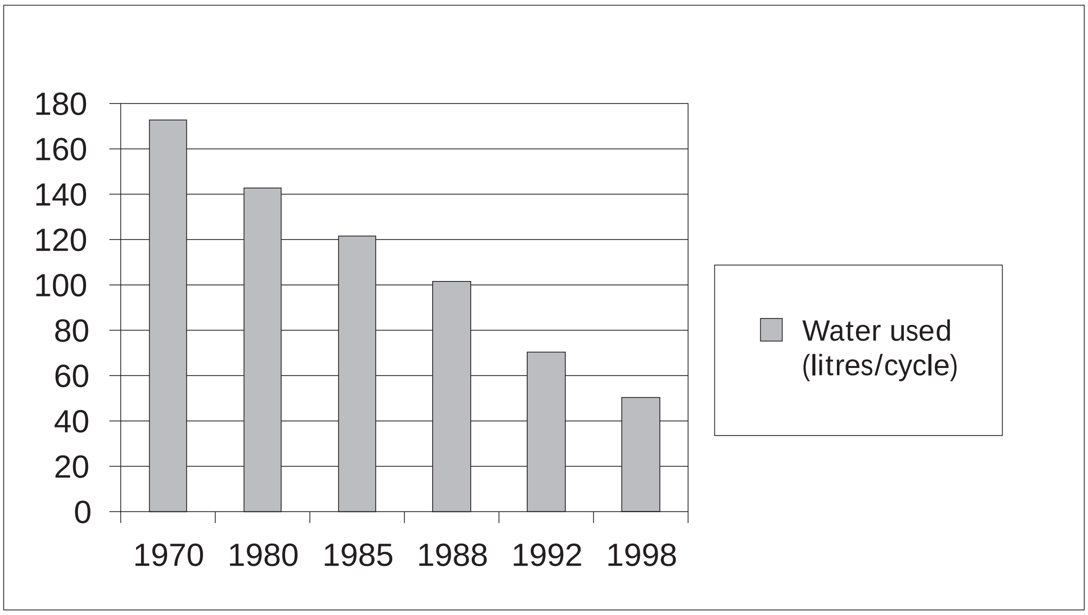
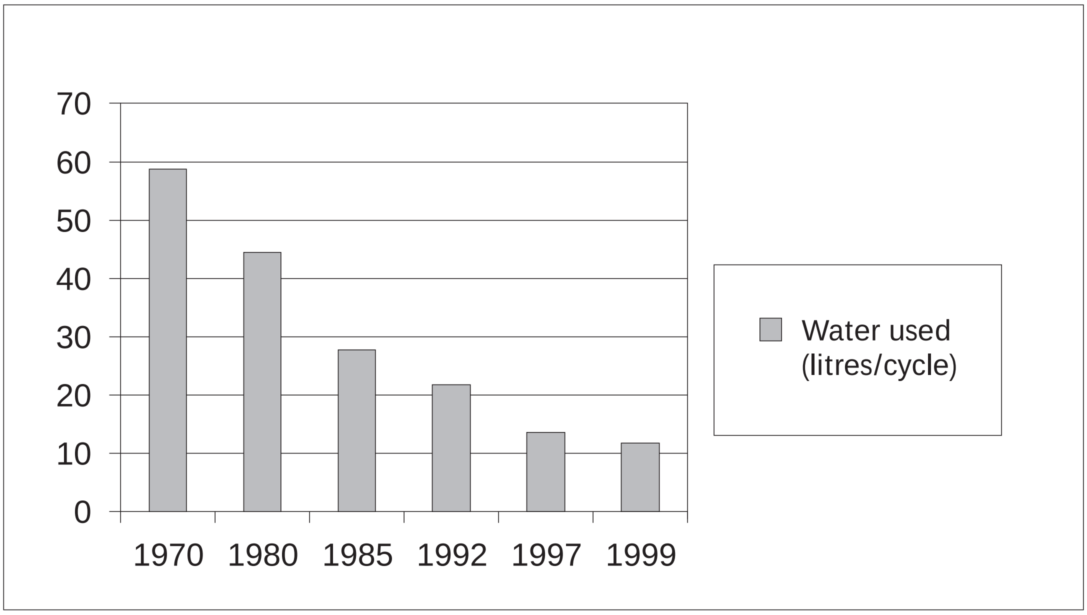


Figure 3.2. **Evolution of water used for dishwashers (1970–99)**

Source: Water Efficiency in Cities, International Conference, 1999.



However, the difficulty is often to encourage use and increase market penetration of these devices. Initiatives can include the short- or long-term renovation of buildings, such as offices, sports facilities, schools or apartment blocks, when companies or local authorities decide to integrate water efficiency as a design criterion. Increasing the market penetration of appliances in the domestic field is more difficult and requires information campaigns explaining the reasons and advantages of the new appliances, for example in terms of reduced water bills. This is obviously a long-term process, since the turnover of such appliances in individual homes is slow.

Case studies 1, 2 and 3 (see Appendix) illustrate some successful projects of this type at small and large scales.

The impact of the use of water-saving devices on water demand is different depending on the importance of household demand in relation to total urban water demand. For example, a 10–70 % reduction in household water demand in the Netherlands, with a total demand for urban use of 1 014 million m^3, 57 % of which goes to households, would result in a water reduction of between 58 and 405 million m^3 (between 6 and 40 % of the total urban demand). In the UK, with a total demand for urban use of 12 117 million m^3 of which 44 % is for household demand, the water reduction would be between 533 and 3 732 million m^3 (between 4 and 31 % of the total urban demand).

3.1.2. Main findings
Water-saving devices in households

1. Most of the water used in households is for toilet flushing (33 %) and bathing and showering (20–32 %). The lowest percentage of domestic use is for drinking and cooking (3 %).

2. Different experiences show that savings can be achieved using various water-saving devices in households, public places and industry (especially hotels and leisure centres). Nevertheless, these kinds of devices are not very widespread in households.

3. Water-saving devices on taps, and toilets with 6 l/flush, could achieve reductions in use of around 50 %.

4. It would be necessary to encourage market penetration of these devices by increasing the information for users and seeking the cooperation of producers (better information to consumers about the available technologies).

5. The impact of the use of household water-saving devices on total urban demand is different depending on the proportion of household demand in total urban demand.

3.2. Water metering

In a number of countries, domestic users are charged a flat rate. Examples include the UK, where the charge is based on the value of property, Ireland, where users pay flat rates for water through their local taxes, and Iceland, where users pay an annual fixed charge per m^2 of property plus an overall charge per property.

However, in most countries, water is metered and the charge is related in some way to the volume consumed.

The impact of the introduction of metering on water consumption is difficult to separate from other factors, in particular the water charges applied. It is also essential to have a correct balance between real water consumption and unaccounted water. Water losses are better measured if a meter is installed at the waterworks as well as at the consumer's.

However, immediate savings from the introduction of revenue-neutral metering are estimated to be about 10–25 % of consumption, and this is because of the effects of information, publicity and leakage repair, as well as the non-zero marginal pricing. Savings are also sustainable over time (Pezzey and Mill, 1998).

In case studies 4, 5, 6, 7 and 9 (see Appendix), the introduction of metering has been an important part of water demand management, accompanied by a revised charging system and regulations on leakage.

3.2.1. Main findings
Urban sector

1. Metering is an essential element in obtaining a correct balance between real water consumption and unaccounted water (water losses). Water losses are better measured if a meter is installed at the waterworks as well as at the consumer's.

2. The impact of the introduction of metering on water use is difficult to separate from other factors, in particular the water charges applied.

3. Immediate savings from the introduction of revenue-neutral metering are estimated to be about 10–25 % of consumption.

4. The introduction of metering, as part of water demand management, is usually accompanied by a revised charging system and regulations on leakage.

5. Usually, water meters have been used to determine water consumption, but in some countries, such as Denmark, meter readings will be used to calculate a pollution tax, on the basis that water consumption indicates the discharge to the sewage treatment plant.

6. In introducing water metering to new regions, there are social effects to be taken into account (effects on socially disadvantaged households which are more vulnerable to water metering and pricing – large family size, medical conditions).

3.3. Leakage reduction in distribution networks

Losses of water in the distribution network can reach high percentages of the volume introduced. The problems associated with leakage are not only related to the efficiency of the network, but also to water quality aspects (contamination of drinking water if the pressure in the distribution network is very low).

The concept of leakage covers different aspects:

- losses in the network because pipes are not properly sealed; leakage usually occurs at the pipe joints, and is particularly relevant in old and extended networks;
- losses in users' installations before the water is metered;
- undermeasurement by meters when the water flow is low (mechanical problems);
- sometimes, when some uses are not measured (e.g. public gardens, street cleaning) and are calculated by estimations, the differences are counted as losses.

The following examples of leakage estimates for different countries show big differences due to the different states of the networks, and also due to the different concepts explained above (see Table 3.4).

The UK regulator has set a mandatory leakage target for each water company in England and Wales, and there is an incentive to show that unaccounted water is actually water being used legitimately rather than leakage (Financial Times Newsletters, October 1998). In 1998/99, leakage levels reported by water companies were 22 % lower than in 1996/97 (DETR, 1999).

Table 3.4. **Estimated losses from water networks**

Sources:
(1) Mountain Unlimited, 1997
(2) WHO, 1997
(3) Mountain Unlimited, 1995
(4) PTL/IW, 1999
(5) Vangsgaard, 1997
(6) FEI, 1999
(7) OFWAT, 1997
(8) Umweltbundesamt, 2000
(9) IRSA, 1996
(10) EEA/WHO, 1999
(11) EEA, 1999
(12) MMA,1998

Country	Estimated losses (% of water supply)	Source
Albania	Up to 75	(1)
Armenia	50-55	(2)
Bulgaria (Sofia)	30-40	(3)
Bulgaria (other than Sofia)	More than 60	(3)
Croatia	30-60	(3)
Czech Republic	20-30	(4)
Denmark	4-16	(5)
Finland	15	(6)
France (national average, 1990)	30	(7)
France (Paris)	15	(7)
France (highly rural area)	32	(7)
Germany (former West Germany, 1991)	6.8	(8)
Germany (former East Germany, 1991)	15.9	(8)
Germany (average, 1991)	8.8	(8)
Hungary	30-40	(3)
Italy (national average)	15	(9)
Italy (Rome)	31	(9)
Moldova	40-60	(3)
Romania	21-40	(10)
Slovakia	27	(11)
Slovenia	40	(4)
Spain	24-34	(12)
Ukraine	Around 50	(3)
UK (England and Wales)	8.4 m^3/km mains pipe/day 243 l/property/day	(7)

In Switzerland, network losses in some communities and small suppliers are estimated to be around 30 % of water introduced. Nevertheless, in cities like Zurich, where leakage control of 40–50 % of the total distribution network length is carried out every year, losses decreased from 10 to 5 % over the last 10 years (Skarda, 1999).

Preventive maintenance and network renewal are the main factors effecting leakage of a network. The international survey for IWSA (Durban 1995) presents an average of 0.6 % of annual pipe replacement.

The present situation can be characterised by very different replacement rates of between

0.1 and 2 %. In Switzerland, the average service life of an installation is assumed to be 50 years, but new types of external and internal well-protected pipes could have a service life of 200 years. The Zurich Cantonal Water Authority recommends replacement rates of 2 % of the total distribution network length (Skarda, 1999).

There are several ways of expressing the efficiency of a distribution network. In each case, an optimal (or benchmark) performance target can be determined and the progress towards its achievement assessed.

(a) Efficiency ratio
This ratio is calculated as follows:

Efficiency ratio (%) = (metered volume/ distributed volume) x 100.

It is the simplest ratio to calculate because it only uses measured values. It compares the measured delivery volumes with the volume released into the network. However, the value of this ratio should be interpreted carefully as

Type of network	Bad (%)	Insufficient (%)	Average (%)	Good (%)
Urban	< 60	60-75	75-85	> 85
Intermediate	< 55	55-70	70-80	> 80
Rural	< 50	50-65	65-75	> 75

it cannot be used to compare different networks, since it does not take into account the total volumes involved (metered, unmetered, network maintenance). It is more useful to use this ratio to analyse trend over time for a particular network, rather than using its absolute value.

Nevertheless, it is possible to give some rough guidelines.

(b) Net efficiency ratio
This ratio is probably a better indicator and can be calculated as follows:

Net efficiency ratio (%) = ((metered volumes + unmetered authorised consumed volumes + volumes used for network maintenance)/(distributed volumes)) x 100.

This value gives a better idea of the actual leakage in the network, since it takes into account all types of water that are used (metered/unmetered/network maintenance). However, two of the expressions (unmetered volumes and network volumes) are rough estimations, which means that the indicator can be erroneous. Also, the network manager can increase the net efficiency value by inappropriate estimates of maintenance volumes (cleaning etc.).

(c) Linear leakage index
The physical state of networks can be compared by relating the lost volumes to the length of the network, where:

Linear leakage index (m^3/day/km) = losses/length of network.

The length of the network may include the total distance of pipework between the producer and the water buyers, or simply only the principal mains distribution pipes, excluding private access pipes.

An alternative expression for urban networks is l/property/day.

Estimated leakage expressed in this manner can be compared to optimal leakage (benchmark annual leakage which takes into account metered connections, base level of leakage and network pressure and its variations) to produce an international leakage index (UK Environment Agency, 1998a). The base level of leakage is the aggregation of loss sources which are individually too small to be detected by active leakage control techniques. Even if all backlog bursts have been eradicated, new bursts are always occurring and take time to become apparent, located and repaired.

(d) Linear flow index
This index can be used to evaluate the rate of use of a network and its nature:

Linear flow index (m^3/day/km) = metered volumes/length of network.

Rural areas generally have a low index (less than 10) whereas urban zones have a higher value (over 30). The index can be used to provide a context for the other indicators mentioned above (optimal efficiency and linear leakage index).

(e) Full network assessments
Many suppliers argue that a large number of factors should be taken into account in leakage performance and that simplistic indicators such as those described above may not be comparable. A full example description is given in Table 3.5 (UK Environment Agency, 1998c).

Table 3.5. **Leakage description in selected distribution units of Suez Lyonnaise des Eaux**

Source: UK Environment Agency, 1998c.

	Northumbrian Water, UK	Essex and Suffolk, UK	Dijon, France
Population	2 532 100	1 662 200	151 000
Connections	887 005	586 851	20 583
Properties	1 108 756	733 564	20 583
IMains (km)	16 294	8 250	550
Night pressure (metres head)	50	45	40
Day pressure (metres head)	40	35	40
Distribution input (million l/day)	799	498	32.5
Total losses (million l/day)	194	85	3.6
Households	1 030 278	686 200	20 324
Household use (million l/day)	364.6	269.3	23.3
Maximum yield of resources (million l/day)	2 000	540	100
Resource headroom (%)	60	8	68
Leakage measures			
l/connection/day	219	145	175
l/property/day	175	116	175
l/head/day	77	51	24
% of distribution input	24	17	11
m^3/km/day	12	10	7
Mains length/connection	18	14	27
Mains length/property	15	11	27
Measured tariff (pence/m^3)	100	110–200	120
Marginal operating cost (pence/m^3)	10	10	8
Per capita demand (l/head/day)	144	162	154
Occupancy rate (person/household)	2.5	2.4	7.4
Occupancy rate (person/connection)	2.9	2.8	7.3

Although drinking water is a ready-to-use product and may be costly to produce if extensive treatment is required, leakage reduction is not always economically viable. Increasing production to ‘feed leaks’ may be cheaper than extensive pipe repairs. For further examples, see case studies 8 to 11 in the Appendix.

3.3.1. Main findings

Technological approaches

1. Maintenance and network renewal is one of the main elements of any efficient water management policy. Losses in the water distribution network can reach high percentages of the volume introduced. Leakage covers different aspects: losses in the network because of deficient sealing, losses in user installations before the water is metered, and sometimes the consumption differences between quantities used (measured) and those not measured are also counted as losses. Leakage figures from different countries indicate not only the different states of the networks, but also the different aspects included in the calculations (e.g. Albania up to 75 %, Croatia 30–60 %, Czech Republic 20–30 %, France 30 %, and Spain 24–34 %).

2. It is possible to use different indices to express the efficiency of a distribution network.

   Efficiency ratio: this uses only measured values and compares the measured delivery volumes with the volume released into the network, but it does not take into account the total volumes involved (it is not used to compare different networks).

   Net efficiency ratio: this takes into account all types of water uses (measured, unmeasured and maintenance). It can be erroneous if there is an inappropriate use of maintenance volumes, which increase the net efficiency value.

Linear leakage index: the physical state of networks can be compared by relating the lost volumes to the length of the network.

Linear flow index: this can evaluate the rate of use of a network and its nature. Rural areas generally have a low index (less than 10) whereas urban zones have a higher value (over 30).

3. Many suppliers argue that a large number of factors should be taken into account in leakage performance and that the indicators described may not be comparable.

4. Generally, network meters are considered necessary to enable good network management.

5. For most rural municipalities, distribution network maintenance is not a priority (lack of regular monitoring, network plans). This situation coincides with a price of water which is lower than the national average and also with a lack of a general use of domestic meters.

6. Tracing and repairing leakage can be very expensive. Increasing water production to feed leaks may prove cheaper in some systems. The consequence is that local authorities may decide not to trace leakage despite low efficiency ratios but continue their wasteful use of water.

3.4. New technologies: changing processes

3.4.1. Industry

Until now, a lot of emphasis has been put on reducing energy use in the industrial sector to reduce costs. It was only during the 1990s that improving water efficiency also began to be considered as a way of cutting costs. Actions to improve water efficiency are focused on the process and on the discharges (see Figure 3.3).

In a study carried out between 1992 and 1997 in the industrial sector of Catalonia, the Institute of Energy (Catalonia, Spain) found that around 35 % of the proposed cost-saving measures were implemented in areas of management and control, 32 % in the process and just 18 % in the reuse of effluents (see Figure 3.4).

Evolution of water demand for the industrial sector in different water supply companies, Catalonia, Spain (1991–95)

Figure 3.3.

Source: ICAEN, 1999.

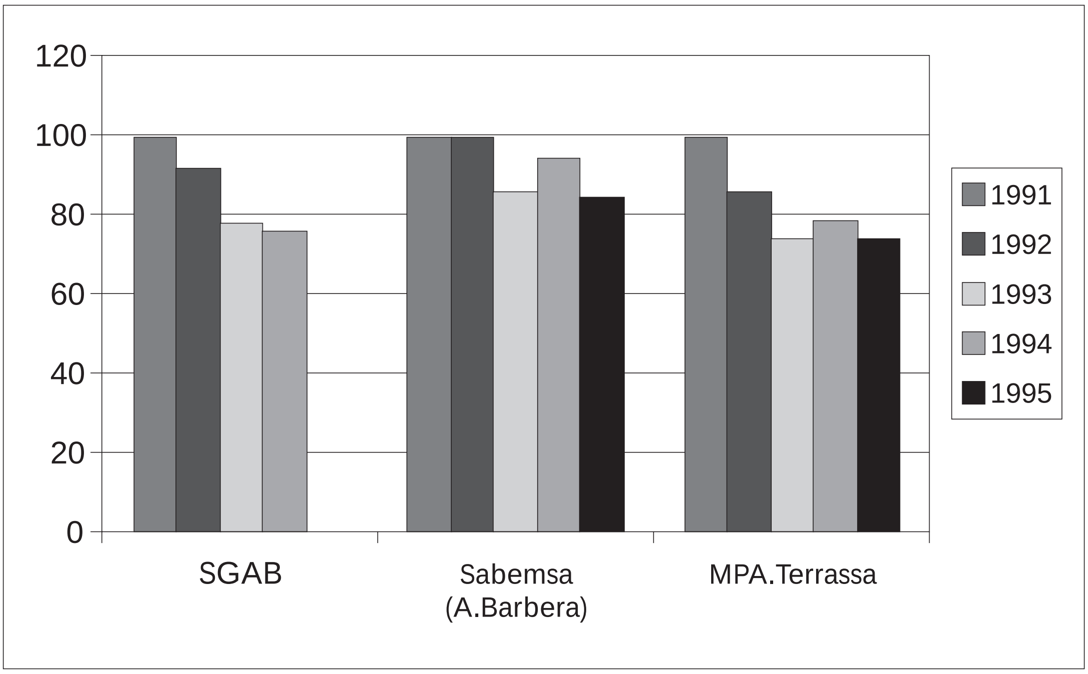


Figure 3.4. **Percentage of water-saving measures implemented, depending on the technology**

Source: ICAEN, 1999.

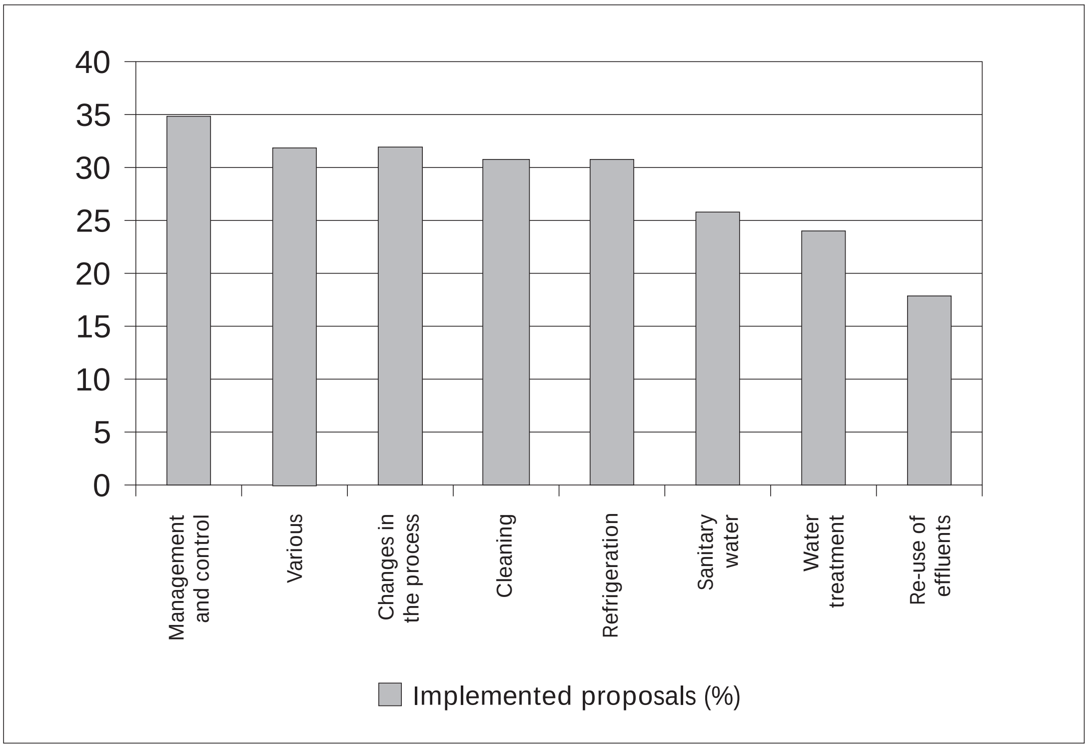
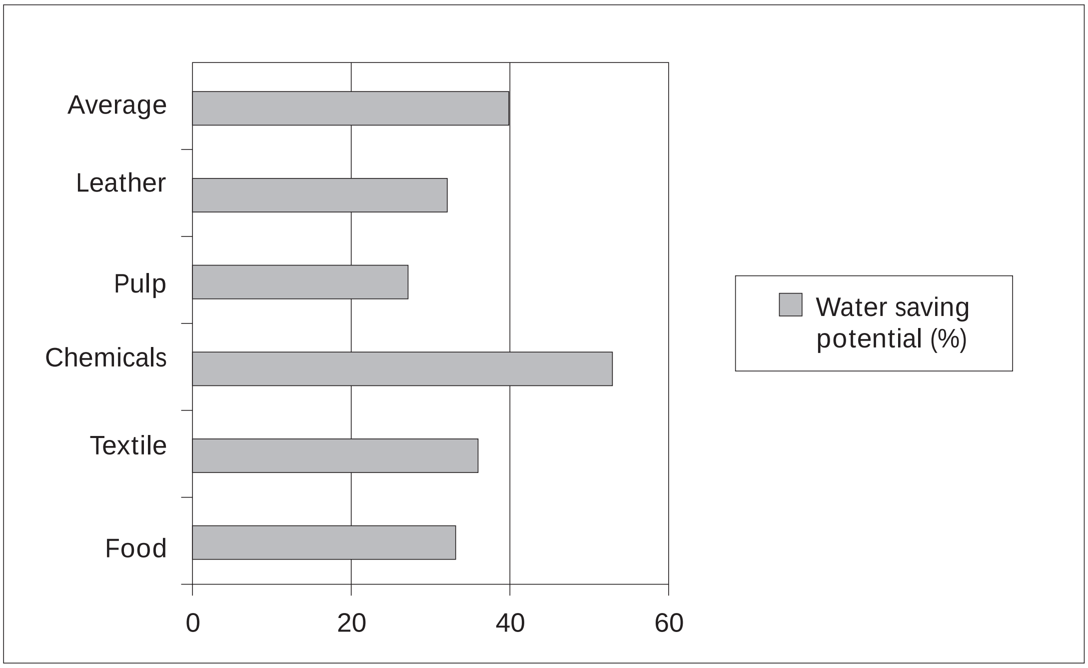


Figure 3.5. **Potential water saving in different industrial sectors**

Source: ICAEN, 1999.



By implementing water-saving measures, the amount of water saved varies depending on the industrial sector. Following a study carried out by the same institute in 1999, the range of potential water saving is from around 25 % to more than 50 % (see Figure 3.5).

For more information, see case studies 12 to 22 in the Appendix.

3.4.2. Agriculture

The main water use within the agricultural sector is for irrigation, with minor contributions to water demand by livestock-farming and fish-farming. Irrigation is the subject of this section, even though in certain areas livestock watering can also represent a significant demand. This latter issue is illustrated by a case study of water savings achieved in the large number of dairies in Brittany in France (see Appendix, case study 27).

(a) Efficient irrigation equipment
Irrigation has a different role in European agriculture, depending above all on the climate of the country considered. The major part of irrigated land in Europe is located in the south of Spain, Italy, France, Greece and Portugal, accounting for 85 % of the total irrigated area in the EU (EEA, 1999).

Consideration of the efficiency of the irrigation systems (e.g. storage, transport, distribution and irrigation equipment) is essential for any policy related to water use efficiency.

Major differences exist among irrigation systems between modern schemes (e.g. drip and sprinkler) and traditional systems (e.g. gravity irrigation). A survey of 39 Spanish irrigation schemes with a total irrigated area of over 82 000 ha indicated that the average efficiency in gravity schemes was below 60 %, compared to around 80 % in pressure irrigation systems (CEDEX, 1992). Within this overall value, which is calculated from the conveyance, distribution and application efficiencies, about 85–90 % corresponds to the conveyance efficiency in concrete-lined canals, which are normally found in pressure and in gravity irrigation systems (CEDEX, 1992).

Global efficiency of irrigation systems (Luján, 1991)

To estimate the global efficiency of each irrigation system, three different efficiencies are considered: conveyance, distribution and application efficiency.

Conveyance efficiency refers to losses of water from the point of abstraction to the distribution network.

Distribution efficiency refers to the water received in the distribution network and the losses that take place until the water reaches the irrigation units.

Application efficiency refers to losses in the irrigation units.

Global efficiency can be expressed as the product of the individual efficiencies.

A way of improving water use efficiency in agriculture would be to transform irrigation schemes from gravity into pressurised systems, a policy which is partly being applied in countries which have a major share of traditional schemes. However, the approximate cost of implementing pressure irrigation is of the order of EUR 10 000/ha, an amount that frequently surpasses the productive capacity of the respective areas.

In eastern Europe, the sprinkler is the most extensively used irrigation method, but because of recent economic problems, there is no control and maintenance and some of the schemes have been abandoned. Farmers do not have the large investment resources for new irrigation equipment (see Appendix, case studies 23, 24, 25 and 26).

Irrigation methods in some Mediterranean countries

Cyprus

The irrigation network in Cyprus consists of closed systems with an overall conveyance efficiency averaging 90–95 %. Field application efficiency averages 80–90 %. In parallel with the government's effort to increase the water available for agriculture, emphasis was placed on the optimum utilisation of water through improved irrigation methods. To encourage farmers to use these methods, the government offered incentives to participating farmers in the form of subsidies and long-term low-interest loans for the purchase and installation of improved irrigation systems. In addition, through extensive demonstrations, the government convinced the farmers that improved irrigation methods, initially sprinklers for vegetables and the hose/basin method for tree crops, to be followed by micro-irrigation systems, not only saved water but also led to increased yields. As a result, the area irrigated by surface irrigation methods decreased from about 13 400 ha in 1974 to less than 2 000 ha in 1995, while the area equipped for micro-irrigation increased over the same period from about 2 700 ha to almost 35 600 ha. The areas irrigated by surface irrigation methods are mostly cropped with deciduous trees and are found in the hilly areas of the country. The cost of irrigation development varies and depends on a number of factors. The average cost of irrigation development using tube wells varies from about EUR 3 890/ha for up to 1 ha, EUR 2 237/ha for 2 ha to EUR 1 683/ha for 3 ha. This includes the cost of on-farm micro-irrigation systems. Excluding the cost of the dam, the development of surface water varies from EUR 1 544/ha to EUR 2 584/ha including on-farm micro-irrigation systems. The average annual cost of maintenance varies from EUR 297–347/ha for private schemes (tube wells) to EUR 49–119/ha for public schemes (FAO, 1997).

Malta

Of a total managed area of 763 ha, it is estimated that 500 ha are equipped with micro-irrigation systems and 150 ha with sprinkler irrigation systems, while surface irrigation is carried out on the remaining 113 ha. The cost of irrigation development is approximately EUR 1 584/ha for micro-irrigation, while the operation and maintenance costs are about EUR 792/ha/year. Through a more efficient use of water by means of micro-irrigation, there is potential for an expansion in irrigated areas. The government is assisting farmers financially in buying irrigation equipment by offering grants and subsidising interest rates under the financial assistance policy (FAO, 1997).

Spain

Irrigated agriculture accounts for 56 % of total agricultural production, occupying only 18 % of the total agricultural surface (EEA, 1999). In all, 41 % of the irrigation uses modern equipment (pressurised systems), the most extended system being gravity irrigation (a network of open channels convey the water to the irrigated land), designed to provide water in periods of maximum needs (MAPA, 1998).

The size of the irrigated properties has to be taken into account when assessing the economic possibility of introducing modern irrigation techniques and equipment. For instance, Spain, which has an average farm size of 18 ha, is facing restructuring to concentrate properties, where possible, to allow the introduction of more efficient equipment (MAPA, 1998).

3.4.3. Main findings

(a) Industry

1. The introduction of water-saving technologies in the industrial sector is focused basically on the most common processes: cooling and washing.

2. Water substitution means immediate savings for an industry (cost savings correspond to the drop in water charges, especially if the substitution did not imply additional investment).

3. Improving the control of process conditions can reduce water consumption by about 50 %.

4. Work in closed circuits can reduce water use by about 90 %.

5. A reduction in the cost of the existing water-saving technologies could encourage further extension to small industries.

6. Better communication between industries with high water consumption may help to disseminate pilot project results on water-saving technologies.

(b) Agriculture

1. The main water use within the agricultural sector is for irrigation, with minor use by livestock-farming and fish-farming.

2. National policies to encourage the modernisation or substitution of traditional irrigation methods are in place in Mediterranean countries.

3. In some Mediterranean countries, policies include plans to increase the size of properties to allow the possibility of introducing modern irrigation techniques.

4. The cost of modernisation of existing irrigation methods (gravity) into pressurised methods depends on several factors and often surpasses the productive capacity.

5. Governments often offer financial incentives or direct subsidies to farmers for changing irrigation equipment.

4. Economic approaches

4.1. Water charges

Water charges are based on different policies, depending on the different availability of water resources (at national or regional level).

This complexity makes the assessment of the influence of water price on the reduction on water demand problematic. It also makes the comparison of water prices between different countries difficult. The complexity relates to the different concepts included in water bills (tariff structures and charging methods), and to the different national water management systems.

In general, water bill composition over the last few years has depended on the development of water policies, in particular in relation to the implementation of European directives.

Components of water bills usually include a part related to the water supply service (e.g. drinking water service, water treatment, and network maintenance) and other parts relate to other institutions (e.g. treatment tax, collection system and other taxes). Examples are given in Table 4.1 (France), Table 4.2 (Spain), Tables 4.3 and 4.4 (Slovenia), and Table 4.5 (Switzerland).

Table 4.1. **Structure of average water bills in France, in FRF * (average water bills for a typical consumption of 120 m³/household/year)**

Source: Financial Times Newsletters, 1999.

Component	1991	1992	1993	1994	1995	1996	1997
Water distribution	654	685	731	765	793	822	842
Resource preservation	12	18	20	26	31	32	33
Wastewater treatment	389	424	477	525	555	585	614
Pollution charges	83	134	165	220	253	284	291
Taxes and para-taxes	91	107	130	153	167	187	194
Total	1 229	1 368	1 523	1 689	1 799	1 910	1 974

* January 1999: FRF 6.559 = EUR 1.

Table 4.2. **Structure of average water bills, for domestic use in Spain (average water bills for a typical consumption of 100 m³/year)**

Source: MMA, 1998.

Component	Water prices for different town sizes (price per m³, in ESP *)				Average 1992	Average 1994
	20 000–50 000	50 000–100 000	>100 000	Metropolitan areas		
Drinking water service	77	149	76	66	68	94
Wastewater treatment	—	19	37	36	17	32
Wastewater collection network maintenance	27	35	19	16	16	23
Meter maintenance	8	11	7	4	7	8
Total (water supply company activities)	88	164	107	123	81	115
Wastewater charges	73	30	23	39	29	47
Wastewater collection charge	28	16	22	17	28	23
Other charges	5	5	10	8	5	7
Total (other institutions)	96	40	44	86	37	65
Total	161	197	146	209	113	168

* December 1998: ESP 166.753 = EUR 1.

In France, the water price increase has been slowing down over recent years. The average water bill rose by 3.3 % in 1997, compared with rises of 11.3 % in 1992 and 1993. The rise during the whole period 1991–97 was 61 %. The average price was FRF 16.45/m^3 in 1997, but actual prices per m^3 varied from FRF 4.80 to FRF 33.57. This meant that the ratio of the most expensive to the cheapest was 7:1. In towns between 50 000 and 100 000 inhabitants, the water price increased by 65.3 % (1991–97), and, in towns over 100 000 inhabitants (excluding Paris), the increase was 51.5 % (below average) for the same period.

There was a major increase in the price of water in Spain between 1992 and 1994, with a relatively higher increase in the activities related to wastewater treatment, and the wastewater collection charge. Nevertheless, there is a great regional difference between prices, due to the different concepts included in water bills and also the different water management systems. For 1998, the highest prices were found in the islands (Canary Islands, ESP 406/m^3; Balearic Islands, ESP 289/m^3) and in the Mediterranean coastal area (Murcia, ESP 362/m^3), and the lowest in the northern regions (Galicia, ESP 108/m^3). For the same year (1998), the average price of urban water in Spain was ESP 229/m^3 (INE, 1998).

In 1996, the average water price per m^3 for drinking water in Slovenia was EUR 0.29 (SIT 50) (Habitat II, 1996).

Water price structure for Rizana Vodovod (regional public supply service for the Slovenian coastal region), Slovenia Table 4.3.

Component	Proportion in the total price (%)	Price per m^3 (SIT) *	Paid to
Water	39.5	145.95	Rizana drinking water supply service
Basic tax 1	2.0	7.33	State
Water return price	1.7	6.3	State
Wastewater collection and treatment	47.2	174.28	Sewage collection service
Basic tax 2	3.1	11.34	State
General tax for water pollution	6.5	23.80	State
Total		369.00	

* March 1998: SIT 179 = EUR 1.

Source: Institucionalna ureditev vodnega gospodarstva v Sloveniji, Vertikalno poro ilo, Vodnogospodarski Institute, 1998.

Water prices for drinking water, Slovenia (1995) Table 4.4.

Sector	Average price (minimum, maximum) (SIT/m^3) *
Drinking water supply (1995)	
Domestic use	46.44 (14.70, 121.44)
Profit-making users (e.g. industry, small business)	88.68 (25.55, 215.50)
Social, public services (e.g. health care, education)	69.91 (34.33, 161.30)
Others	82.75 (17.94, 215.50)
Sewage water collection and treatment ** (1996)	
Domestic use	14.39 (1.44, 56.08)
Profit-making users (industry, small businesses, etc.)	28.16 (4.42, 129.38)
Others	29.92 (4.42, 75.90)

* March 1998: SIT 179 = EUR 1.
** The charges on sewage water collection and treatment are based on water quantities supplied from the public network.

Source: Slovenian Ministry of the Environment and Physical Planning (1996): Sanacija komunalne infrastrukture in izhodišca za urejanje prostora, II faza, Water Management Institute, C-565, 1996.

Table 4.5. **Water bill structure in Zurich, Switzerland**

Source: Skarda, 1999.

Component	Nature	Price (CHF) *
Drinking water		
Yearly basic fee	Based on the insurance sum of the building value	0.024 %
Yearly basic fee	Based on the size of the water meter	e.g. water meter 1 m^3 = CHF 50 2 m^3 = CHF 100 3 m^3 = CHF 150
Consumption price	Price for 1 m^3 of water delivered	CHF 1.45/m^3
Wastewater		
Yearly basic fee	Based on the size of the water meter	e.g. water meter 1 m^3 = CHF 50 2 m^3 = CHF 100 3 m^3 = CHF 150
Rainwater	Based on the size of the property	CHF 1.60/m^2
Consumption price	Price for 1 m^3 of the water drained off	CHF 2.25/m^3

* January 1999: CHF 1.607 = EUR 1.

Example of an annual water bill, Zurich (Skarda, 1999)

		DW	WW	**Total**
Size of water meter: 3 m^3	Basic fee	150	150	
Insurance on property: CHF 1 million	Basic fee	240		
Water used: 200 m^3/year	Collection price	450		
Size of property: 1 000 m^2	Rainwater collection		1 600	
	Total	680	2 200	**2 880**

The average price per m^3 of water in Switzerland in 1996 was CHF 1.5 (Swiss Organisation for Gas and Water Supply, web page).

In Italy, a recent report on water tariffs by the consumer body Federconsumatori (Financial Times Newsletters, March 1999) indicated that, in most cases, consumers are charged value added tax (VAT) on their clean-water use, but not on their wastewater and sewage services. In Milan, people have been paying for wastewater services since 1996, but no treatment plants are yet operational. Overall, water prices increased by 8 % between 1995 and 1996, by 1.7 % in 1998, and are expected to increase by 11.2 % in the year 2000 because of a mechanism introduced by the government awaiting the enactment of Law No 36/94 (known as the Galli Law). Until the Galli Law becomes operational, prices will be based on a low-use tariff, intended to allow universal access to basic services, with prices increasing sharply with consumption. But the concept of universal access is different for different areas: in Forli, the lowest water price applies for 60 m^3/year; in Turin, the allowance rises to 100 m^3/year; in Milan, it is 128 m^3/year. Tariffs for basic consumption vary from ITL 182/m^3 in Milan to ITL 1 060/m^3 in Forli.

In general, users can see the inclusion of different components or aspects into water bills as a way of paying more taxes not necessarily related to the water used, especially if the new taxes are calculated for a fixed quantity of water. It would be necessary to separate clearly the components included in the water bill, and the charges and taxes included should be related to the water cycle.

Table 4.6 summarises the system of water charges and taxes related to water management for different European countries.

Water charges and taxes for water management Table 4.6.

Country	Year	Type	Level	Payer	Nature	Comments	Source
Austria		Drinking water charge	Local admini-stration		On a volumetric basis		OECD, 1995 **
		Waste-water fee	Local admini-stration				OECD, 1995 **
		No pollution charges				For discharging into natural waters	OECD, 1995 **
		No resource costs to any user for taking surface- or groundwat er		Any user			OECD, 1995 **
		Sewerage and wastewater charges	Local admini-stration	User	Charges reflect the full capital and operational cost to the municipality of providing the water services	There is no nationallyuniform method forsetting the charges (i.e. Salzburg charges are related to the area of the dwelling, hotels are charged per bed, restaurants per seat)	OECD, 1995 **
Belgium	1994, 1996	Abstraction charge	Flanders, Wallonia		BEF 3/m^3 for groundwater, for drinking water (passed on to consumers at BEF 4/m^3 to cover losses), for other purposes when abstraction > 100 000 m^3		OECD, 1998a **
		Waste-water charge	Water companies, three regions		For households, based on water consumption (Brussels: BEF 14/m^3, Wallonia: BEF 16/m^3, Flanders: BEF 25/m^3). Industrial discharges pay per m^3 of effluent discharged, at a rate that varies with the pollution content	Used in all three regions to finance the construction of water treatment infrastructure	OECD, 1998a **
		Drinking water charge	Water companies, three regions	User		Flanders: price is a fixed charge, a zero charge for the first 15 m^3/person in the household and a volumetric charge of BEF 35-38/m^3 (1997)	OECD, 1998a **

Source: ETC/IW, 1999, from different sources.

* **Source:** Referred to in Water resources and uses in the Mediterranean countries: figures and facts (Margat and Vallée, 1998).

** **Source:** OECD Environmental Performance Reviews

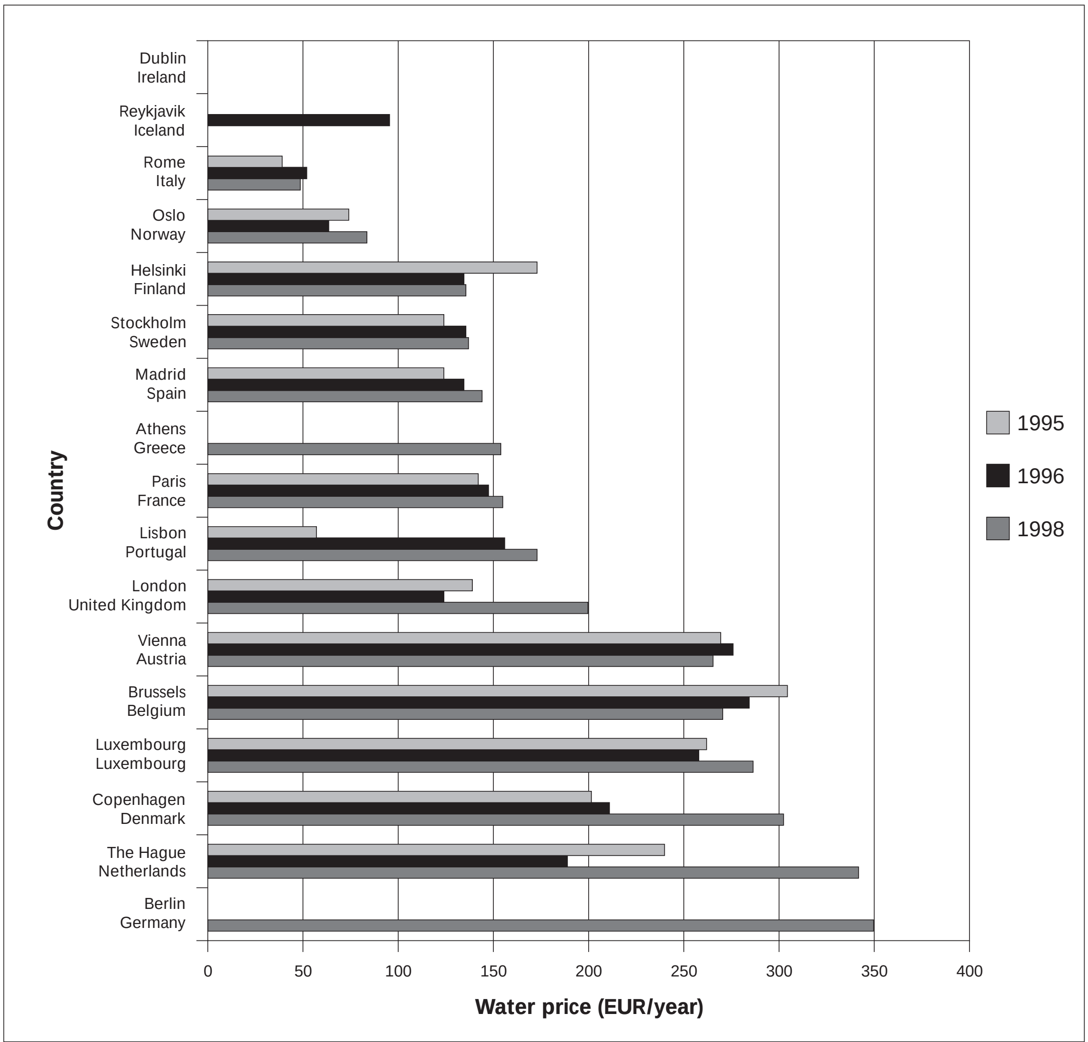
Country	Year	Type	Level	Payer	Nature	Comments	Source
Finland	1995	Drinking water charge	Munici-pality	User	FIM 4.94/m^3 (average)	The average annual investment in public water supply and sewage collection in the early 1990s was about FIM 1.8 billion	OECD, 1997b **; FEI, 2000
		Wastewater charge	Munici-pality	User	FIM 7.84/m^3 (average)	The wastewater fee is directly connected to the water use even if the fee is a separate one	OECD, 1997b **; FEI, 2000
France	1964	Pollution levy	Water agencies	Munici-pality, indu-stry	On measured or estimated quantity of substances discharged (decided by the Basin Committee)	Revenue: FRF 9.4 billion (1995), redistributed to industries, regional authorities and farmers	OECD, 1997a *
		Withdrawal levy	Water agencies	User	On net and raw volume withdrawn		OECD, 1997a *
		Taxes on water used	State	User	On volume used	FRF 833 million (1992) for FNDAE (Fonds National pour le Développement des Adductions d'Eau, Ministère d'Agriculture et la Pêche)	OECD, 1997a *
Germany	Diffe-rent	Ground-water abstraction charge	Federal states (Länder)	Public water-works and indu-stry	Volumetric basis (DEM 0.03-1.1/m^3)	There are big differences between charges in the federal states. Some states have not introduced these charges. A high amount of the charges is used for water protection measures	Umwelt bundes-amt, 2000
		Surface water abstraction charges	Federal states (Länder)	Every user	Volumetric basis (DEM 0.01-0.07/m^3)		Umwelt bundes-amt, 2000
		Waste-water charge	State: the charge shall be levied by the federal states (Länder)	Muni-cipali-ties, indu-stry (dis-char-ger)	The charge is based on the concentration of certain pollutants and on toxic units (noxious substances and groups of noxious substances	The charges increased in several steps (from 1981) up to DEM 70/unit (1997). They have to be used for water protection measures	Umwelt bundes-amt, 2000
Greece		Waste-water charge with sanitation fee	Local water and sewerage company	House hold	Based on volume in big properties or contractual price	Insufficient to finance wastewater treatment, cover operation costs in big towns	Margat and Vallée, 1998
Hungary		Drinking water charges	Private water supply companies	User		Price rose from HUF 0.6 (1980) to HUF 70 (1998)	PTL/IW, 1999
		Water and sewerage charges					PTL/IW, 1999

Country	Year	Type	Level	Payer	Nature	Comments	Source
Italy		Waste-water tax	Local water company	User	On volume and water quality	Partially finance the collection and treatment	OECD, 1994 *
		Tax on polluted discharges into the environ-ment	Local water company	Pollut-ing firm	On quantity of pollutants, weight	Partially finance the compensation of damages	OECD, 1994 *
Malta		Sanitation fee	Local admini-stration		Based on volume	To cover the sanitation and treatment systems for wastewaters	CMMD, 1997 *
Norway						There is no natural resources pricing and wastewater treatment is subsidised	OECD, 1993a **
Portugal		Drinking water charge					OECD, 1993b **
Slovenia	1995	Drinking water charge	Regional and local services	User	Different, depending of the regions and sectors		PTL/IW, 1999
	1995	Water pollution fees	Munici-palities		Based on quality and quantity of discharges. The tax is proportional to the pollution loads of the wastewater	To cover investment and operating costs for technology and reducing pollution loads of effluents to permitted levels	PTL/IW, 1999
		General tax for water pollution	State			A company offering a sanitation plan to reduce polluting discharges may be exempted from the tax if it spends the money on the proposed activities	PTL/IW, 1999
Spain		Water pollution fee on discharges into rivers	Central	Munici-pality, indu-stry	On polluting substances and tariff units for permit holders	Expected 1992 revenue: ESP 5.9 billion but collection is limited (42 %)	OECD, 1997c *
		Waste-water charges	Regional (eight regions)	Munici-pality, indu-stry	Based on estimated discharges into the natural waters	To cover wastewater treatment	OECD, 1997c *
		Municipal sewage service charge	Household, industry		Charges may take into account pollutant concentrations, but are often based on volume only for both households and industry	To cover sewage and wastewater treatment	OECD, 1997c *
		Drinking water charge	Local water company	User	Charges per m3 in a two-tier pricing system that covers pumping and treatment costs and part of capital costs		OECD, 1997c *

Country	Year	Type	Level	Payer	Nature	Comments	Source
Sweden		Tax for collection and treatment of wastewater	Local administration	User, industry			OECD, 1996 **
Switzerland		No special charge for the discharge of wastewater					OECD, 1998b **
		No charges for water abstraction, there is just an authorisation	Cantonal or local administration				OECD, 1998b **
		Tax for collection and treatment of wastewater		User (per residence)	Calculated by reference to parameters such as surface area and drinking water consumption		OECD, 1998b **

Figure 4.1. **Annual water charges in selected European cities (for a family living in a house using 200 m^3/year)**

Sources: IWSA, 1995; IWSA, 1997; IWSA, 1999.



NB: Year 1995, EUR as per May 1995.
Year 1996, EUR as per June 1996.
Year 1998, EUR as per June 1998.

According to the figures shown in Figure 4.1, for a family living in a house using 200 m^3 of water per year, Germany has the highest water charges in Europe (EUR 350.16), followed by the Netherlands (EUR 344.35), and Denmark (EUR 303.57). Italy (EUR 49.62) and Norway (EUR 84.83) have the lowest.

Nevertheless, when assessing these figures, it is necessary to consider that the components and aspects contributing to them can be very different and thus make comparisons difficult and sometimes misleading. Data and information that take all the factors into account are not available.

Among the components making up the final water price, taxes and fees on water abstraction can be important. For example, in Denmark, a water supply tax was instituted in 1994 as part of an ecological tax reform; it has been continually increasing and went from DKK 1/m^3 in 1994 to DKK 5/m^3 in 1998. Most of the German *Länder* charge is for water abstraction fees which vary greatly in their form and rate structure. They vary from DEM 0.03/m^3 in Saxony to DEM 0.60/m^3 in Berlin (Kraemer et al., 1998).

Water prices are also influenced by the quality of the water supplied. The quality of water delivered to the user, the state of the supply network and the quality of customer service must be considered in order to arrive at a comprehensive judgment on the overall price (Kraemer et al., 1998).

4.2. Urban sector

Essential elements of water demand management programmes in the urban context are measures dealing with economic incentives. Price structures are generally fixed at municipal level and can vary widely within a country. The differences, in general, take into account different types of users (e.g. domestic, industrial and agricultural), and tend to reflect differences in cost structures.

Water charges are determined by a number of different factors (e.g. availability, treatment costs, social and political factors). Many studies have been carried out to analyse the effect of water price on domestic water use. However, there are few large-scale case studies where it is possible to prove that an increase in the water price has reduced water use by a known percentage (see Appendix, case studies 28, 30 and 31).

In the first part of this section, the different types of tariffs, their supposed effects and the measurement of their effects (elasticity) are discussed. Subsequently, case studies are presented which illustrate specific aspects of pricing structures.

4.2.1. Effects of tariff structure

There is a huge variety in the types of metered tariff which can be used (Pezzey and Mill, 1998). The main types of tariff structure (excluding the initial connection charge) are:

- flat-rate tariff;
- uniform volumetric tariff;
- two-part or binomial tariff (sum of a flat-rate tariff and a uniform volumetric tariff);
- block tariffs, which also usually incorporate a flat-rate charge, plus declining block tariffs and rising block tariffs.

Frequently, tariffs include a basic allowance (charged at zero or a low rate) to allow for equity concerns. A minimum charge for a volume consumed can also be applied. The same or different tariffs may apply to different types of user. Rates and thresholds may vary over time, according to customer characteristics (property value or income) or location.

Two-part, rising block and declining block tariffs are widespread. The two former types are gaining ground due to a general shift of opinion away from consideration of water supply as a public service to its use as a commodity with a correct price. Seasonal tariffs (summer/winter) are uncommon, but are becoming more widespread. Peak tariffs (hourly or daily) have only been tested in experiments.

Rising block tariffs, where successive blocks of water are sold at a higher price, exist in Italy, Portugal and Spain. In Spain, there is a large diversity of tariff structures, but most involve increasing block tariffs. In addition, a connection charge may be levied separately, as is the case in Denmark, Finland, France, Greece, the Netherlands, Norway, Spain and the UK.

The existence of a connection charge, stabilised to cover one part of the fixed cost of the suppliers, is independent of water consumption, and has the result that the water of low-volume consumers is more expensive per litre than that of high-volume consumers.

At the same time, it is necessary to take into account the basis of calculation of the block tariffs. If the calculation is on a unit household basis, without taking into account the number of people in the household, the water price per capita will be higher for families with more members.

Sometimes, sewerage services are not charged separately from water services, and, even where they are separately identified in the bill, they are often simply calculated as a percentage of the water bill (e.g. Ireland and Poland) (OECD, 1998c).

Tariffs may be designed with several aims, which may in some cases be in conflict:

- efficiency (maximum net benefit for society);
- raising revenue to cover the costs of supply in a fair and equitable way;
- reducing environmental costs (abstraction and pollution);
- understandable for customers and applicable for administration purposes.

In fact, improving the fairness or efficiency of a tariff often makes it more complex and more difficult to understand.

4.2.2. Price elasticity

The usual economic measure to describe the sensitivity of demand towards price changes is elasticity. This is the percentage change in consumption caused by a 1 % increase in price. Therefore, a 1 % fall in consumption gives an elasticity of – 1.0. Many studies of elasticity have been carried out (often in the United States) and have recorded wide ranges of values, usually from – 0.1 to – 1.0, but in some cases even higher (more negative). In all cases, the response is greater in the long term than in the short term, since in the first periods, leaks are fixed, habits adapt and more efficient water-saving devices are progressively installed.

In practice, there are many methodological problems associated with studying this relationship. One of the main problems is that water consumption patterns are influenced by a great number of factors (e.g. network repairs/pressure variations, information campaigns and climate variations), making it very difficult to isolate price as the main factor explaining the variation of water uses.

From this, it has been concluded that water price is difficult to use as a demand management tool. However, increased tariffs are often considered a useful tool to make users more responsible for their water use, when applied in conjunction with other water conservation advice and techniques.

In Hungary, water use and water supply are in close reverse correlation with the price of water. Figure 4.2 shows the relation between water prices and water supply in the last 18 years in this country (PTL/IW, 1999).

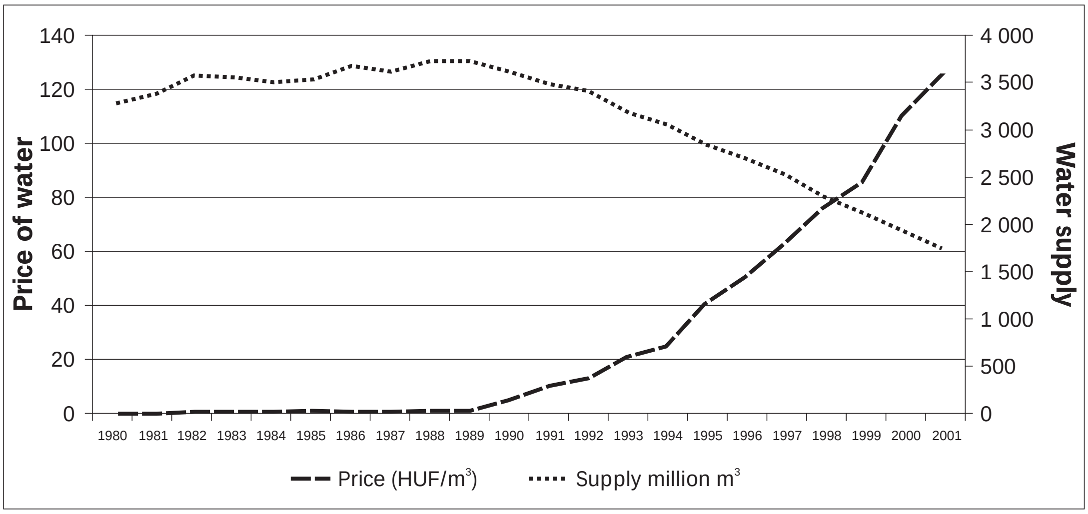
From Figure 4.2, it is possible to state that drastic price rises of drinking water can cause considerable water savings. The price of 1 m^3 of water in 1980 was HUF 0.6, and in 1998 it was HUF 70. Over this period, water supply decreased from 3 300 million m^3 to 2 300 million m^3/year, which equates to 30 % less supply and use.

4.2.3. Socially acceptable tariffs

When addressing water tariffs, it is necessary to take into account vulnerable customers who may have difficulties in paying for the water used for essential purposes, since it is generally recognised that no one should have to compromise personal hygiene and health in order to be able to pay the water bill. For example, the proposed water framework directive requires an affordable price to guarantee a basic level of domestic water supply (Article 12a) (see Appendix, case study 30).

Disconnection or the introduction of flow reduction devices are practices used by some water companies when customers fail to pay their bills. Different policies are established by governments to palliate this problem: free water for schools and hospitals; grants from the local authorities for vulnerable customers. They establish at the same time mechanisms to allow suppliers to recover the money (e.g. debt retrieval through the courts or through attachment of earning orders).

In the UK, disconnection rates fell from 21 000 a year in 1989 to 640 by the end of 1998. Recently, the UK Government has ended the right of water companies to cut off supplies to non-payers in homes, schools and hospitals (Financial Times Newsletters, Relation between water supply and drinking water prices in Hungary (1980–2001) — Figure 4.2.



Source: PTL/IW, 1999.

20 November 1998). The changes introduced in the UK include the following.

- Increased choice in water charging: customers should have a new right to remain on an unmeasured charge in their present home where they are using water for essential purposes only. Customers should also be able to opt for a meter, to be installed free of charge, with the protection that those who request one can revert to an unmeasured charge within a year of requesting the change.
- Protection for vulnerable groups with high essential water use who have to pay a measured charge.
- Removal of the restriction on the use of rateable value as a basis of water charging after 31 March 2000.

The average percentage of household expenditure on water charges in the UK decreased from 1.5 % in 1994/95 to 1.3 % in 1997/98 (DETR, 1999).

4.3. Industry

The industrial sector faces two different ranges of prices depending on the water source: direct abstraction or from the public water supply. Abstraction charges can take the form of a nominal licence fee linked to an abstraction permit regime, or they can vary depending on the quantity used. They can also have explicit environmental objectives, including, for example, consumption reduction incentives.

Abstraction charges for industrial water uses are in place in Belgium, the Netherlands, Poland, Spain and the UK. No abstraction charges are in place in countries where water is deemed to be abundant (e.g. Sweden). In Belgium, there is no distinction according to the type of use in the abstraction charge regime.

It is usually cheaper for industrial users to invest in water abstraction and treatment facilities than to pay for supplied water, although information is often difficult to obtain. Frequently, direct abstraction and discharge fees are a viable option in order to compare costs for self-supplied water between countries (OECD, 1998c).

In most countries, little information is available on tariff structures for industrial users because companies tend to enter into special contracts with water suppliers (e.g. the Czech Republic, Finland, France and Germany). In other countries, like the UK, standard charges are available to all customers in similar circumstances, rather than by special agreement (OECD, 1998c).

In some countries, subsidies can be available to industrial users when they are willing to improve their water abstraction or treatment capacities (e.g. Austria, where subsidised loans are available for water and wastewater projects).

4.4. Agriculture

This section deals mainly with pricing of irrigation even though water in agriculture is also used for other purposes such as livestock watering.

Irrigation has a different purpose in different geographic and climatic areas of Europe. In southern European countries, irrigation is necessary to secure crop growth each year, whereas, in central and western Europe, it is used to maintain production in dry summers.

This different role is important when analysing water pricing policies in the agricultural sector because these policies are often derived from more general policies (economic and social development in rural areas). This difference is also important when comparing agricultural pricing policies between countries or regions (see Table 4.7).

The situation regarding water tariffs for irrigation is often very different from other sectors:

- irrigation tariffs can be extremely low and there is significant lobbying pressure to resist any increases;

Table 4.7. **Agricultural water pricing policies in some EEA countries**

Source: OECD, 1999

Country	Water rights	Water pricing	Other economic instruments
Austria	GW: licensed	Irrigation: GW free of charge.Livestock: from PWS at household rates.	
Belgium	SW: user rights	Agricultural water from PWS at household rates, from GW and SW a levy on declared volumes (from 1998).	Pollution charges
France	SW: user rights	Charges have a catchment component and a consumption component. The prices are established by the regional development companies.	Quotas depending on water availability
Germany	SW: user rights GW: licensed	Water prices are the responsibility of the Länder. Water tax (from 1998).	Tax exemptions for farmers
Greece	SW: user rights GW: licensed	Pricing from agreements between local land improvement boards and private suppliers. Water fees, in general, are dependent on extraction costs.	Agricultural policies; rural development policies
Italy	SW: licensed	Irrigation boards are responsible for irrigation projects.	Quotas; progressive pricing in the south
Netherlands	SW: user rights GW: licensed	Water control boards (66 in total) are in charge of water management; the costs are covered by water users. Farmers pay the full supply cost and the full drainage cost.	Pollution levies and flood control levies
Portugal	SW: public and private rights	Agricultural water prices are levied by user associations. From 1999, all licensed water has been subject to a water levy, depending on the amount of water used, returns generated by each type of user, and the region's relative scarcity of water.	Agricultural policies; rural development policies
Spain	SW: user rights GW: licensed	The irrigation water price has two components: the regulation levy (to cover capital investments for water works) and a tariff to cover the operational and maintenance cost of storage and transportation. The river basin agencies and the irrigation districts are in charge of the prices.	Quotas; occasional markets
Sweden	GW: permits when shortage of water in given regions (10 % of irrigation farmers)	Water for irrigation can be abstracted freely by farmers.	
UK	SW: licensed GW: licensed	National river authorities and water companies are in charge of water pricing. Only direct abstractions for spray irrigation require an abstraction licence. Licences are based on volume, nature of water resource, season in which abstraction is allowed and on the water returned directly to water resources; 25-50 % of the annual charge is based on actual recorded consumption. Where mains are used for agriculture, the tariff is fixed by the official regulator (OFWAT).	Quotas

NB: SW: surface water, GW: groundwater, PWS: public water supply.

- water use in the sector has been subsidised in most of the countries (subsidies as a tool for developing irrigation for food production and/or social development);
- tariffs can be based on forfeits;
- meters may not be installed on many abstractions or uses;
- public pressure concerning the environmental image of agriculture is much less than for industry for example.

For further information, see case studies 32 and 33 in the Appendix.

4.4.1. Pricing structures for irrigation

Most agricultural water prices distinguish between charges for water resources and charges to cover part or all of the cost of water supply for irrigation. The aim of the former component is to ration water use (especially if it is scarce), while that of the latter is to guarantee that the supply system is financially self-sufficient. Nevertheless, it is only in the regions where water is scarce, and as a consequence is a tradable good, that water prices tend to reflect their scarcity values, as distinct from supply cost (OECD, 1999).

The cost of irrigation water supply consists of the variable costs of processing and delivering the water to end-users and of the fixed cost of capital depreciation, operation and maintenance. Variable costs depend on the amount of water delivered, while fixed costs do not. In most countries, fixed costs are heavily subsidised (UN, 1980).

The method by which irrigation water is delivered affects the variable cost, as well as the irrigation technology applied and the feasible pricing schemes. Often, the irrigation water in a region is delivered by more than one method, depending on tradition, physical conditions, and water facilities and institutions (UN, 1980).

The most common pricing methods for irrigation are described in Table 4.8.

Bos and Walters (1990) investigated water use by farmers utilising 12.2 million ha of irrigated land worldwide and found that, in more than 60 % of the cases, water charges are levied on a per unit area basis. In less than 15 % of the irrigation projects, water is charged based on a combination of per unit area and volume used. In about 25 % of the cases studied, the charging method is volumetric (quoted in World Bank, 1995).

The main conclusions of the World Bank report *Efficiency and equity considerations in pricing and allocating irrigation water, 1995* (see Table 4.9), which investigates efficiency and equity performance of the above described water pricing methods, are as follows.

- In general, efficiency of water use is attainable whenever the pricing method affects the demand for irrigation water.
- The volumetric, output, input-tiered and two-part tariff schemes all effect the water demand and can achieve efficiency, though the type of efficiency (short or

Pricing methods Table 4.8.

Volumetric	Water charge is based on the direct measurement of volume of water used. Variations of the volumetric approach include: (a) indirect calculation based on measurement of minutes of known flow; and (b) a charge for a given minimal volume to be paid for, even if not used.
Output	Irrigation water is charged on per output basis (users pay a certain water fee for each unit of output they produce).
Input	Water is charged by taxing inputs (users pay a water fee for each unit of a certain input used).
Per unit area	Water is charged per irrigated area, depending on the kind and extent of crop irrigated, irrigation method, the season of the year, etc. In many countries, the water rates are higher when there are storage works than for diversions directly from streams. The rates for pumped water are usually higher than those for water delivered by gravity. In some cases, farmers are also required to pay per ha charges for non-irrigated ha.
Tiered pricing	This is a multi-rate volumetric method, in which water rates vary as the amount of water consumed exceeds certain threshold values.
Two-part tariff	Users are charged a constant marginal price per unit of water purchased (volumetric marginal cost pricing) and a fixed annual (or admission) charge for the right to purchase the water. The admission charge is the same for all users.
Betterment levy	Water fees are charged per unit area, based on the increase in land value accruing from the provision of irrigation.
Water market	In some developed economies, markets for water or water rights have been formed and determine water prices.

Sources: Rhodes and Sampath, 1988; Sampath, 1992.

Table 4.9. **Comparison of key variables of various pricing methods**

Source: World Bank, 1995

Pricing method	Implementation	Efficiency achieved	Time horizon of efficiency	Ability to control demand
Volumetric	Complicated	First best	Short run	Easy
Output	Relatively easy	Second best	Short run	Relatively easy
Input	Easy	Second best	Short run	Relatively easy
Per area	Easiest	None	-	Hard
Tiered	Relatively complicated	First best	Short run	Relatively easy
Two part	Relatively complicated	First best	Long run	Relatively easy
Water market	Difficult (without pre-established institutions	First best	Short run	-

long run, first or second best) varies from one method to another.

- Pricing methods that do not influence water input directly, such as per unit area fee, lead to inefficient allocation. Such methods, however, are easier to implement and require only a modest amount of information.

As regards equity performance, the conclusion is that the extent to which water pricing methods can affect income redistribution is rather limited. Farm income disparities are due mainly to such factors as farm size and location, and soil quality, and not to water prices.

The conclusions give some support to the view that income redistribution policies should not be carried out via water prices, not because this involves wrongdoing but because water prices serve as a poor means of reducing income inequality. However, pricing schemes that involve water quota rules can reduce income inequality.

4.5. Price elasticity and irrigation

In general, the amount of water used for irrigation responds moderately to water price levels but is more influenced by factors such as climate variations, agricultural policies, product prices or structural factors (OECD, 1999). See Table 4.10.

Examples of pricing methods for irrigation

Cyprus: *Water charges cover 34 % of the average cost of water provision. Farmers are charged on a volumetric basis or an hourly basis (FAO, 1997).*

England and Wales: *Multi-rate volumetric pricing is common. Water authorities vary greatly in the complexity of their charging systems. For example, in 1984/85, the Wessex Water Authority had 9 different rates and the Yorkshire Water Authority 45 rates (OECD, 1987).*

France: *Irrigation water is commonly priced by a two-part tariff method, which consists of a combination of a volumetric and a flat rate. In 1970, the Societe du Canal de Provence et d'Aménagement de la Région Provencal, which supplies 60 000 ha of farmland and nearly 120 communes, introduced a pricing scheme in which rates vary between peak demand and off-peak periods. The peak period rate is set to cover long-run capital and operating costs. The off-peak rate is set to cover only the operating costs of water delivery. About 50 % of total supply costs (variable and fixed) are subsidised by the State (OECD, 1987).*

Greece: *Per area charges are common. The proceeds usually cover only the administrative costs of the irrigation network. The irrigation projects are categorised as of basic, local and private importance and the project areas are also classified as areas of national, public or private interest. The proportions of the capital costs of an irrigation project paid by farmers are 30, 50, and 40 % for projects classified as of national, public and private interest, respectively (Gole et al., 1977).*

Spain: *The water charges are established per agricultural area and not per volume consumed. This means that the user pays the same amount despite the amount of water used and there is no real incentive for saving water (MMA, 1998).*

Cross-sectional price elasticity estimates for irrigation demands Table 4.10.

Source: OECD, 1999.

Source	Method/context	Region/country	Water demand elasticity
Moore et al., 1994	Groundwater price variations Econometric model Cross-sectional data	US north-west US central plains US south-west	- 11.72 3.99 - 16.88
OECD, 1999	Institutional price simulations Dynamic math. programming model Long-term results	Spain (Andalusia) Spain (Andalusia) Spain (Castile) Spain (Castile)	LP - 0.06, MP - 1.00 LP - 0.12, MP - 0.48 LP - 0.09, MP - 0.26 LP - 0.00, MP - 0.03
Montginoul and Rieu, 1996	Math. programming models over 170 irrigated farms	France (La Charente)	LP - 0.04, MP - 0.27

NB: LP: low water price ranges; MP: medium water price ranges.

Cross-sectional studies of irrigation districts, at both the national and international levels, have found conflicting evidence of the influence of water price levels on water management efficiencies (OECD, 1999). The box below includes some of the conclusions.

4.6. Main findings

1. The tariff structure has a high impact on the final water price, and creates sectoral (industry, agriculture, urban) and geographical (local, regional, national level) differences.

2. Over recent years, the development of water policies in Europe has had an important impact on water bill composition.

3. Users can see the inclusion of different components and aspects into water bills as a way of paying more taxes, especially if the new taxes are calculated on a fixed quantity of water. This is a consequence

- *Water demand is usually inelastic only up to a given price level. This 'price threshold' depends on: (1) economic productivity of the water; (2) the set of alternative production strategies that farmers actually adopt in order to substitute for water consumption; (3) the proportion of land devoted to permanently irrigated crops.*

- *The 'price threshold' indicates possibilities for increasing water charges without significantly perturbing farming activities. Although net farm returns would be reduced by price increases, these (operating) losses would eventually be captured by reductions in the (capital) values of land.*

- *Farmer responses to price increases could include: (1) changes in cropping patterns; (2) reductions in the amount of irrigated land; (3) improvements in on-farm water management practices; (4) changes in irrigation technologies; and (5) abandonment of irrigation.*

- *Price increases, combined with more efficient distribution systems, might actually end up increasing total water consumption. This could result from the net reduction of on-farm water costs caused by the reduction of leakage in the water distribution system. The volume of water returns generated in the irrigation district as a whole might then be reduced more than the reduction in the amount of water demanded on the farm. As a result, the basin's water balance might be worsened by price increases.*

- *The adoption of more efficient irrigation technologies is accelerated by higher water charges or higher water application costs. But other factors, such as land quality, well depths, and agricultural prices, are just as important, if not more so, as the price effect of water itself.*

- *Subsidies for the rehabilitation of irrigation districts and for new irrigation technologies might end up increasing on-farm water consumption. Although water productivity, measured as revenues per m^3 used, would increase, total water consumption at the level of the basin might also increase, unless allocations are simultaneously revised downwards.*

of the heterogeneity of the organisations with responsibility for water management at different levels (national, regional, local).

4. It is necessary to separate clearly the components and aspects included in water bills and the charges and taxes included should be related to the water cycle.

Urban sector

5. Price structures are generally fixed at municipal level and can vary widely within a country. The differences, in general, take into account different types of users (domestic, industry and agriculture), and tend to reflect differences in cost structures.

6. The main types of tariff structure (excluding the initial connection charge) are:

   - flat-rate tariff;
   - uniform volumetric tariff;
   - two-part or binomial tariff (sum of a flat-rate tariff and a uniform volumetric tariff);
   - block tariffs, which also usually incorporate a flat-rate charge, plus declining block tariffs and rising block tariffs.

7. Through different case studies, it is possible to show that an increase in water prices has reduced water use. Nevertheless, the elasticity is very short.

8. Block tariffs, which include a connection charge independent of the water use, are widespread. This is the case in Denmark, Finland, France, Greece, the Netherlands, Norway, Spain and the UK.

9. For a family living in a house using 200 m^3 of water per year, Germany has the highest water charges in Europe (EUR 350.16), followed by the Netherlands (EUR 344.35), and Denmark (EUR 303.57). Italy (EUR 49.62) and Norway (EUR 84.83) have the lowest.

10. It is necessary to find a way of discouraging excessive water use which is compatible with the guarantee of a basic level of domestic use with affordable prices for all citizens.

11. Information to users is essential in any process of water tariff changes (structure and price increases).

Industry

12. The industrial sector faces two different ranges of prices depending on the water source: direct abstraction or from the public water supply.

13. Abstraction charges can take the form of a nominal licence fee linked to an abstraction permit regime or they can vary depending on the quantity used.

14. Abstraction charges for industrial water uses are not in place in countries where water is deemed to be abundant (e.g. Sweden).

15. It is usually cheaper for industrial users to invest in water abstraction and treatment facilities than to pay for supplied water, although information is often difficult to obtain.

16. In most countries, little information is available on tariff structures for industrial users because companies tend to enter into special contracts with water suppliers (e.g. the Czech Republic, Finland, France and Germany). In other countries, such as the UK, standard charges are available to all customers in similar circumstances.

17. In some countries, subsidies can be available for industrial users when they are willing to improve their water abstraction or treatment capacities (e.g. Austria).

18. The main motive to implement water conservation programmes in companies tends to be economic incentives, normally in the form of abstraction charges and wastewater fees. Other factors can be legislative requirements for cleaner technologies, environmental image and concern for the reliability of water supply.

Agriculture sector (irrigation)

19. Irrigation has a different purpose in different geographical regions of Europe. In southern European countries, irrigation is necessary to secure crop growth each year whereas,

in central and western Europe, it is only a means of maintaining production in dry summers.

20. Agricultural pricing policies are often derived from more general policies: economic and social development in rural areas, environmental local policies (erosion and flood control, landscape maintenance, etc.), and there are large differences across Europe.

21. Those differences make it difficult to compare irrigation water prices between countries or even regions within the same countries.

22. Most agricultural water prices distinguish between charges for water resources and charges to cover part or all of the cost of water supply for irrigation. The aim of the former component is to ration water use, while that of the latter is to guarantee that the supply system is financially self-sufficient. Nevertheless, it is only in the regions where water is scarce, and as a consequence is a tradable good, that water prices tend to reflect their scarcity values, as distinct from supply cost.

23. Agricultural water use has been subsidised in most of the European countries but most of these countries tend to introduce reforms to make users pay a higher proportion of the cost of the supplied water.

24. Irrigation tariffs can be extremely low compared to other economic sectors and there is significant pressure to resist any increases.

25. The most common system for irrigation charges is based on the irrigated surface, followed by a combination of per unit area and volume used.

26. In general, the amount of water used for irrigation responds moderately to water price levels but can be more influenced by factors such as climate variations, agricultural policies, and product prices or structural factors.

27. The adoption of more efficient irrigation technologies is accelerated by higher water charges but other factors, such as land quality, well depths, and agricultural prices, are just as important, if not more so, than the price effect of water itself.

28. Subsidies for the rehabilitation of irrigation districts and for new irrigation technologies might end up increasing farm water consumption. Although water productivity would increase, total water consumption at the level of the basin might also increase, unless allocations are simultaneously revised downwards.

29. Cross-sectional studies of irrigation districts, at both the national and international levels, have found conflicting evidence of the influence of water price levels on water management efficiencies.

5. User education and information

Information and educational campaigns in all sectors are always part of a wider plan for using water more efficiently in order to encourage more rational water use and change habits.

Information campaigns are considered to be an important part of initiatives such as promoting water-saving devices, raising prices to pay for leakage and encouraging more rational water use. Cases studies 34 and 43 in the Appendix illustrate examples where information supply has played a particularly important part of a city's water conservation plan.

In the agricultural sector, the aim of the programmes is to help farmers optimise irrigation. This can be achieved through training (on irrigation techniques), and through regular information on climatic conditions, irrigation volume advice for different crops, and advice on when to start/stop the irrigation period adjusting irrigation volumes according to rainfall and type of soil (see Appendix, case studies 34, 43, 44, 46, 47 and 51).

In the industrial sector, water savings are just part of a wider programme which includes measures to reduce water pollution and implement environmental management systems.

It is difficult to quantify the effect of a public educational campaign because it is always part of a wider water-saving programme which includes other measures.

6. Water reuse

6.1. Introduction

Treated wastewater can be indirectly reused when it is discharged into a watercourse, diluted and used again downstream. Direct reuse means the direct supply of treated effluent from the treatment plant to the user (e.g. industry, agriculture, recreational facility and domestic users). It can also apply to the recharge of an aquifer. This section deals with the direct reuse of treated water.

In general, the reuse of treated wastewater in Europe does not have widespread acceptability. Nevertheless, treated wastewater is reused in some Mediterranean countries such as Cyprus, France, Greece, Italy, Malta, Portugal and Spain, particularly for irrigation (see Appendix, case studies 36, 37, 38, 40, 41 and 42).

Other European countries are undertaking pilot studies and gaining experience, especially in the industrial and domestic sectors. For instance, in the UK, most water abstractions are from streams and surface waters which receive significant quantities of treated wastewater (indirect reuse). However, in recent years an increasing number of initiatives and research projects have been undertaken into the direct reuse of water, particularly in the domestic and commercial sectors (see Appendix, case study 39).

In general in Europe, until recently, the direct reuse of treated water has been in response to water shortages rather than as a planned activity.

Recycled water can be used in different economic sectors (see Table 6.1).

At present, the most important use of reused water in Europe is for irrigation for different purposes (e.g. crop cultivation, public gardens, parks and golf courses), followed by industrial use. Domestic use appears to be the least developed sector and only focused on in pilot studies.

The indirect reuse of water for potable supplies is a common practice in Europe, but there are no known examples of direct

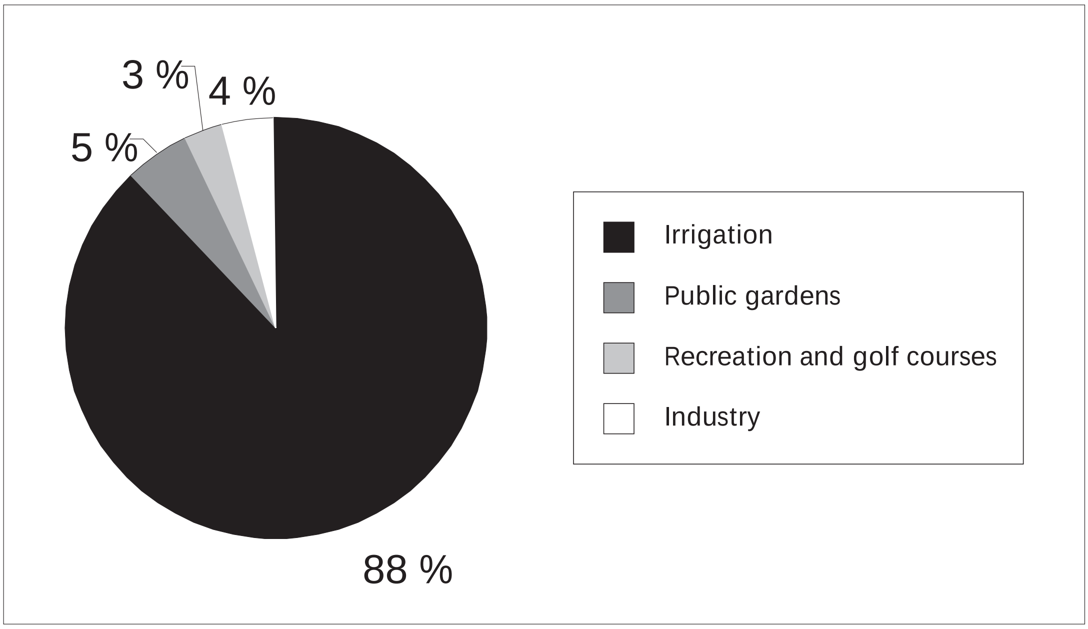
Treated wastewater reuse applications Table 6.1.

Reuse field	Applications
Environmental	Streamflow regulation Marshes and wetlands Recreational areas (lakes, parks) Fisheries and aquaculture Snow-making
Agricultural and landscape irrigation	Fodder, fibre and seed crops Edible crops Stock feed water Lawns and forests Nurseries Frost protection
Groundwater recharge	Recharge potable aquifer Saltwater intrusion control Storage
Urban	Fire protection Toilet flushing Street/car washing Dust control Air conditioning
Industrial	Cooling Boiler feed Construction Process water Stack scrubbing
Potable	Direct potable Indirect potable

Source: Levine et al., 1997.

Figure 6.1. **Water reuse by different sectors in Spain**

Source: Catalinas and Ortega, 1999.



potable use, and in some countries, such as Spain, this use is not permitted by law.

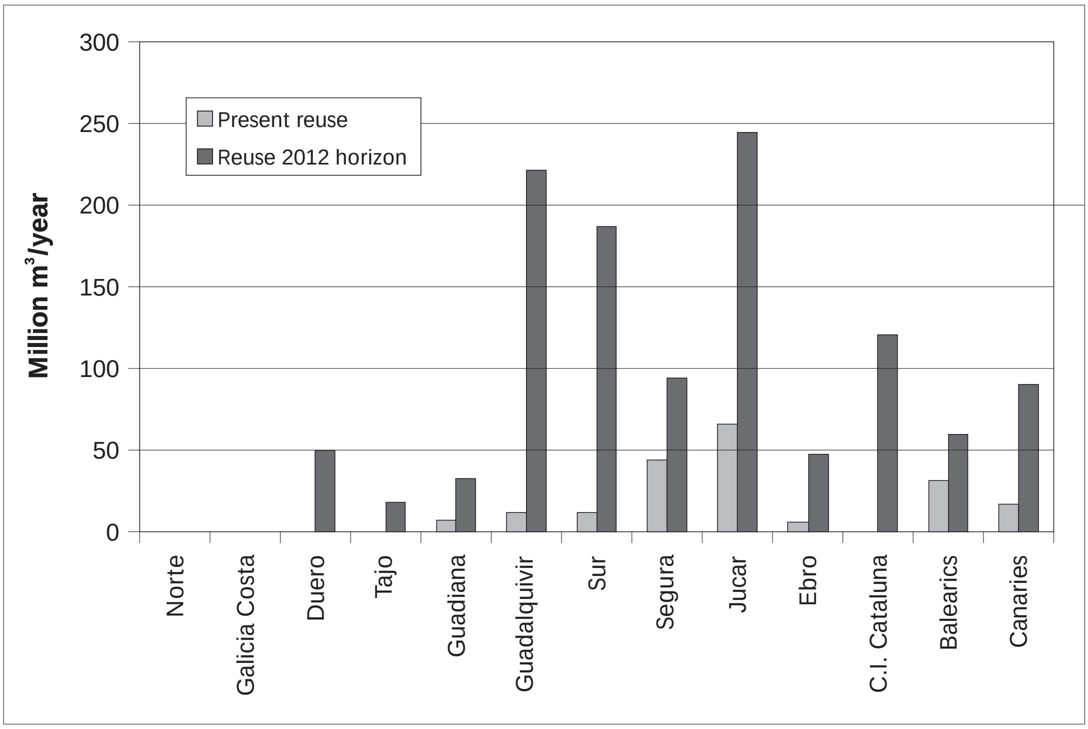
Figure 6.1 gives an example of wastewater reuse by economic sectors in Spain.

Article 12 of the urban wastewater treatment directive (Directive 91/271/EEC) indicates that treated wastewater should be reused whenever appropriate. This article implies that the amount of treated wastewater available for reuse will increase considerably by the year 2005. Nevertheless, the last part of the article, 'whenever appropriate', needs further development (e.g. definitions, standards and guidelines).

In addition, the proposed water framework directive introduces a quantitative dimension of water resources, which could have an impact on the use of treated wastewater as an alternative source of water.

Figure 6.2. **Present and potential reuse of treated wastewater in river basins in Spain (forecast 2012)**

Source: Catalinas and Ortega, 1999.



As an example, the present volume of recycled water in Spain is around 200 million m^3/year, the potential use of recycled water by the year 2012 could be around 1 200 million m^3/year, equivalent to a potential increase of 600 % (Catalinas and Ortega, 1999) (see Figure 6.2).

6.2. Standards and guidelines for treated wastewater reuse

The quality of the wastewater and the required quality of the effluent in terms of intended use, or any applicable standards or guidelines, determine the level of treatment necessary. Existing wastewater reuse regulations depend on the type of application, the regional context and the assumption that there is a possible risk associated with the use of recycled water. But, the notion of 'risk exposure' is arbitrary and comparisons between different guidelines become difficult. Table 6.2 shows key water quality parameters involved in treated wastewater reuse and associated risks.

The regulatory guidelines for water reuse in irrigation that have been the model followed worldwide by different countries are the State of California's wastewater reclamation criteria (1978), which have a regulatory purpose, and the World Health Organisation guidelines (1989) (see Table 6.3).

Key water quality parameters relevant to treated wastewater reuse (adapted from US EPA, 1992) Table 6.2.

Source: Levine et al., 1997.

Category	Constituents	Parameters of interest	Comments
Pathogenic organisms	Protozoa	*Entamoeba histolytica; Giardia lambia*	• Infectious dose between 1 and 20 organism • Survival time in water between 10 and 30 days
	Helminths	*Ascaris lumbricoides*	• Infectious dose, 1-10 helminth eggs • Highly persistent in the environment • Considered as the main pathogenic risk in reuse for irrigation
	Bacteria	*Shigella, Salmonella, Vibro cholerae, Escherichia coli*	• Infectious dose, highly variable • Survival time in water between 10 and 60 days • Commonly used as an indicator
	Viruses	*Hepatitis*	• Detection methods are not sensitive • Variable incubation times, survival time in water until 120 days • Person-to-person contamination main mode of transmission • Infectious dose, 1-10 viruses
General parameters	Suspended solids	Total suspended solids	• Sorb organic pollutants and heavy metals • Shield micro-organisms • Plug irrigation systems and soil
	Nutrients	Nitrogen, phosphorus, potassium	• Induce eutrophication when combined with high concentrations • Nitrogen can lead to nitrate build-up in groundwater after leaching
	Hydrogen ion concentration	pH	• Impact on coagulation, disinfection, metal solubility and soils
Inorganic constituents	Dissolved inorganic substances	Total dissolved solids, electrical conductivity, specific elements (Ca, Na, B, Cl)	• High salinity may damage crops • Destabilise soil structure (sodium adsorption ratio – SAR) • Salt can contaminate groundwater
	Heavy metals	Specific elements (Cd, Zn, Hg, Ni)	• Accumulate in certain plants and animals • Limit suitability of recycled water
Organic constituents	Biodegradable organic substances	BOD, COD, TOC	• Aesthetic and nuisance problems • Provide food for micro-organisms • Contribute to chlorine demand
	Stable organic substances	Specific compounds (pesticides, PAH, chlorinated hydrocarbons)	• Toxic to the environment and public health • Limit suitability of the recycled water

Microbiological monitoring requirements, in the two sets of guidelines, are different. The WHO guidelines include intestinal nematodes whereas the California guidelines emphasise faecal coliform removal. The kind of wastewater treatment is also different. The WHO guidelines indicate the necessity for a series of stabilisation ponds, whereas the California guidelines require secondary treatment with filtration and disinfection.

Both standards are used worldwide as a reference for the development of national or regional standards which tend to be more stringent. Guidelines at a European level do not exist and, at a national and even at a regional level, the situation across Europe varies. In general, the development of standards and guidelines for wastewater reuse reflects the situation in each country. For example, Table 6.4 shows the microbiological criteria adopted in Cyprus.

The recommendations elaborated by the Conseil Supérieur d'Hygiène Publique de France (CSHPF) follow the WHO guidelines. They also add restrictions on crop irrigation techniques and set distances between irrigation sites and residential areas and roadways. As a consequence, spray irrigation is limited in urban areas (CSHPF, 1991).

In Italy, wastewater reuse for agriculture is regulated at the national level by the 'criteria, methodologies and general technical standards' (Ministero dei Lavori Pubblici, 1997). However, regions with regulatory autonomy may have their own standards. This is particularly the case in regions where wastewater reuse for irrigation is more developed (see Table 6.5).

Table 6.3. **Comparison of microbiological quality guidelines and criteria for irrigation by WHO (1989), State of California's wastewater reclamation criteria (1978) and US EPA (1992)**

Source: Angelakis et al., 1997.

Organisation	Reuse	Intestinal nematodes *	Faecal or total coliforms	Wastewater treatment requirement
WHO	Irrigation of crops to be eaten uncooked, sports fields, public parks	< 1/l	< 1 000/100 ml	A series of stabilisation ponds or equivalent treatment
	Landscape irrigation where there is public access, such as hotels	< 1/	< 200/100 ml	Secondary treatment followed by disinfection
	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	l< 1/l	No standard recommended	Stabilisation ponds with 8-10-day retention or equivalent removal
California	Spray and surface irrigation of food crops, high-exposure landscape irrigation such as parks	No standard recommended	< 2.2/100 ml **	Secondary treatment followed by filtration and disinfection
	Irrigation of pasture for milking animals, landscape impoundment	No standard recommended	< 23/100 ml **	Secondary treatment followed by disinfection
US EPA	Surface or spray irrigation of any food crop including crops eaten raw	No standard recommended	Not detectable ***	Secondary treatment followed by filtration (with prior coagulant and/or polymer addition and disinfection)
	Irrigation of pasture for milking animals; fodder, fibre and seed crops and landscape improvement	No standard recommended	< 23/100 ml ****	

* Intestinal nematodes (Ascaris and Trichuris species and hookworms) are expressed as the arithmetic mean number of eggs/l during the irrigation period.

** California wastewater reclamation criteria are expressed as the median number of total coliforms per 100 ml, as determined from the bacteriological results of the last seven days for which analyses have been completed.

*** The number of faecal coliform organisms should not exceed 14/100 ml in any sample.

**** The number of faecal coliform organisms should not exceed 800/100 ml in any sample.

In Greece, no guidelines or criteria for treated wastewater reuse have yet been adopted.

At national level in Spain, the Water Law (1985) and Section III 'Treated wastewater reuse' of Royal Decree 849/1986 mention the need for the regulation of the direct reuse of treated wastewater. As a result, the Spanish Ministry of the Environment is now developing draft regulations that include:

- a proposal for minimum physico-chemical and biological criteria to determine the quality of treated water for different uses;
- a proposal for criteria to control toxic substances for different uses;
- methodologies and quality criteria for analysis;
- a monitoring system.

There are also examples of regional legislation in Spain, for example, in Catalonia and in the Balearic and Canary Islands.

In the case of urban reuse, where the objective is to use treated water for applications which do not need the same level of quality as drinking water, standards tend to be more stringent than agricultural

Microbiological standards for water reuse in Cyprus Table 6.4.

Source: Angelakis et al., 1997.

Irrigation *	Faecal coliforms (number/100 ml)	Intestinal worms	Wastewater treatment required
Amenity areas of unlimited access	50 ** 100 ***	Nil	Secondary and tertiary followed by disinfection
Crops for human consumption	200 ** 1 000 ***	Nil	Secondary and storage for more than one week followed by disinfection, or tertiary followed by disinfection
Amenity areas of limited access	200 ** 1 000 ***	Nil	Stabilisation maturation ponds with total retention time > 30 days, or secondary and storage > 30 days
Fodder crops	1 000 ** 5 000 ***	Nil	Secondary and storage for more than one week, or tertiary followed by disinfection
Industrial crops	3 000 ** 10 000 ***		Secondary followed by disinfection, stabilisation maturation ponds with total retention time > 30 days, or secondary and storage >30 days

* Irrigation is not allowed for: vegetables, ornamentals for trade purposes; substances accumulating in the edible parts of crops and proved to be toxic to humans or animals are not allowed in effluent.
** Value must not be exceeded in 80 % of samples per month.
*** Maximum value allowed.

Microbiological standards for water reuse in Italy Table 6.5.

Source: Bontoux, 1997.

Level of application	Reuse	Total coliforms	Treatment
National	Crops can be eaten raw	< 2/100 ml	Secondary followed by disinfection
	Pastures	< 20/100 ml	Secondary followed by disinfection
	Crops that do not come into contact with the water and all the other cases		Primary treatment, but chemicals that may leave undesirable residues in the crops must be absent
Puglia region	All cases	< 10/100 ml	-
Emilia Romagna	Crops that can be eaten raw and pastures	< 12/100 ml	-
	Crops without contact with the treated water	< 250/100 ml	
Sicily	Irrigation is forbidden for fodder crops and food crops in direct contact with treated water		-
	Rest of the cases	< 3 000/100 ml < 1 000/100 ml absence of salmonella1 helminth egg/l	

reuse standards, since, despite the absence of direct consumption, potential public exposure from inhalation or accidental ingestion is also important.

In addition to quality standards, safety measures for non-potable reuse applications should include:

- separate storage and distribution systems;
- use of colour-coded labels to distinguish potable and non-potable systems;
- back-flow prevention devices;
- periodic tracer studies to detect cross connections between potable and non-potable systems;
- out-of-working-hours usage to further minimise potential human contact;
- warning and information signs at sites using recycled water.

(Asano, 1994; Crook and Surampalli, 1995, quoted in Levine et al., 1997).

There are generally no defined standards for industrial reuse applications. Usually, it is the industry itself which defines its water quality requirements (Levine et al., 1997).

In general, microbiological quality standards can be controversial, especially in the case of irrigation of vegetables that can be consumed raw, and in the case of watering of sports fields.

The two key parameters present in most of the regulations are total suspended solids (turbidity) and the disinfection efficiency of the treatment process through the measurement of different organisms considered to be sanitary indicators (e.g. coliforms and intestinal nematodes).

6.3. Benefits and issues relating to treated wastewater reuse

The use of recycled water has important benefits such as:

- an increase in available water resources;
- better water management – it allows the substitution of freshwater for other uses whilst reserving the latter for direct human use;
- a potential reduction in pollutants to be discharged into freshwater;
- a better use of the nutrient content in the treated water;
- the guarantee of regular water supply, especially in the areas where water is scarce.

At the same time, its use can be controversial, especially because of the associated potential risk for public health. This issue is also linked to the lack of standards and guidelines to regulate reused water quality, and to the lack of validation of the existing ones.

The costs associated with the implementation of water reuse schemes must also be taken into account. The cost of treating 1 m^3 of water can vary from:

- EUR 48–84 (installation cost) and EUR 0.01–0.02 (exploitation cost) using sand filtration; to
- EUR 151–193 (installation cost) and EUR 0.26–0.27 (exploitation cost) using reverse osmosis (Catalinas and Ortega, 1999).

The necessary investment could constrain the development of the use of recycled water, and, at the same time, have a great impact on water bills which could discourage potential users.

Another important issue is associated with the lack of water in certain rivers, especially in the Mediterranean area. Because of the lack of rain during several months each year, rivers on the Mediterranean coast have no running water, except treated or untreated wastewater. If this is reused, some of the rivers will become dry. As a result, some interest groups are asking for the water not to be diverted. This will lead to problems and objections when trying to reuse wastewater in some parts of the countries (Angelakis et al., 1997).

6.4. Main findings

1. In general, the reuse of treated wastewater in Europe does not have widespread acceptability. Nevertheless, treated wastewater is reused in some Mediterranean countries such as Cyprus, France, Greece, Italy, Malta, Portugal and Spain, particularly for irrigation.

2. Until recently, the direct reuse of treated water has usually been in response to water shortages rather than as a planned activity.

3. At present, the most important use is for irrigation for crop cultivation, public gardens, parks and golf courses, followed by industrial use. Domestic use

appears to be the least developed sector and is focused on only in pilot studies.

4. Article 12 of the urban wastewater treatment directive indicates that treated wastewater shall be reused whenever appropriate. It means that the amount of treated wastewater available for reuse should increase considerably by the year 2005 as the requirements of the directive are implemented across Europe.

5. The proposed water framework directive introduces the quantitative dimension of water resources which can have an impact on the consideration of the reuse of treated wastewater as an alternative source of water.

6. The existing wastewater reuse regulations depend on the type of application, the regional context and the assumption that there is a possible risk associated with the use of recycled water. But, the notion of 'risk exposure' is arbitrary and hence comparisons of different guidelines become difficult.

7. Guidelines at the European level do not exist. At the national and regional level, the situation is variable where, in general, the development of standards and guidelines for wastewater reuse reflects the level of development of wastewater reuse in each country.

8. Existing standards and guidelines for the use of treated wastewater should be validated, and, if required, new ones should be developed, to safeguard public health and the environment.

9. The main benefits of treated wastewater reuse are conservation of water resources and pollution reduction.

10. The large investment required for treatment may inhibit the development of recycled water use. These costs will be lower if the site of reuse is as close as possible to the water producer.

11. The lack of running water in the rivers of some Mediterranean areas during some periods of the year makes the reuse of treated water impractical in these areas. This is because the water present in these rivers during the dry periods is the treated effluent arising from treatment works. The reuse (removal) of this water would leave the rivers completely dry.

7. Integrated water management approaches

7.1. Background

This section is based on relatively little information obtained from a limited number of available case studies. However, integrated water management is now considered to be an essential part of the sustainable use of water. This has recently been acknowledged in the proposed water framework directive. For these reasons, it was felt that the salient points arising from these case studies should still be presented in this short section.

Traditionally, measures concerning water resources management have been applied in different sectors, but often in a piecemeal fashion with a multitude of different initiatives which could occasionally be contradictory, and not necessarily implying a more efficient use of water. In the 1990s, there was a series of major droughts in Europe, and many cities and regions have realised that an integrated approach is needed to deal not just with water as a resource but also with water as a natural habitat. Several case studies are illustrated in the Appendix (see case studies 43, 44, 45, 46, 47, 48, 49, 50 and 51).

In the industrial sector, the concept of environmental management is now well developed and widely applied in large companies. It is, however, less widespread and only slowly gaining ground in medium-sized and especially smaller enterprises, which may have relatively high water consumption and can achieve significant reductions in water and wastewater charges through such management.

Although water demand reduction is not always the main reason for pursuing an environmental management policy, it is very often a result of policies primarily intended to reduce pollution. Cleaner technologies which reduce pollution levels often also reduce quantities of water and thereby result in a lower water demand.

In the Appendix, some examples are described where a catchment-scale approach is adopted or an association is created to promote the exchange of experience (see case study 51).

In other cases, different aspects have been highlighted to show possible approaches. However, most examples include a wide variety of water reduction measures, as well as other environmental management measures which cannot be separated from water use reduction:

- new technology/processes;
- water substitution;
- improvement of process conditions and monitoring;
- closed circuits;
- recycling process water.

Education, information and training for employees are important accompanying measures in most initiatives of this kind.

Other approaches can also be adopted. A particular example is to favour the building of new power stations at coastal sites in order to use seawater as cooling water instead of large abstractions of fresh surface water. Although other factors were also involved, this shift was seen throughout the 1970s and 1980s in France for the nuclear and thermal power stations, of which a significant proportion are now on the coast.

In the agriculture sector, plans to improve the productivity of irrigated areas usually include a large variety of measures. Some of them relate to the improvement of existing infrastructure (modernisation of irrigation, drainage and communication infrastructures). Others relate to non-structural aspects of irrigation such as the improvement of organisation and management, encouragement of users' initiatives, improvement of knowledge about water losses, changes in tariff systems, and adjustment of water allocations of crop demand (see Appendix, case study 50).

7.2. Main finding

Traditionally, measures concerning water resources management have been applied in different sectors in Europe. But, following the droughts in the 1990s, integrated approaches related to water as a resource and as a natural habitat have been developed.

8. The way forward

This report is mainly based on case studies derived from different sources and also on reports, publications and web sites, at international and national level. From all the reviewed documentation, it is possible to highlight the following points.

At the European level

- Management of water is very heterogeneous in Europe, and there is a range of regional and decentralised policies. The proposed water framework directive is one important step towards integrated management of the resources at the river basin level and towards harmonisation of policies throughout Europe.
- Sustainable use of water, apart from a technical approach, needs a socioeconomic approach to understand better the interactions between different actors (users, water companies, public institutions) in order to establish the adequate policy instruments.
- At institutional level, it should be necessary to adapt the different water institutions to the new water management model (less building, more management).
- More information and research are necessary concerning water price structures in Europe in order to assess the socioeconomic implications of the 'full-cost-recovery' approach of European policies.
- More research is necessary concerning wastewater reuse for irrigation purposes in order to establish quality standards to ensure the protection of users and public health.
- Coordination of water policies within the common agricultural policy (CAP) is necessary in order to determine the water requirements of crops in different physical-geographical conditions.
- Implementation of criteria and the use of the best technologies to reduce pollution and water consumption should be encouraged.

At the national and regional level

- Coordination of policies to encourage good water management.
- Development of integrated approaches with the involvement of all the actors involved (e.g. public institutions, water suppliers and users).
- Collection of data and information on water use and pricing (e.g. domestic, agriculture, and industrial sector).
- Development of mechanisms to provide better information to users in any process related to water management changes.
- Encouragement of socio-cultural and economic studies to analyse water demand patterns and the factors that influence them.
- Definition of management indicators in order to assess with accuracy the conditions of the supply services, defining minimum standards of the service (e.g. water supply, minimum levels of pressure, rehabilitation and renovation criteria, and regulation of the cuts of the supply).
- Better information for users about the available technologies to reduce pollution and water consumption (e.g. household, industry and agriculture). Also, cost reduction of the water-saving technologies and devices will help their extension.
- Implementation of incentives to encourage cleaner and water-saving technologies (e.g. in agriculture encouraging alternative agricultural practices, and in industry encouraging innovation in the processes – dry processes or closed water circuits).
- Improvement of the available desalination technologies in order to reduce investment and operating costs, especially the cost linked to energy consumption.

9. Conclusions

1. At national or regional level, conservation policies are being implemented as a long-term public strategy for providing reliable drinking water supplies and affordable wastewater treatment.

2. Water demand management can be considered part of water conservation policies, which tends to be a more general concept, describing initiatives, that aim to protect the aquatic environment and make more rational use of water resources.

3. The term 'water demand management' can be defined in many different ways. In this report, demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used.

4. The need for a more efficient management of water resources is explained by the change from the concept that water is free and abundant to a scarce resource and an economic commodity.

5. The management of water is very different across Europe, and there is a range of regional and decentralised policies. The proposed water framework directive is one important step towards integrated management of water resources at a river basin level and towards harmonisation of water policies of Member States.

6. Through a number of case studies discussed in the report, the importance of developing sound partnerships between water authorities, water users and water suppliers is demonstrated.

7. Over the last few years, economic considerations have become more relevant in water policies, giving more relevance to the private sector (water supply and water demand management). Therefore, it is necessary to make economic decisions compatible with social objectives.

Technological approaches to reduce demand

8. Higher standards of living reflected in an increase in the use of domestic equipment such as washing machines, garden watering, more attention to hygiene, etc., imply an increase in water use. The most important uses of water in households are for baths and showers (20–32 %), and toilet flushing (33 %). The percentage used for cooking and drinking is around 3 %. Water efficiency can be improved by using water-saving appliances.

9. Better information for users about the need to reduce water use and the available technologies to achieve this is required.

10. Water saving in households using such appliances ranges between 10 and 70 %. As an example, in the Netherlands, with a total demand for urban use of 1 014 million m^3/year and a share of 57 % for household demand, the water savings would be between 58 and 405 million m^3/year (6–40 % of the total urban demand).

11. Water savings are likely to increase when linked with metering. Therefore, there seems to be a better acceptance by users if they can see a reduction in their water bills.

12. Metering is an essential element of water demand management. Immediate savings from introduction of metering are estimated to be about 10–25 % of supply. The introduction of metering is usually accompanied by a revised charging system and leakage reduction schemes. It is difficult to separate the impact of meters from the other measures, in particular from the water charges applied.

13. Leakage reduction through preventive maintenance and network renewal is a main element of an efficient water policy. Losses in the water distribution network can reach high percentages of

the volume introduced. Leakage estimates from different countries not only show different states of the networks, but also reflect different ways of estimating them (Albania up to 75 %, Croatia 30–60 %, Czech Republic 20–30 %, France 30 %, Spain 24–34 %).

14. There are different ways of expressing the efficiency of a distribution network. Some of the indicators are described in the report. Nevertheless, many suppliers argue that these kinds of indicator may not be comparable and a large number of factors should be taken into account to assess leakage performance.

15. In the industrial sector, different technological approaches may reduce water consumption: water substitution, improving control of process conditions (water reduction about 50 %), and work in closed circuits (water reduction about 90 %).

16. The most important use of water for agriculture is for irrigation. Its importance varies across Europe, depending above all on the climate of the country considered. The major part of irrigated land in Europe is located in the south of Spain, Italy, France, Greece and Portugal, accounting for 85 % of the total irrigated area in the EU.

17. Transforming irrigation schemes from gravity into pressure irrigation systems is partly being applied in countries with a major share of gravity irrigation. However, the approximate cost of implementing pressure irrigation is of the order of EUR 10 000/ha, an amount that frequently surpasses the productive capacity of the respective areas.

18. In eastern Europe, the most extensively used method is sprinkler irrigation, but, due to economic problems, there is no control and maintenance and some of the schemes have been abandoned. Farmers cannot face the large investment resources for new irrigation equipment.

19. Financial instruments to encourage and help farmers to replace old irrigation equipment appear to be necessary to increase water use efficiency.

Economic approaches

Urban sector

20. The evolution of water policies in Europe, especially the implementation of the urban wastewater treatment directive, has had an important impact on the content of water bills.

21. Water prices are generally fixed at the municipal level and hence a country average covers large regional variation in prices. In Europe, for a family living in a house using 200 m^3 of water per year, Germany has the highest water charges in Europe (EUR 350.16), followed by the Netherlands (EUR 344.35) and Denmark (EUR 303.57). Italy (EUR 49.62) and Norway (EUR 84.83) have the lowest. Nevertheless, when assessing these figures, it is necessary to consider that the components and aspects contributing to them can be very different and thus make comparisons difficult and misleading.

22. The tariff structure has a high impact on the final water price. Different types of water tariffs can be used. The main types (excluding the initial connection charge) are:

- flat-rate tariff;
- uniform volumetric tariff;
- two-part or binomial tariff (sum of a flat-rate tariff and a uniform volumetric tariff);
- block tariffs, which also usually incorporate a flat-rate charge, plus declining block tariffs.

23. Two-part, rising block tariffs are widespread. Raising block tariffs, where successive blocks of water are sold at a higher price, exist in Italy, Portugal and Spain. In addition, a connection charge may be levied separately, as is the case in Denmark, Finland, France, Greece, the Netherlands, Norway, Spain and the UK.

24. Different case studies have shown that an increase in the water price has reduced the water use. Vulnerable water users may be affected by increased water prices. It is recognised that it is necessary to find a way of discouraging excessive water use which is compatible with the guarantee of a basic level of

domestic use with affordable prices for all citizens.

25. Participation of users is important in any process of water tariff changes (structure and price increases).

Industry

26. The industrial sector faces two different ranges of prices depending on the water source: direct abstraction or from the public water supply. Abstraction charges can take the form of a nominal licence fee linked to an abstraction permit regime or they can vary depending on the quantity used. Abstraction charges for industrial water uses are not in place in countries where water is deemed to be abundant (e.g. Sweden). It is usually cheaper for industrial users to invest in water abstraction and treatment facilities than to pay for supplied water.

27. In most countries, little information is available on tariff structures for industrial users because companies tend to enter into special contracts with water suppliers (e.g. the Czech Republic, Finland, France and Germany). In other countries, such as the UK, standard charges are available to all customers.

28. In some countries, subsidies can be made available for industrial users when they are willing to improve their water abstraction or treatment capacities (e.g. Austria).

29. The main motive to implement water conservation programmes in companies is abstraction charges and wastewater fees. Other factors can be legislative requirements for cleaner technologies, environmental image and concern for the reliability of water supply.

Agriculture

30. Irrigation has a different purpose in different geographical regions of Europe depending on their hydrological and climatic conditions and the crops grown.

31. The most common system for irrigation charges is based on the irrigated surface area, followed by a combination of per unit area and volume of water use.

32. In general, the amount of water used for irrigation responds moderately to water price levels, but can be more influenced by other factors such as climate variations, agricultural policies, product prices or structural factors.

User education and information

33. Educational and information campaigns in all sectors are always part of a wider plan for saving water, accompanying other initiatives to encourage more rational use of water. Because of this, it is difficult to quantify the effect of this kind of measure on water demand.

34. In the industrial sector, water savings are just part of a wider programme which includes measures to reduce water pollution and implement environmental management systems. The motivations can be reduction of environmental costs, legislative requirements, reduction of environmental risks, personal convictions of managers, and improvement of the company's public image. One of the objectives of an educational campaign targeting managers is the creation of a new mentality where environmental problems are as important as industrial (process) problems.

35. In the agricultural sector, the aim of the programmes is usually to help farmers optimise irrigation. This can be achieved through training (on irrigation techniques), and through regular information on climatic conditions, irrigation volume advice for different crops and advice on when to start/stop the irrigation period adjusting irrigation volumes according to rainfall and type of soil.

Water reuse

36. In general, the reuse of treated wastewater in Europe does not have widespread acceptability. Nevertheless, treated wastewater is reused in some Mediterranean countries such as Cyprus, France, Greece, Italy, Malta, Portugal and Spain, particularly for irrigation.

37. Until recently, the direct reuse of treated water in Europe has usually been in response to water shortages rather than as a planned activity.

38. At present, the most important use is for irrigation for crop cultivation, public gardens, parks and golf courses, followed by industrial use. Domestic use appears to be the sector least developed and is focused on only in pilot studies.

39. Article 12 of the urban wastewater treatment directive indicates that treated wastewater shall be reused whenever appropriate. This means that the amount of treated wastewater available for reuse should increase considerably by the year 2005 as the requirements of the directive are implemented across Europe.

40. The proposed water framework directive introduces the quantitative dimension of water resources which can have an impact on the consideration of the reuse of treated wastewater as an alternative source of water.

41. The existing wastewater reuse regulations depend on the type of application, the regional context and the assumption that there is a possible risk associated with the use of recycled water. However, the notion of 'risk exposure' is arbitrary and hence comparisons become difficult.

42. Guidelines at the European level for water reuse do not exist. At the national and regional level, the situation is variable where, in general, the development of standards and guidelines for wastewater reuse reflects the level of development of wastewater reuse in each country.

43. Existing standards and guidelines for the use of treated wastewater should be validated, and, if required, new ones should be developed, to safeguard public health and the environment.

44. The main benefits of treated wastewater reuse are conservation of water resources and pollution reduction.

45. The large investment required for treatment may inhibit the development of recycled water use. This cost will be lower if the site of reuse is as close as possible to the water producer.

46. The lack of running water in the rivers of some Mediterranean areas during some periods of the year makes the reuse of treated water impractical in these areas. This is because the water present in these rivers during the dry periods is the treated effluent arising from treatment works. The reuse (removal) of this water would leave the rivers completely dry.

Integrated water management approaches

47. Traditionally, measures concerning water resources management have been applied in different sectors in Europe. However, following the droughts in the 1990s, an integrated approach treating water not just as a resource but also as a natural habitat has been developed.

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Appendix — Case studies

1. Technological approaches

A. Water-saving devices

Case study 1. Water-saving devices at Raynesway and Mansfield, UK

Water-efficient equipment was fitted into the staff toilets of Severn Trent's Raynesway and Mansfield sites (UK Environment Agency, 1998d). The washrooms, used by manual and office staff, included shower blocks. Infra-red toilets, one-spout electronic taps, thermostat for hot taps, push taps, and new toilet flushes (7.5 l cisterns, rather than 9.5 l cisterns) were installed. At the Raynesway site, the cost of equipment was around EUR 3 000.

The new equipment resulted in an overall 60 % reduction in water use in the first few weeks. The savings achieved through the different appliances were as follows:

- gents urinals:
  mean decrease in water use = 93 %;
- ladies toilets:
  mean decrease in water use = 28 %;
- gents cold taps:
  mean decrease in water use = 78 %;
- ladies hot taps:
  mean decrease in water use = 54 %.

Case study 2. Water management in buildings of Kirklees Metropolitan Council, UK

In 1989, the Kirklees Metropolitan Council started a programme of reducing water use and implementing water metering to save water supply and sewerage charges in its buildings (UK Environment Agency, 1998d).

All the council's buildings were previously charged for their water supply and sewerage on the rateable value of the building. During the programme, water meters were introduced and usage carefully monitored. Overcharged accounts were identified and rebates requested from Yorkshire Water services. In addition to this, the following water-saving devices were fitted:

- 4 066 tank dams to toilets;
- 12 081 tap restrictors to taps;
- 488 push tap conversions;
- 433 electronic flush controls to urinals.

This strategy has reduced overall water consumption by a total of 127 500 m^3/year. In the first year of the programme, 53 sites were fitted with meters, costing EUR 28 500 but saving nearly EUR 137 000/year. The cost of the scheme between 1989 and 1994 totalled less than EUR 322 000, resulting in a saving per year of over EUR 475 000. Staffs costs amounted to less than EUR 71 000 over this period.

Case study 3. Water saving in seven pilot cities in Brittany, France

A major pilot project was initiated in seven cities in Brittany because of significant quantitative and qualitative problems of the local water resources (e.g. water stress, droughts and agricultural pollution). The cities involved were Brest, Lorient, Pontivy, Quinter, Rennes, Morlaix (St-Martin-des-Champs) and Vannes, corresponding to a total population of around 800 000. The project was financed by the regional council, the Environment Ministry, the water agency and the town councils. The project included a wide range of actions (Apogee, 1997), including:

- an information campaign (users and professionals);
- letters to domestic users;
- tests and installation of various types of water-saving equipment;
- investigations of leakage in the public distribution system and in private households.

The following figures show the significant quantities of water saved as a result of these actions using different methods.

B. Water metering

Case study 4. Metering policy in Yorkshire, UK

Since 1990, the water supplier Yorkshire Water has had a policy of installing meters in all new houses. Also, all commercial customers using more than 30 m^3/year must have a meter. From April 1997, the provision and installation of meters has been free of charge to customers who choose to pay by meter. Plus, from the same time, if customers have a swimming pool or use a garden sprinkler, they must have a water

Brittany case study - Water savings achieved Table A.1.

Action	Location	Investment cost	Volume saved	Percentage of water saved
Water-saving equipment for municipal irrigation	Brest	EUR 2 000	43 m^3/week	About 62 %
Water-saving equipment and leakage detection in individual schools	Brest		2.96 m^3/year/ pupil	51 %
	Lorient		5 500 m^3/year	79 %
Installation of meters and water-saving equipment in a community hall	Pontivy		About 1 600 m^3/ year	50 %
Installation of water-saving equipment in apartments	Rennes(43 apartments)		29 m^3/ apartment/year	
	Vannes(47 apartments)	EUR 360		30 % for toilet use
Water-saving equipment in a swimming pool and leakage reduction	Rennes	EUR 180		14 %
	Morlaix (St-Martin-des-C hamps)	EUR 560	2 340 m^3/year	30 %
Detection of leakage in network	Morlaix (St-Martin-des-C hamps)	EUR 3 800	1 300-1 800 m^3/ year	

meter fitted (free of charge also). The demand forecast is 160 000 households at the end of a three-year period being metered, with an estimated saving of 13 million l/day (YWSL, 1997).

Case study 5. Metering policy in Seville, Spain

In 1997, the supplier Emasesa implemented a plan to introduce individual metering in the flats of Seville city which had a collective meter. There were 18 300 buildings in this situation (around 225 000 households), and individual meters implied a water saving of 5 million m^3/year.

Different actions were taken:

- agreement with a credit company to give financial facilities to the users;
- free telephone information line;
- free materials granted for 10–20 % of the general works in the buildings;
- cooperation with different institutions to develop the plan (user and professional associations, manufacturers, etc.).

After one year, 6 557 households had an individual meter and the water use had been reduced by approximately 25 % (Emasesa, 1999).

Case study 6. Water metering and taxes, Denmark

Danish regulations require that water supply must be on a break-even principle, with accounts balancing over the years. In general (with few exceptions), customers must pay the costs, and suppliers cannot receive money from the municipality, State or country (Vangsgaard, 1997).

Despite a low price for producing water, the water bill reaches a considerable amount when the water sanitation fee, State tax (environmental tax) and VAT are added to the annual supply fee and/or charge for consumption. An average household with a water consumption of 170 m^3/year paid approximately DKK 600 in 1997.

The Danish Government aims to modify the tax system so that there is a reduction in income tax by increasing taxes on pollution and resources. The water bill is, therefore, expected to increase over the next few years, since the State tax (environmental tax) will be raised.

In many areas, water meters have been used for many years to determine water use (3.5 million out of the 5.3 million users currently having meters). However, as from January 1999, all private households have had to have a water meter installed. For flats, a single meter can serve a whole building. The meter readings will be used to calculate a pollution tax, on the basis that water use indicates the discharge to the sewage treatment plant.

Table A.2. **Network losses of drinking water production, Zurich (1985-97)**

Source: Skarda, 1999.

Year	Losses (%)	Year	Losses (%)
1985	10.5	1992	5.7
1986	10.4	1993	5.7
1987	10.0	1994	5.3
1988	9.0	1995	5.0
1989	8.2	1996	5.5
1990	6.4	1997	5.8
1991	6.4		

In addition, the communes must pay a fee to the State if the loss of water in distribution is greater than 10 % (metered water volume/ distributed volume). In many communes, there was previously very high leakage and this measure led to significant repairs all over the country. The average leakage level for the metered population is now 8.9 % (Danish Water Supply Association, 1997), with levels typically varying from 4 to 16 %.

Case study 7. Socially acceptable metering, Severn Trent water, UK

The benefits of water metering of domestic users are well known and used to encourage water conservation in many countries through charging systems based entirely or partially on used volumes. In introducing water metering to new regions, there are, however, social effects to be taken into account (UK Environment Agency, 1998b).

Survey evidence in the UK, where there are very few metered households, suggests that a substantial sector of the general public in England and Wales (30–50 %) is not convinced of the fairness of measured charging. An increase in metering should therefore be accompanied by significant information efforts.

C. Leakage reduction in distribution networks

Case study 8. Decreasing of network losses in Zurich, Switzerland

The Zurich water supply company carries out a leakage control of 40–50 % of the total distribution network length every year. The water losses are usually caused by leakage through external corrosion, joint leaks and leak idling valves, as well as by pipe breakage (Skarda, 1999).

The index to assess the network performance according to water losses is the specific value in m^3/hour based on the total distribution network length. The IWSA Congress, Durban, 1995, presented this indicator with limits of between 0.5 and 4.0 m^3/hour/km. In Zurich, the value has moved in the last 10 years from 0.57 to 0.22 m^3/hour/km. During the same period, leakage losses decreased from around 10 to 5 % (see Table A.2).

The company focuses its maintenance approach on the following tasks.

- Network monitoring and leakage control by annual inspection of at least 40 % of the overall network length is conducted by network service technicians and leakage specialists. Roughly 10 % of all damaged pipes can thus be located and repaired more economically.
- Network flushings on the dead ends and hydrant controls are carried out regularly. Around 10 000 hydrants are checked, flushed and repaired biannually. A check list is used by which around 3 000 technical defects are located yearly. Annually, 0.6 hours are necessary for the maintenance of one hydrant.
- Areal network maintenance is periodically carried out. Valves, street surface boxes, signs, etc., are locally inspected, cleaned, made accessible or restored. As an actual approach, regular checking and elimination of air is made.
- Pressure surge measurements and stray current measurements are periodically carried out to maintain the up-to-date situation of performance analysis.

The costs of the above operations are as follows.

Concepts	Man-hours/ km/year	CHF/ km/year
Repairs	5	5 000
Preventive maintenance	25	3 000
Renewal	25	15 000
Total	55	23 000

Case study 9. Assessment of the efficiency of rural water supply networks in Savoie, France

During the tourist periods (summer, autumn and winter holidays), the population of Savoie (in the French Alps) doubles and the water use increases significantly. This effect is illustrated by the case of the rural municipality of Tignes, which is an important ski resort (see Figure A.1). Unfortunately, this coincides with the lowest river water flows, meaning that water resources can easily come under stress.

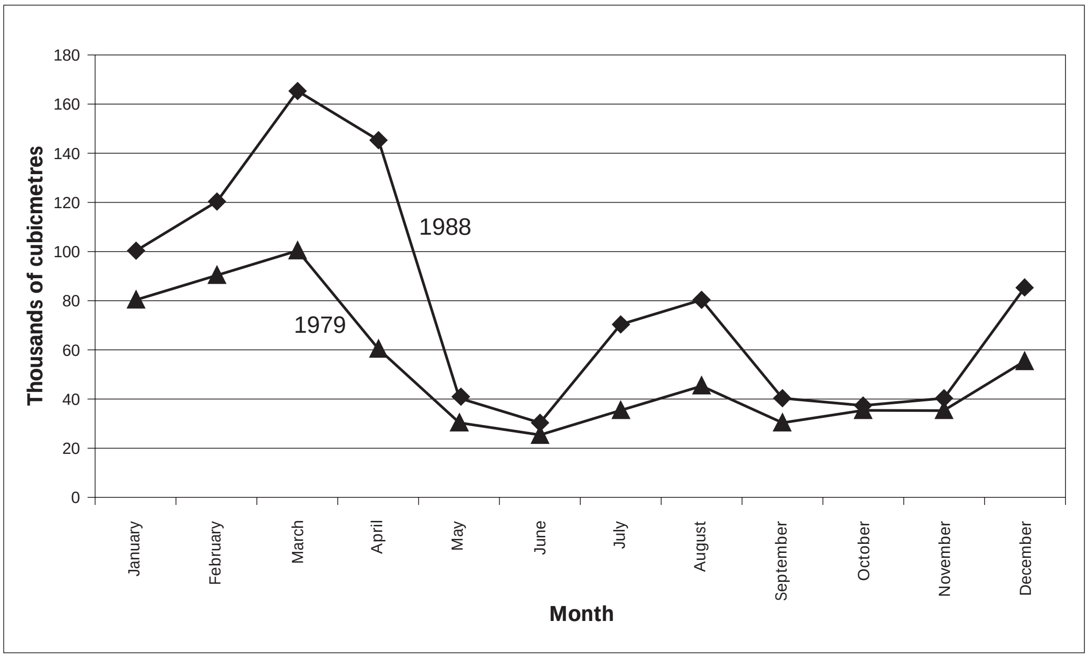
The water, agriculture and forests service (DDAF) carried out a study to evaluate the state of the freshwater network for 28 rural local authorities (Requilart et al., 1992). The evaluation method was simple and adapted to small or medium-sized municipalities. It involved the analysis of flows recorded at water reservoirs over one week (hour-by-hour production, analysis of night consumption to estimate leaks) in collaboration with the local operator. The results were as follows:

- 11 % of local authorities have distribution networks in a satisfactory state (linear leakage index of less than 5 m^3/day/km);
- 21 % of local authorities have distribution networks in a satisfactory state, but they should be continually monitored because they are old (linear leakage index of between 5 and 10 m^3/day/km);
- 21 % of local authorities have distribution networks with real leakage problems (linear leakage index of between 10 and 20 m^3/day/km). Most of these authorities have undertaken leakage searches or intend to do so in the future. For example, one of these local authorities subsequently decided to trace and repair the leakage. Its efficiency ratio (volume meter at the house level/volume produced) was originally about 41 %. After the leakage tracing and repairs, the ratio is now around 86 %;
- 47 % of local authorities have severe leakage problems (linear leakage index of more than 20 m^3/day/km), which may be due either to network leakage or to wasteful use due the absence of meters for users. Most of these authorities have undertaken work to improve the situation (installation of domestic meters, leakage searches, overall pipe replacement programme).

Through contacts with the different local operators, it became apparent that distribution network maintenance is not a priority for most rural municipalities. It was observed that:

- regular monitoring and maintenance of existing network taps are not carried out;
- network plans, when they do exist, are rarely up to date – often only one person knows the network well;
- the municipal employee who operates the network has other responsibilities and

Monthly distributed water volumes at a French skiing resort, Tignes, in 1979 and 1988 Figure A.1.



only spends limited time on maintenance, often because of the lack of available advice on the subject;
- 15 % of municipalities do not insist on meters for domestic users. With a few exceptions, the price of water is estimated to be 40 % lower than the national average. This low price is explained by two factors: lack of knowledge concerning the real costs and the decision to meet costs through taxes rather than user payments.

General network meters are considered necessary to enable good network management. For this reason, the DDAF has produced a guide intended to encourage good meter installation.

It should be noted that tracing and repairing the leakage can be very expensive. Since increasing water production to 'feed' the leaks may prove cheaper in some systems, some local authorities decide not to trace leakage despite low efficiency ratios.

Case study 10. Leak detection in Cornwall, UK

During the period 1992–95, the water company South West Water developed a leakage control programme, and enough water was saved to supply the domestic needs of Cornwall.

The company started to install valves and measuring equipment in its 471 district meter areas (DMAs). They were split into 20 leakage control types – pubs and farms, for instance – and a survey was undertaken into legitimate night use in each category. It also introduced the so-called 'super-key meters' which measure the water that leaves each water treatment works.

The company also developed a mathematical model known as MELT (modelling economic leakage targets). The first step in creating the model was to break down the company into 65 'water into supply' zones. Any water entering or leaving or being produced in a zone was measured. The measuring devices were connected to telemeters to obtain details of instantaneous demand. The model sets leakage targets for each zone.

Case study 11. Maintenance of the collective Neste irrigation canal, Toulouse, France

The Neste canal was originally constructed in the 19th century to transfer Pyrenean water to Gascon rivers (CACG, undated). The canal follows the Neste valley for 29 km through mountainous terrain before flowing into 90 km of sub-canals which supply 17 different rivers. At the head of the system are a number of large reservoirs which stock water during the winter in order to increase flows in downstream rivers. The canal now transports 250 million m^3 of water each year for all uses, including drinking water (200 000 inhabitants), irrigation (30 000 ha of direct irrigation plus filling of smaller reservoirs during the winter), industry (including Atochem and Pechiney) and ecological flow.

Since its construction 130 years ago, only very limited work had been carried out on the canal (flow increase from 7 to 14 m^3/second and repair of some collapsed sections). In the late 1980s, it was observed that the canal was degrading, posing problems for the operator (difficult access and real-time management), users (low efficiency and leakage) and populations (instability and risk of collapse). A restoration programme was undertaken over 10 years to modernise the canal and the estimated cost was around EUR 40 million.

In particular, the significant leakage meant that, in 1989, 13.3 m^3/second were distributed, but only 11.5 m^3/second were delivered. In order to remedy this, fissures and holes were filled in and then sprayed reinforced concrete was applied along nearly 20 km. The works required the canal to be emptied and other temporary water supplies found for users during certain periods.

2. New technologies

A. Industry

Case study 12. Recovery of waste effluents at a textile factory, Separem, Italy

A new process and type of membrane that can integrate reverse osmosis with traditional systems was introduced in a textile factory in Italy in 1989 (UNEP ICPIC, 1996). This allowed the complete recovery of the waste effluents from the dyeing and finishing processes. After a series of steps which include biological and physical-chemical treatment, prefiltration, reverse osmosis and conventional decolouring/concentration and make-up processes, the recovered water and auxiliary chemicals can be recycled back to the plant. Besides the recovery of water (95 %), highly polluting waste discharges were virtually eliminated and energy was recovered. The process pays for itself and the payback time for the investment was estimated to be one to two years.

Case study 13. Water substitution: replacement of water by an enzyme in textile finishing, Skjern Tricotage-Farveri a/s, Denmark

Natural fabrics like cotton are normally bleached with hydrogen peroxide which is highly reactive and must be removed before dyeing. The traditional method, known as 'bleach cleanup', is to remove the agent by rinsing the fabric with large quantities of water (in some cases up to 40 l/kg of fabric). Enzymes provide a more convenient alternative for decomposing hydrogen peroxide because they are easier and quicker to use; they also result in reduced water and energy consumption.

Full-scale trials on a commercial catalase enzyme (Terminox Ultra manufactured by Novo Nordisk) were carried out in the early 1990s at a Skjern Tricotage-Farveri A/S, a modern dyehouse with an annual production of around 5 000 t of fabric and which previously used the 'bleach cleanup' approach (UNEP ICPIC, 1996).

The results showed that water use at the factory dropped from 19 to 10 l/kg of fabric with the use of the enzyme method. There were no additional investment or operational/maintenance costs, since the same machine is used and no further equipment is necessary. The payback time is therefore immediate. The cost savings correspond to the drop in water charges.

Case study 14. Water substitution and recycling: Powergen's Kingsnorth power plant, UK

Recovery and recycling of wastewater, the use of reverse osmosis and substitution of mains water by saline borehole water for fire and general washdown systems have allowed the plant to reduce water consumption by 90 % and cut water treatment costs by 75 %, saving GBP 800 000 a year (*Water UK*, 1998b).

Case study 15. Revising a wastewater treatment system: Danfoss factory, Denmark

In 1983, the company Danfoss, whose other products include hermetic processors, compressors, motors and electrical components, initiated a series of water-saving programmes and revised its wastewater treatment system. By 1994, it had reduced consumption by 80 % (*Water UK*, 1998b).

Case study 16. Improving control of process conditions: sensors and monitoring at a laundry service, Kvalheim Vask as, Norway

The company Kvalheim Vask AS (43 employees) washes and cleans clothes for hotels, hospitals, private customers, the army and other institutions (UNEP ICPIC, 1996). Prior to the project, water with detergent was discharged to the sea, no formal quality assurance system was in place and maintenance was manual. The quantity of water used was 28.8 l/kg of cloth.

A nationally funded project to establish a strategy for cleaner production and bring economic benefits was carried out in 1992. The project involved process modifications and 'good housekeeping'. In particular, the measures which contributed to reducing water consumption included:

- process monitoring of washtubs (amounts of water, dosing of detergent);

- reuse of washing water, requiring the installation of a circulation tank, a microfilter and a storage tank;
- installation of a new washing machine.

These measures reduced water consumption by about 50 % (to 14.6 l/kg of cloth). They have acceptable payback times (generally five to seven years) when reduced water costs and maintenance costs are taken into account.

Case study 17. Closed circuits: wastewater reclamation and reuse at a sugar factory in Valladolid, Spain

In the early 1980s, the ACOR-1 sugar-processing factory was a heavy consumer of water. The application of the European Community directives and the Spanish Water Act imposed stricter water management, taxing pollution and wastewater discharges. The factory carried out a series of actions with the following objectives (Kuzminski et al., 1991):

- to comply with compulsory regulations before the given deadline;
- to reduce the environmental impact of the industrial activity;
- to obtain more autonomy on the management of water;
- to update the technology used at the facility in order to be more competitive;
- to enhance the environment-aware public image of the company.

In terms of water use, the main consumer component in the factory was the barometric condenser (designed to use 10 m^3/tonne of processed beet or 230 l/second in the 1960s). It should be noted that the transport and washing circuit (using 15 l/second) was already a closed-circuit design, in contrast to many other plants which were designed with open circuits (200 l/second).

The actions included:

- education of the management staff and creation of a new mentality, where environmental problems were as important as industrial (process) problems;
- segregation of different process and wastewater streams;
- closed barometric condenser with cooling tower system;
- installation of a biological anaerobic treatment plant with recirculation of a fraction (5 l/second, corresponding to 20 %) of the effluents (with increased alkalinity) towards the transport and washing circuit.

These actions (achieved over the period 1984–90) were designed and monitored by the Universidad de Valladolid. They enabled a reduction in water consumption from 330 l/second to 35 l/second in 1990 (for 3 500 t/day of processed beet in 1990), corresponding to a decrease of nearly 90 %. In addition, the discharges to the environment were reduced by more than 90 % in terms of biological oxygen demand (BOD) pollution.

In terms of costs, the different installations (wastewater treatment plant and cooling tower system) required an investment of EUR 1.52 million. Operating costs for the different components are as follows:

- wastewater treatment plant (pumping energy, operation and maintenance): approximately EUR 85 000;
- cooling tower system (pumping energy and maintenance): EUR 66 700.

The costs of the installation, operation and maintenance were easily offset by the savings made on discharge tax reductions. The discharge tax was EUR 412 250 in 1984 as against EUR 42 400 in 1990 after the new process installation. There are also profits from biogas utilisation (EUR 103 000).

Case study 18. Recycling process water: FIAT, Italy

The car manufacturer FIAT has been using modelling to cut its water consumption since the 1960s. High-quality water is used for drinking water and special production operations, while lower-grade water is used for less sensitive processes. In addition, 92 % of drinking water and all cooling water are recycled back into industrial operations rather than going to waste. As a result, the company has reduced its annual water bill by ITL 2 billion.

Case study 19. Recycling process water: electro-zinc plating in an ironware factory, Vom, The Netherlands

A low-cost reduction in water consumption (and waste production) was achieved in the 1980s at a small ironware factory in the Netherlands producing 700 t/year of door locks, screws, etc. (UNEP ICPIC 1996), by introducing in-line measures, including longer dripping times, cascade rinsing, continuous regulation of baths and rinse water reuse. For this, some water purification and filtering treatment were necessary. The required equipment is commercially available.

In terms of organisation, it was necessary to divide the two existing drum lines into four different plating lines. In particular, rinse water is reused and water from previous lines is used in subsequent lines. The techniques resulted in a water reduction of 80 000 to 8 000 m^3/year, as well as lower metal pollution levels in the wastewater.

Case study 20. Closure of the water cycle in a steel factory, Bankova, Poland

A steel factory in Bankova, Poland, eliminated industrial wastewater and reduced around 80 % of the intake of water from the Czarna Przemsza river to the forged rolled rings department. The action consisted in the application of two pumps with smaller deliveries and a system of asynchronous cascade to control capacity.

The motivating factor was the high ecological fees. The cost of the new process was EUR 0.3 million.

Case study 21. Repair and building of the biological treatment plants in the Makoszowy Cokeries in Zabrze, Radlin and Knurow, and reuse of treated wastewater, Poland

A biological wastewater treatment plant was built with the aim of reusing wastewater in the wet quenching of coke process. After the treatment process, water is directed to supplement the cycle of wet quenching of coke. The action had financial support from different institutions (National Fund for Environmental Protection and Water Management, Bank for Environmental Protection, Regional Fund for Environmental Protection in Katowice). The objectives of the initiative were: reduction of water use, reduction of ecological fees and protection of the environment. A reduction of 50 % of water use was achieved and the cost was around EUR 0.7 million in each factory.

Case study 22. Reusing of washery effluent in water supply factories, Poland

In order to reduce water use and charges for water abstraction, the water supply companies of Maczki, Goczakowice and Dzieckowice cities built an installation to recycle part of washery effluents which were previously discharged to lagoons.

The water saved was:

- Maczki 6 000–7 000 m^3/day;
- Goczakowice 10 000 m^3/day;
- Dzieckowice 7 000–13 000 m^3/day.

The total cost of the action was EUR 0.23 million.

B. Agriculture

Case study 23. Irrigation land in the Russian federation

In 1967, the irrigated area of the Russian Federation was 1.62 million ha, which was eight times greater than that of 1916, while the drained area of 1.64 million ha was almost twice that of 1916. By the end of the 1980s, up to 200 000 ha of newly irrigated areas and 160 000 ha of newly drained areas were added every year for agricultural use. However, the negative effect resulting from the drying-up of wetlands and from the salinisation of irrigated areas was the lack of speed. The speed of development of irrigation and drainage work slowed down at the beginning of the 1990s.

Based on climate and soil conditions, it is estimated that 15–20 % of the cultivable area needs irrigation in the moderately warm dry semi-desert zone, 5–8 % in the moderately warm semi-dry steppe zone, 2–5 % in the moderately warm semi-dry forested steppe zone, and 1–2 % in the moderately warm forest zone. The figure for irrigation potential is estimated at almost 29 million ha under permanent irrigation. Other sources give a potential of more than 74 million ha of complementary irrigation.

In 1990, irrigation covered 6.12 million ha. In 1994, however, it had fallen to 5.16 million ha, which was equal to about 4.4 % of the cultivated area. One reason for the decrease was the economic recession. The sprinkler systems (accounting for almost 96 % of the area equipped for irrigation in 1990) are overused, and there is no maintenance and operation system. This progressively results in the complete destruction and subsequent abandonment of the schemes. Another reason might be that, in the past, the statistics were overestimated; the figures for more recent years seem to be more reliable. The largest irrigation development has taken place in the north Caucasian and Volga regions.

Irrigation was undertaken mainly on huge *sovkhoz* and, to a lesser extent, on *kolkhoz*. Water fees were formally introduced in 1982, but the charges were quite insignificant and never actually collected. Until 1996, no organisational forms of water administration for the newly created farms existed.

Most of the water for irrigation comes from reservoirs, and open canals convey the water to the irrigation schemes. The largest canals are Saratovski, Donski, Magistral, Great Stavropolski, Tersko-Kumski and Kumo-Manycki. Within the schemes, underground pipes convey the water to the emitters (rain guns). Sprinkler irrigation is the most widely used technique (96 % of the area), surface irrigation being used on the remainder. In 1990, only 21 % of the irrigated land was equipped with a drainage system.

In 1994, irrigated crops covered almost 4.1 million ha, equal to 79 % of the equipped area. Fodder represented the largest irrigated crop area with almost 2.6 million ha, 62 % of the total. It was followed by cereals. Yields of irrigated crops are higher than those of rain-fed crops. Irrigated maize yields are about 2.7 t/ha compared with 1.7 t/ha for rain-fed maize. For barley, the respective figures are 2.25 and 1.65 t/ha (FAO, 1998).

Case study 24. Irrigation in Estonia

The irrigation potential in Estonia is estimated at 150 000 ha. All irrigation is sprinkler irrigation. Different types of sprinkler irrigation systems have been constructed during the last 20 years, depending on the scheme size and technological improvements. The large irrigation systems were generally of poor quality and were soon abandoned. During the 1980s, only drag hose irrigation systems were used. The area equipped for irrigation reached almost 14 000 ha by the end of the 1970s, but was reduced to 3 680 ha in 1995 due to the liquidation of the *kolkhoz* and *sovkhoz*. More than 50 % of the area equipped is reported to need rehabilitation. The irrigation areas are mainly located in the north and east of the country. All the area is irrigated by surface water, of which 80 % is by pumping from rivers and 20 % from reservoirs. The main irrigated crops are pasture and vegetables.

Almost 70 % of the irrigated areas are found in large-scale schemes, with areas between 100 and 300 ha each, while under 1 % of the irrigated areas are in schemes of less than 10 ha each. The cost of the development of sprinkler irrigation schemes varies from EUR 495/ha for large-scale schemes to EUR 802/ha for small-scale schemes.

Only small-scale irrigation schemes (5–10 ha) with drag hose equipment are expected to be profitable. At present, farmers lack the large investment resources needed for new irrigation systems (FAO, 1998).

Case study 25. Irrigation in Latvia

In order to increase yields, improve quality and secure production, experiments with sprinkler irrigation on vegetable plantations, early potatoes and sugar beet started in the 1970s in Latvia. The first sprinkler systems were installed on the 'Peternicki' experimental farm in the Jelgava district and then on the 'Uzvara' *kolkhoz* in the Bauska district and on the 'Kekava' *kolkhoz* in the Riga district, all in the Zemgales plain. At present, the irrigated area covers about 20 000 ha. All irrigation is sprinkler irrigation, and irrigation, in general, is supplementary irrigation. The main irrigated crops are potatoes, vegetables and sugar beet (FAO, 1998).

Case study 26. Irrigation in Lithuania

By the end of 1970, irrigation in Lithuania covered 5 100 ha, in 1975 it was 22 300 and in 1990, 42 700 ha, but in recent years there has been a rapid decrease due to the privatisation of farmland. Private owners started working in small areas (8–20 ha), and many of the large irrigation systems stopped functioning. Farmers are not interested in using large, costly irrigation schemes (FAO, 1998).

Case study 27. Water use for livestock: water savings in dairies, Brittany, France

The principal animal produce in Brittany is milk, with 900 000 head of cattle present in the region. As for many agricultural activities, water consumption is very high, with the most likely source of water saving being the milking rooms through which two thirds of all Brittany cows pass. Although there is much variability between dairies, water use in each milking room can be estimated as follows:

- milking equipment and pipes (150–450 l/day);
- tanks (40–55 l/day);

- platform humidity maintenance (20–70 l/day);
- washing of equipment (30–250 l/day);
- cleaning of platforms, channels, waiting area (200–370 l/day).

This corresponds to 15–26 l/milked cow/day, and, for the 600 000 cows currently milked in Brittany, to approximately 12 000 m^3/day. For the other 300 000 cows which are kept in sheds, the drinking water use is 8 l/day, corresponding to a total of 2 400 m^3/day in the region. This results in a total use of 14 400 m^3/day, of which it is considered that much water could be saved.

The milking equipment and pipework use around 36 % of the total water used; however, it is often difficult to evaluate how much water is being used at a particular site unless metering is carried out. In order to measure the volumes being used and to limit water required for the prewash–wash–rinse cycle, a tank can be installed before the wash. Although the practice is sometimes observed, it is not advisable to reuse rinsing water for pre-washing because of the effects on milk quality. Water savings at the 'lactoduc' can represent up to 20 % of the total milking room use.

Another strategy to save water is to stock the washing water of the milking equipment/pipework in a large tank for use in cleaning the milking room. A pump (costing EUR 200) is needed, but it enables 45 % of the milking room's use to be saved and corresponds to a reduction in water costs of EUR 80–160/year.

A model project was carried out on five farms in Brittany and resulted in 38–60 % of water savings for each farm. An advantage of reducing water use is that the quantities of farm slurry are reduced, requiring less storage capacity and lower transport and spreading costs.

3. Economic approaches

A. Water charges

Urban sector

Case study 28. Implementation of new tariff structure, Santa Cruz de Tenerife, Canary Islands, Spain

The water use in the city of Santa Cruz de Tenerife increased between 1985 and 1991. From 1992, it has slowed down after the implementation of the following measures (see Figure A.2):

- campaign of education for water saving;
- new tariff structure (rising blocks) with variable prices by m^3.

The new tariff included a fixed service charge and a variable tariff divided into five rising blocks for domestic use and just three rising blocks for industrial use (see Table A.3).

Case study 29. Socially acceptable metering: Severn Trent Water, UK

The effects on socially disadvantaged households should be taken into account when pricing is determined. Those households which are most vulnerable to water metering and pricing are those which have low incomes and high levels of essential water use (large family size and poor medical conditions). Two options are possible: direct subsidies via the social security system and cross subsidies through a designed measured tariff system. For the latter, it is difficult to measure factors that lead to high essential use and most options relate to social security status or property type.

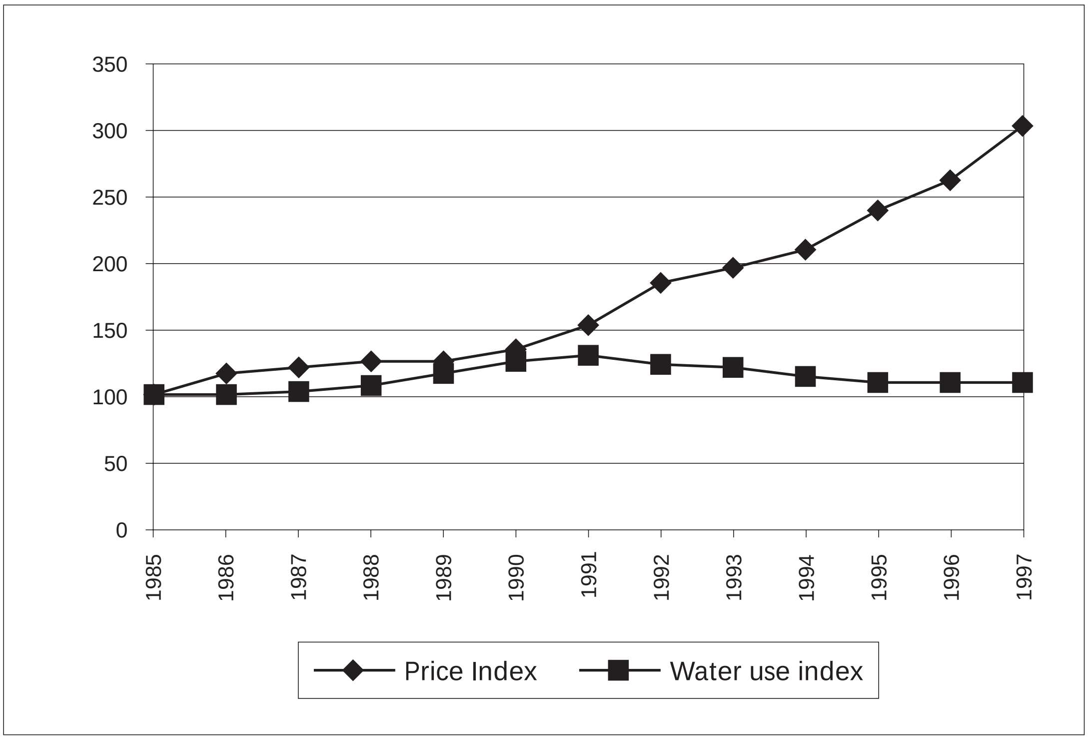
An example of a rising block tariff related to property type has been tested for Severn Trent Water, based on the property band defined by the council tax. This would enable a reduction in 20–30 % of the peak summer use, while leaving 80 % of vulnerable households financially better off than the present system.

Case study 30. Hosepipe permits and charges in Cambridge, UK

The area served by the Cambridge water company is one of the driest in England, with an average rainfall of 550 mm/year. In all, 96 % of the water supplied is derived from the unconfined chalk aquifer to the south and the east of Cambridge. But, from

Figure A.2. **Tariff structure and water demand in Santa Cruz de Tenerife, Canary Islands, Spain (1985-97)**

Source: Emmasa, 1999.



Tariff structure for water use, Santa Cruz de Tenerife, Canary Islands, Spain (1998 and 1999) Table A.3.

Concepts	Tariff for 1998 (ESP)	Tariff for 1999 (ESP)
Domestic water		
Fixed service charge	2 001/bimonthly	2 051/bimonthly
Rest of sections	Variable	Variable
Fixed charge for meter maintenance	53/month	54/month
Charges for wastewater collection and treatment	41/month	42/m^3
Water demand (m^3/bimonthly)		
From 1 to 10 m^3	56/m^3	57/m^3
From 11 to 20 m^3	67/m^3	69/m^3
From 21 to 40 m^3	174/m^3	178/m^3
From 41 to 60 m^3	221/m^3	227/m^3
More than 60 m^3	287/m^3	294/m^3
Industrial water		
Fixed service charge		2 513
Fixed charge for meter maintenance (section 13 mm)	53/month	54/month
Charges for wastewater collection and treatment	41/month	42/m^3
Water consumption (m^3/bimonthly)		
From 1 to 10 m^3	77/m^3	79/m^3
From 11 to 20 m^3	133/m^3	136/m^3
More than 20 m^3	339/m^3	347/m^3

Source: Emmasa, 1999.

1988 to 1992, the area experienced its worst drought since modern records which commenced 100 years ago. Groundwater levels fell by over 8 m from the maximum levels reached in January 1987.

The population of the towns and villages around Cambridge had grown at the fastest rate in the UK. The increase in population (to 284 000 inhabitants) led to a greater demand for water, which threatened to outstrip supplies. Most alarming was the growth in summer peak demands.

The water supply company decided to meter all sprinkler users compulsorily (Kay, 1996). Customers were offered three options:

- continue to use a sprinkler and be metered at the company's expense;
- use a hand-held hosepipe only and pay the appropriate permit fee;
- abandon the use of a hosepipe or a sprinkler.

Personal contact was made with every customer having a sprinkler permit, and over 20 % opted for a meter with most of the others moving to a hosepipe permit. All the meters were fitted by May 1993, ensuring that all legitimate sprinkler uses were recorded during the summer of 1993.

There are no precise data about the quantity of water saved, but lower-peak flows were observed during the dry periods in 1995 and 1996. The company experienced its single highest daily demand in 1989 (105 million l/day), and its highest seven-day average in 1990 (98.8 million l/day). Since then, the population supplied has increased by 4.5 %, but the average demand in the peak week was 96.3 million l/day in 1995 and 95 million l/day in 1996 with a peak of 100.8 million l/day. When the peak week for 2000, forecast in 1990, is compared with the peak week for the same year, forecast in 1996, the reduction is 16 %.

In the customer survey carried out as part of the project, over 90 % of customers expressed satisfaction with the company's performance in implementing the policy.

Case study 31. Gelsenwasser group, Germany
An example of how decreasing demand can affect the economic result of a supply company is the case of the Gelsenwasser group in Germany (Financial Times Newsletters, 1998a).

The Gelsenwasser group, which supplies water and gas in the North Rhine-Westphalia city of Gelsenkirchen, saw sales drop in the first half of 1998 and anticipated an overall drop for water for the whole of 1998. Water sales dropped from 137.4 million m^3 in the first half of 1997 to 133.5 million m^3 in the first half of 1998. However, an increase in water prices helped Gelsenwasser to lift turnover from DEM 210.3 million to DEM 213.6 million, and pre-tax profits rose from DEM 36.8 million to DEM 37.2 million.

Agriculture

Case study 32. Water charges in Malta

In Malta, there are three categories of farming in the irrigation subsector and an estimated 3 000 farmers, both full-time and part-time, are involved. Most of the irrigated farms are normally leased to farmers and operated by individuals. The source of water is often shared with others, since both the land and water rights are inherited with the lease resulting in land fragmentation. Very often, the irrigated farm is scattered over various localities giving rise to problems of access to fields, conveyance of water and laying of irrigation networks and schemes. Some farmers frequently have shares of water rights from various groundwater sources which may further complicate the irrigation scheduling. There are no water charges for abstraction of groundwater from these private boreholes.

Irrigation schemes which are supplied with treated wastewater from sewage treatment plants are run by a government agency. Treated water is supplied to five government reservoirs and is distributed to farmers by means of a channel system for a nominal fee of EUR 99/ha, within a social project to increase revenue in the farming community. The running of the individual farms is, however, entirely the responsibility of the farmer. Water from government-owned boreholes producing 0.09 million m^3/year second-class water (high nitrate or high salinity) is offered to farmers in the vicinity at EUR 0.10/m^3, in preference to using it for domestic supply (FAO, 1997).

Case study 33. Irrigation pricing by a regional water development company, BRL, France

The Compagnie d'Aménagement du Bas-Rhône Languedoc (BRL) is one of the largest regional water development companies in France, and was created in the 1950s in order to enable agricultural development through hydraulic works (reservoirs, canals) between the Rhône river and Spain. Agriculture is the principal client of BRL (130 000 ha), accounting for 70 % of the water use with, however, only 50 % of the invoices.

The objectives, instruments and consequences of water pricing systems used by BRL through three periods between 1960 and 1995 illustrate the complexities of financial and water demand management for this type of infrastructure and show how tariffing can be adapted as objectives and environmental considerations change (see Table A.4).

Table A.4. **BRL water pricing systems (1960-95)**

Source: Montginoul, 1997.

Period	Objectives	Instruments	Consequences
1960-70	Development of irrigation in the region and elaboration of a pricing mechanism	1. Initial fixed tariff per ha is not a sufficient incentive 2. Tariff proportional to volumes	• Irrigation develops • Poor cost recovery for proportional tariff
1970-92	Stable tariffing accepted by farmers	1. Binomial tariff (specified flow and consumed volumes). 2. Minimum fixed price 3. Regular tariff revision based on a fixed part, agricultural product prices, and energy and manpower costs of BRL	• Poor control of costs due to overestimation of irrigation installations (low investment by farmers), based on theoretical coefficients • Badly adapted price revisions, which do not follow inflation • Advantage for consumers over non-consumers because of the minimum fixed price
1992-95	Tariffing as a function of demand, within budgetary constraints(better cost evaluations indicate that an increase of 20 % in income is needed)	1. Binomial tariff (specified flow encourages farmers to use lowest flow possible even for large consumption) 2. Different contracts according to commitment period 3. No differentiation of zones nor of periods	The pricing system: • is fair (all types of farmers have the same system) • enables choice between different contracts for different demand characteristics • takes into account costs (tariffs are above marginal costs)

4. User education

A. Urban sector

Case study 34. Water-saving measures in Copenhagen, Denmark

Over 98 % of water supply in the Copenhagen agglomeration (half a million people) comes from groundwater abstractions. The need to reduce the water demand was based on the following factors (Hansen, 1997):

- multiple close-down of groundwater wells due to pollution (at present the Copenhagen water supply company has closed wells with a total capacity of 5.4 million m^3/year due to pollution; another 25 million m^3 are threatened by pollution);
- public concern for groundwater levels in order to protect streams and wetlands;
- increasing water prices (200 % over 1989–95) due to huge investments in wastewater treatment – the introduction of a governmental tax on drinking water which would increase the price even further is planned.

From 1989 onwards, the Copenhagen water supply company has initiated several projects for the reduction of water consumption, using the following strategy:

- influencing consumption habits through information about drinking water;
- implementing special information efforts targeted at schools and kindergartens;
- making an effort to prevent water loss in houses – information meetings with house owners, cooperative housing societies and tenants associations, etc., have been held;
- providing advice for firms, industry and trade to implement cleaner technologies, especially concerning water-saving measures;
- minimising water loss in the public distribution system.

The following methods have been used.

- Information campaigns aimed at the domestic consumer in Copenhagen: the first of these was launched in 1989, followed by a second in 1992 and a third 1995. The campaigns were carried out through advertisements on buses, taxis and trains as well as on television and radio. Pamphlets and posters were distributed to all households.
- Establishment of a water-saving advice centre: this centre was formally established in 1992 and organises information campaigns aimed at the domestic consumer in Copenhagen. The initial information activities concentrated only on water-saving measures (information campaigns and technical actions for large water consumers and domestic users).
- Water-saving devices: the staff in this section advise plumbers, consulting engineers and other clients on employing water-saving devices when construction work is carried out.
- Systematic investigations for leakage in the public distribution system: the staff in the urban pipeline section carry out systematic leak tests. The section is also concerned with pipeline renovation and, therefore, constantly tests new methods of renovation techniques.

The total supply from the Copenhagen water supply company was reduced from 82 million m^3/year in 1989 to 66.2 million m^3/year in 1994. This amounts to a total reduction of 15.8 million m^3/year for the whole agglomeration.

In the central city of Copenhagen, water use fell from 44.9 to 36 million m^3 over the period 1989–94; however, it is considered that further savings can be achieved. In 1994, the Copenhagen City Council approved a proposal for a comprehensive plan concerning the future water supply of the city (the Copenhagen water supply plan). The highest priorities within this plan are as follows:

- efforts against leakage in the public distribution system;
- renovation of the water distribution system in the city;
- efforts and initiatives to reduce water use.

The Copenhagen water supply plan aims to reduce water use so that it reaches 32 million m³/year by 2000. This reduction is mostly expected from a fall in domestic demand, which is currently at around 138 l/inhabitant/day. The target is to reduce this to 110 l/inhabitant/day by the year 2000. Efforts are also being made to reduce the significant leakage part in the unmeasured use. The distribution into the different categories is shown below.

Sector	Water use in 1994 (million m^3/year)	Water use in 2000 (million m^3/year)
Domestic	23.7	18.9
Industrial	7.8	7.9
Institutions	2.5	3.1
Recreational	0.4	0.4
Unmeasured (fire fighting, pipeline work, meter defects, leakage in distribution)	1.6	1.7
Total	36.0	32.0

B. Industrial sector

Case study 35. Cleaner technology and water demand reduction in France

Table A.5 provides some examples of recent results in industries in France (Orée, 1997). In each case, the strategy has been to improve overall environmental performance and management. Frequently, water saving is only part of a larger programme which includes a whole range of measures, often aiming to reduce water pollution, but also to manage wastes, reduce odours and noise and implement environmental management systems (e.g. ISO 14001).

The Orée is an association created in order to promote partnerships between small and medium-sized enterprises and local authorities by developing methods to increase environmental management in companies and by encouraging the exchange of experience. The association has over 50 members, comprising local authorities and companies mainly in the food, beauty and chemical industries.

Through the European initiative ADAPT (under the European Social Fund and co-financed by the Environment Ministry), it

Table A.5. **Examples of water savings within environmental management initiatives in French industries**

Source: Orée, 1997.

Company (location)	Raw material/production quantities	Brief description of actions related to water savings	Results
Coralis (Cesson Sévigné)	Processing of 120 million l of milk per year to produce milk, butter, cream and evaporated milk/buttermilk	• Closed-circuit network • Process modification • Recycling of recovered streamwater • Optimisation of cleaning	Water saving of 40 % over 1990-95
Distillerie du bois des Dames (Violes)	Distillation to produce alcohol (15 employees)	• Metering of water consumption in order to identify areas of high consumption • Pre-evaporation on the marc distillation • Awareness training for personnel	Water saving of 5 m^3/hour (60 % of water consumption) through the recycling of water
Général Traiteur (Briec de l'Odet)	Food production of 5 000 t/year (pizza, ready-prepared food)	• Technical equipment (water level readers, timer and electronic control on product cooling racks) • Maintenance to avoid leaks • New washing machine with lower consumption • Awareness training for workers	Global reduction of 20 %; for certain areas (e.g. washing machine), the reduction was 75 %
Spillers Petfoods (Quimperlé)	Petfood production of biscuits and canned food (128 000 t/year)	• Installation of meters at every work station • Closed-circuit cooling water • Awareness training for workers	Total water demand reduction of 30 %
Teisseire (Crolles)	Soft drink production (78 employees)	• Training programme for rational use of water for cleaning • Optimisation of processes	Demand reduction of 30 %
Cabot (Berre)	Combustion and cracking of heavy hydrocarbons (85 000 t/year of granulates for tyres)	• Recycling of rainwater and cleaning water for use in production	20 % water saved in production

was possible in a first phase to describe the approaches followed by nearly 50 companies in order to promote exchange of experience. In each case, the motivations, strategies, actions and results were analysed in detail.

The motivations for undertaking this approach included:

- reduction of environmental costs (taxes, wastewater, waste-disposal costs);
- legislative requirements;
- reduction of environmental risks;
- personal convictions of managers;
- improvement of the company's public image.

In each case, awareness training for personnel constituted an important element of the strategy, accompanied by meters on different work stations, maintenance of equipment and installation of new devices.

In 1997, pilot operations were planned in several French regions, where over 100 small and medium-sized companies would be invited to a half-day information meeting followed by training and diagnosis for around 10 of them.

5. Water reuse

Case study 36. Reuse of water for irrigation in Limagne, France

In Limagne, the water demand for irrigation is so great that small rivers in agricultural areas are at risk. A project was set up to reuse treated wastewater coming from the wastewater treatment plant of Clermont-Ferrant for the irrigation of 700 ha of maize, beet and lucerne (Bomstein, 1996). Reuse of water from the wastewater treatment plant means that the eutrophication risk in the receiving river can be reduced.

The wastewater treatment plant produces 50 000 m^3/day, whilst the irrigation needs of the 51 farms involved in the project are approximately 18 000–24 000 m^3/day. All the irrigation needs are therefore covered by the treated wastewater and the quantity of water saved is between 2.16 and 2.88 million m^3 during a normal year. For a dry year, the quantity of water saved is even greater (between 3.24 and 4.32 million m^3).

The main difficulties are due to the potential risk for public health, since there are workers in the fields during the irrigation period. This means that water quality must be carefully monitored.

The project was jointly financed by the *département*, a LIFE programme, the farmers and the water agencies. The investment costs were around EUR 4.7 million.

Case study 37. Cyprus

Currently, around 40 million m^3 of wastewater are produced annually on the whole island of Cyprus. Only 16 million m^3 of this amount are being treated, mainly in the Lefkosia province where the city of Nicosia is located. About 11 million m^3 are being reused for irrigation purposes. Water demand for domestic and industrial purposes will continue to increase and will receive priority over water demand for agriculture. This leaves the use of treated wastewater as one of the main sources for increasing water supply for agriculture in the foreseeable future (FAO, 1997).

Case study 38. Malta

In 1990, in Malta, the total water managed area, all equipped for full or partial control irrigation, was estimated at 763 ha, which was about 7 % of the agricultural land. Of this area, 280 ha was equipped for irrigation by treated sewage water from a sewage treatment plant which was completed in 1983 to provide 7 000 m^3 of water per day, but at present 240 ha are actually irrigated per year using 1.22 million m^3 of treated wastewater. Tenders have been issued to upgrade this sewage treatment plant to produce 17 000 m^3/day for irrigation and industrial purposes. Work was expected to be completed by early 1997.

Plans are also under way to construct three other sewage treatment plants, two in Malta and one in Gozo, with a total capacity of 73 000 m^3/day to treat all the sewage produced in the country by the year 2000. Hence the total available treated wastewater would be about 90 000 m^3/day. Since the maximum daily irrigation water requirements are estimated at 60 m^3/ha/day (July/August), the potential area for irrigation from treated wastewater would be 1 500 ha if all the wastewater was reused for irrigation. The potential area to be irrigated from treated wastewater could even be increased up to 2 500 ha if wastewater could be stored in winter (when irrigation water requirements are lower) for use during the summer.

However, this solution is financially prohibitive. Thus, the total irrigation potential is estimated at 2 000 ha, of which 500 ha irrigated by groundwater and 1 500 ha irrigated by treated wastewater. Nevertheless, there are several limitations to reaching this potential, including fund availability, problems of access to fields, the size and fragmentation of farm holdings, farm labour demand, marketing, water charges and the groundwater protection zones. From preliminary cost estimates of water distribution networks to supply treated wastewater to farmers from the new sewage treatment plants, the capital investment required would amount to EUR 10 890/ha (FAO, 1997).

Case study 39. Different experiences from the UK

In the UK, water reuse is not applied at a similar scale as in Mediterranean countries, but there are now many case studies where water companies, the Environment Agency, universities and research organisations are involved.

Water reuse pilot studies for domestic purposes

The company Anglian Water has provided a water recycling system for the UK's BBC Television, launched on 6 January 1999. The programme shows how used water from baths, showers and handbasins is first treated, using filtration and disinfection, and then stored in a loft header tank until it is needed to flush the toilet. This manages to save around 30 % of an average house's annual water use. A back-up system is in place in case there is insufficient grey water to fill the tank (Financial Times Newsletters, 5 March 1999).

The same company is collecting data from a trial house where the grey water is collected in a tank outside the building between 7 a.m. and midnight with excess overflowing into the sewer. From midnight to 6.30 a.m. a membrane treatment unit operates and the recycled water is stored in a loft tank. Initially, the shower and bath water was sampled for pH, BOD, COD, SS, *E. coli* and coliforms. The quality of water for flushing the toilet should be such as to be harmless to pets and children, not cause excessive foaming and not leave scum deposits on the toilet bowl. On the basis of these results, a pilot plant was developed using a series of membranes (*Demand Management Bulletin,* 1996).

Rainwater collection and reuse system (Nottingham Trent University)

The Department of Building and Environmental Health at Nottingham Trent University has field tested a rainwater collection and reuse system. The quality of the water was an important concern, especially regarding atmospheric pollutants and particulate matter from the roof, but, in fact, it complied with the physical and chemical minimum standards for drinking water, with the exception of turbidity, mainly for the first flush following a dry period. The microbiological quality was not acceptable. Overall, the water was satisfactory for toilet flushing and would not cause undue problems in the storage tank.

A 2 m^3 tank was used with a roof area of 85 m^2 to augment supply to a house occupied by three to five people. Table A.6 shows the very variable effect of the climate on the WC water conserved. The data have enabled a model of roof size, occupancy, tank size and weather to be developed to answer future questions.

Rainwater and grey water for the Millennium Dome (London)

The company Thames Water is working on a recycling system to supply treated water to the Millennium Dome for toilet flushing. In all, 500 m^3 of water per day will be treated and utilised. The Dome, apart from being a recycling showpiece, will incorporate experiments to ascertain public attitudes to water conservation.

Percentage of WC flushing water conserved each month — Table A.6.

Month	WC demand (l)	Rainfall (mm)	Mains water (l)	Overflow (l)	Rainwater collected (l)	WC water conserved (%)
July	4 951	16.0	4 298	0	794	13.2
August	5 650	26.8	4 372	0	1 806	22.6
September	4 949	110.2	0	2 010	7 247	100.0
October	5 071	49.8	1 537	673	3 897	69.7
November	5 134	75.4	975	2 746	6 404	81.0
December	5 970	94.8	502	1 903	8 084	91.6
January	5 417	87.4	787	2 244	7 556	85.5
February	4 856	50.6	0	0	4 038	100.0
March	5 493	39.8	2 070	0	2 909	62.3
April	6 515	11.0	5 637	0	692	13.5
May	4 718	33.2	2 299	0	2 553	51.9
June	4 998	6.0	4 810	0	214	3.8

Source: Demand Management Bulletin, 1996.

The high number of visitors expected will be able to see how water collected from the Millennium Dome roof, combined with grey water from the handbasins, can be used for toilet flushing (*Demand Management Bulletin,* 1999b).

Treated wastewater for golf courses

The company North West Water has set up a prototype plant to supply treated water to a golf course and to monitor the environmental effects and, in particular, economics of supplying reused water (*Demand Management Bulletin,* 1999a).

'Buildings that save water' – Risk perception in domestic water recycling

This project, undertaken by a group of companies, started in February 1998, with the aim of identifying the barriers to the uptake of rainwater reuse and grey-water recycling systems.

Some of the most important barriers identified to date are the following.

- Unproven technology: whilst the component parts of rainwater and grey-water systems are common place (tanks, piping, valves, pumps, filters, disinfection), the technology is relatively unproven as a total system. There is a perception of risk that discourages developers from including the technology and building owners from installing it. End-users are not clear how to assess the technology for their given circumstances.
- Unproven cost-benefit: one of the selling features of rainwater and grey-water systems is that they reduce the costs of water usage but public perception seems unconvinced.
- Water quality standards and public health: the lack of appropriate standards against which systems can be evaluated leaves an uncertainty in people's minds on the health risks. This is further confused by a general lack of information on the dose rates of different bacteria and viruses that will cause illness and it is complicated by the degree of risk of coming into contact with water.
- Odours and colour: the initial perception of these may dissuade people from taking up the systems.
- Lack of design guidance: the low uptake and use of these systems in development were largely attributed to a lack of guidance for those designing the development.

(*Demand Management Bulletin,* 1999a)

'Water recycling opportunities for city sustainability' (WROCS) project

The objective of the WROCS project is to use the latest risk assessment techniques, in combination with technology receptivity studies, to ascertain which developing technologies are more suitable for water recycling in cities.

The aims are:

- to assess water quality parameter guidelines for recycled and reuse water in the urban environment;
- to relate the required water qualities to their source, treatment, final reuse, public risk and receptivity;
- to provide a policy for selection of a given technology for a given reuse application;
- to take account of receptivity, risk assessment and building design in the provision of the above aims;
- to link water recycling technology with building infrastructure design and policy.

The risk model will be developed combining micro-organism growth and decay kinetics, disinfection decay, dose response data and epidemiological data. Data describing the above parameters will be obtained and collated in a data table. These values will then be used in the risk model to assess the risk associated with different micro-organisms.

The initial perception study is planned for a single-house, grey-water system site. The householders will be left with a diary to record day-to-day comments over two/three months. An exit interview will complete the survey.

As the perception study and the water quality testing programme run concurrently, a link between actual and perceived risks may be possible (Cranfield University web site).

Case study 40. Different experiencies from Spain

Water reuse for irrigation (Canary Islands)

The Canary Islands have severe problems related to water supply for irrigation purposes, especially during the summer and autumn seasons. Therefore, recycled water has become an alternative water resource which reduces the hydrological deficit and contributes to decreasing the overexploitation of groundwater.

In Gran Canaria, for example, more than 100 km of distribution mains exist, which distribute around 25 million m^3 of treated water per year, mainly for irrigation purposes.

Irrigation of tomato and potato fields in the areas of Barranco Seco and Moya, Gran Canaria

The water requirement of the cultivated area is estimated at around 10 000 m^3/ha for the whole cultivation cycle (nine months for tomatoes, 120 days for potatoes) and the estimated production is about 120 000 kg/ha (tomatoes) and 20 000 kg/ha (potatoes).

The principal advantages of the use of treated water in the area are:

- the decrease in the risk of obtrusion for the irrigation equipment;
- the highest conductivity, which implies that, in the medium term, there is less risk of soil permeability loss;
- the reduction in the use of fertilisers (nitrogen, phosphorus and potassium) (see Table A.7); nevertheless, it is necessary to pay attention to the fertilisers because the content of salts produces an increase in conductivity.

Study, assessment and monitoring of the use of treated water for irrigation (Tenerife, Canary Islands)

In 1984, the regional government carried out a study to determine the water reuse infrastructure for two cities, Santa Cruz and La Laguna, in order to use treated water for the irrigation of the San Lorenzo, Güimar and Guerra valleys.

The irrigated area in 1997 was around 725 ha, and 60 % of this was irrigated with treated water. The cultivated crops were bananas (87 % of the irrigated area), tomatoes (8 %), and other tropical fruits (3 %).

Previous studies to determine the possibility of water reuse (1982–90) arrived at the following conclusions:

- treated water could be used for several purposes, such as cultivation of bananas and tomatoes, and for golf courses, but not for the cultivation of some sensitive crops (avocado and ornamental plants) because of high salinity (conductivity between 1.5 dS/m and 1.7 dS/m, and chloride level higher than 7 meq/l);
- it would be necessary to take measures to prevent medium-term soil permeability problems (because of the alkalinity level of the treated water);
- due to the lack of industrial activity in the area, the content of heavy metals was low and did not create problems;
- disinfection treatments were recommended to avoid contamination of users;
- the content of phosphorus, nitrogen and potassium in the treated water was considered high enough to cover the needs of crops.

The assessment (*in situ*) of the effect of the treated water on the soil, crops and irrigation equipment, during four cultivation cycles (from 1991), arrived at the following conclusions:

- the most important problems arising from the use of treated water were related to the high conductivity, and high concentrations of sodium and chlorides;
- the fertilising capacity of phosphorus was not enough to cover the needs of the plants;
- there was a tendency for soil salinity and soil alkalinity to increase, especially in greenhouses;
- the general health, development and productivity of the plants were not affected;

Fertiliser needs and calculated total contribution of treated water Table A.7.

(kg/ha/year)	Barranco Seco area (tomatoes)		Moya area (potatoes)	
	Fertiliser need	Calculated contribution of treated water	Fertiliser need	Calculated contribution of treated water
N	450	120	60–100	215
P2O5	180	145	20–60	135
K20	540	230	25–75	165

Source: Marrero and Palacios, 1997.

- there were no important effects on the irrigation equipment except that some models were more susceptible to blockage;
- there was a need to study more deeply the health issues related to the use of treated water.

From 1994, a monitoring programme has been established in the area concerned. The aim is to monitor the evolution of the whole system (water distribution and supply, water quality, soil evolution, crop development and irrigation equipment). After two years of monitoring, the main changes have been related to the quality of the treated water. From the summer of 1995, there has been a reduction in conductivity and in the levels of sodium, carbonates and chlorides as a consequence of the introduction of white water into the system and the introduction, in 1996, of water from the desalination plant. This improvement in quality has been followed by a reduction in the fertilising capacity of the treated water. The direct use of treated water is better than short-term storage (e.g. in ponds), where the risk of development of algae is high (Aguiar and Marrero, 1996).

Use of treated water for golf courses on the Costa del Sol

The Costa del Sol covers 95 km of the Mediterranean coastline and has a population of 800 000 inhabitants during the summer season. The economy is based mainly on tourism. The total water use is estimated at around 60 million m^3/year, of which 10 million m^3 are used solely for irrigation.

At present, there are 28 golf courses which will increase to 34 in the coming years. The average water used for irrigation of a golf course in the area is about 350 000 m^3/year, with a peak use of 1 500–2 500 m^3/day depending on the kind of grass and soil.

The use of treated water for irrigation of golf courses started in 1989 and, during 1993, the local authorities developed a plan to irrigate all the courses with this kind of water. The aim of the plan was to use a volume of 14 million m^3/year of treated water. Now, 70 % of the water used for the irrigation of golf courses is treated water (Marzo and Ceballos, 1997).

Multiple wastewater reuse system in the industrial area of Puertollano (Ciudad Real region)

The industrial area of Puertollano, with a population of 50 000 inhabitants, is located at the headwaters of the Guadalquivir river in central southern Spain. The industrial activity is focused on charcoal, oil and gas production and distribution, and petrochemical and fertiliser production. These last two have a heavy impact on the quality of the receiving water through discharges of nitrogen and phosphorus. However, there are attempts to reduce the impacts: the petrochemical plant has specific physical, chemical and biological treatments and the fertiliser industry has a recycling system with final physical and chemical treatment.

Usually, the water comes from the Montoro reservoir (capacity: 28 million m^3) which drains to the Ojailén river 50 km downstream. The water drawn from the reservoir is normally around 15–20 million m^3, but, during the 1993 drought, this amount was reduced to 10 million m^3 per year.

This water, after treatment, is supplied to the different users, to use and treat again before being discharged into the river headwaters. During the drought, a water transfer was made from the Ojailén river, downstream of the Jándula dam, utilising the purification capacity of the whole river (54 km) and the two reservoirs. At the same time, a smaller reuse cycle was constructed where the petrochemical and fertiliser factories used the wastewater from the power plant and the wastewater treatment plant of Puertollano for their own production processes after treatment and nitrification.

The result of this system was the saving of 6.7 million m^3 of water per year, 40 % of the total water used (16.6 million m^3/year) (Brieva and Monteoliva, 1997).

Water reuse plan for Campo Dalias – Environmental use of treated wastewater (Almería)

The area of Campo Dalias is located near Almería and its most important economic activity is intensive agriculture in plastic greenhouses.

In 1950, the irrigation area was around 500 ha and the population around 6 000 inhabitants. In 1997, the irrigation area in the greenhouses was around 20 000 ha and the expected population for 2014 is around 230 000 inhabitants. This expansion of agriculture has increased the use of groundwater for public water supply and also for irrigation purposes leading to the overexploitation of some aquifers.

The central government, together with the regional government and local authorities, has developed a general plan which includes:

- urban wastewater reuse for utilisation in agriculture and recharging aquifers (in this way it is expected to recover 10 million m^3 of water per year);
- reduction of leakage in the distribution systems for irrigation (it is expected to save 10 million m^3/year);
- increasing the resources with water from desalination plants;
- limitation of the agricultural areas.

Case study 41. Reuse for irrigation in Portugal
There are few cases of planned irrigation with treated wastewater in the southern half of Portugal, especially orchards and vineyards, and also golf courses. A large wastewater treatment plant, presently under construction, near Lisbon, plans to irrigate 1 000 ha with tertiary treated wastewater (Marecos do Monte et al., 1996, quoted in Angelakis et al., 1997).

A research project was carried out by the Laboratorio Nacional de Engenharia Civil (LNEC) and the Laboratorio Quimico Agricola Rebelo da Silva (LQARS), which are both in Lisbon. The objectives were to assess and compare the effects of irrigation of various types of treated urban wastewater in the same crops irrigated with potable water and given commercial fertilisers. The last objective was to provide experimental data to support the production of Portuguese guidelines for treated wastewater reuse for irrigation.

The main conclusions of the project were the following:

- primary and secondary effluents were found to be suitable for well-drained soils and salinity-tolerant crops but unsuitable for sensitive crops;
- the nitrogen content of both effluents was high enough to avoid the use of commercial fertilisers;
- the facultative pond effluent appears to be of higher fertilising capacity than primary and secondary effluents, since increased yields were obtained comparatively.

Another objective of the project was to transfer knowledge and technology to different sectors, in particular the farmers (Angelakis et al., 1997).

Case study 42. Treated wastewater reuse in Greece
Two major pilot projects dealing with recycled water are under way. One is based at Iraklio as part of the LIFE 94 project. In this project, tertiary wastewater treatment efficiency and reliability are being evaluated and design criteria for a full-scale project will be developed for wastewater treatment, groundwater recharge and irrigation. The aims of the second project, based at Thessaloniki and under the direction of the National Agricultural Research Foundation, are:

- to investigate the performance of natural systems, especially stabilisation ponds and constructed wetlands, in treating municipal wastewater under Greek conditions;
- to study the feasibility of reusing the treated municipal effluent discharges, either from the natural systems and/or from the nearby conventional activated sludge wastewater treatment plant of the city of Thessaloniki, for agricultural irrigation.

(Angelakis et al., 1997)

6. Integrated water management approaches

Case study 43. Barcelona, Spain

In Barcelona, where the drought reached its most critical level in 1990, the following measures were adopted:

- alert for sensitive users (hospitals, health centres, etc.) concerning the convenience of adapting their facilities to assure reserves and cope with low-pressure periods in the water supply network;
- restriction of practically all urban irrigation, reduction of irrigation in gardens and the obligation for public fountains to operate in closed circuit;
- elaboration of a plan to restrict complementary commercial and industrial water use and luxury domestic water use;
- public information and motivation campaign.

The effect of the measures adopted was a decrease in demand by 5 % between November 1989 and June 1990. Considering that the average growth during previous years had been around 2.6 %, the total water saving can be considered to be between 5 and 8 %. The highest decrease was registered among public users (18 %), followed by commercial and industrial use (7 %) and domestic use (4 %).

Case study 44. Madrid, Spain

An example of demand management under difficult conditions is the programme applied by the city of Madrid during the 1992–93 drought. Here the following measures were applied:

- creation of a 'drought office';
- reduction of irrigation in parks and gardens;
- use of treated wastewater for irrigation;
- reduction of leaks, uncontrolled abstractions and excessive consumers; cut-off of irrigation faucets;
- increased metering in large mains and distribution pipelines, as well as in parks and gardens;
- programme of 'internal efficiency', distributing devices for taps, showers, closets, etc.;
- public information campaigns.

Thanks to these measures, total water use decreased from 590 million m^3/year in 1991 to 522 million m^3/year in 1992 and 476 million m^3/year in 1993, equivalent to a reduction of around 20 %. The effectiveness of different measures was quite varied. While the voluntary saving of water promoted by information campaigns was rather effective, the reduction of irrigation and the reuse of treated wastewater did have a very limited impact. Among users who installed water-saving devices, 50 % achieved reductions of more than 20 % and one fifth saved more than 40 %. It is interesting to note that the effect of water-saving initiatives has, at least in part, turned out to be permanent. In the summer of 1993, for example, when restriction of irrigation in parks and gardens had ended, water demand was still 24 % less than during the summer of 1991 (MMA, 1998).

Case study 45. Murcia, Spain

Another interesting case study of demand management is the example of the city of Murcia in south-eastern Spain. Since the creation of a municipal water services company in 1984 and its partial privatisation in 1989, total water demand has been contained and even reduced, in spite of an increase in the number of users and the size of the network. This has been achieved through a combination of efforts to improve maintenance, detect fraud, and improve and renovate the supply network. The average per capita demand has decreased from 330 l/capita/day to 230 l/capita/day. Within six years, total network losses have been reduced from 45 to 25 %.

The main factor leading to the improvement of efficiency and water conservation has been the severe natural water scarcity in the region of Murcia, which has been exacerbated by singular drought events.

Case study 46. Zaragoza, Spain

The Ecology and Development Foundation under the LIFE programme is developing a project with the aim of saving 1 million m^3 of water for domestic uses between October 1997 and October 1998 in the city of Zaragoza (700 000 inhabitants) (Fundación Ecología y Desarrollo, 1999). The foundation promotes a new water-saving awareness through more efficient management. It emphasised the importance of simple technological change to achieve a sustainable reduction in water use. The project foresees the following water-saving mechanisms to seek its objectives:

- purchasing of new water-saving sanitation appliances (taps, showers, toilets, etc.);
- installing of water-saving mechanisms in old appliances;
- introducing individual household hot-water meters in buildings with communal service;
- repairing leaks, reutilising domestic water;
- changing water use habits.

Some initiatives of the educational campaign are:

- involvement of different institutions (industries, shops, public institutions, schools, trade unions, etc.);
- production of an educational programme for schoolteachers (teachers receive a dossier with information and teaching materials for different educational age groups);
- the 'Big water book', which is a book of blank pages in which the pupils of the schools can contribute with inventions or drawings connected with the subject of water. The book is in constant motion, moving from school to school throughout the city (two thirds of the city's schools took part in the awareness campaign).

As a results of the measures implemented, in June 1998, 0.6 million m^3 of water had been saved.

In terms of raising public awareness of water saving, the campaign was considered a success by the organisers, but a similar amount of water saving may have been achieved, for example, by improving the efficiency of the city's water distribution system by less than 2 % or by reducing agricultural use of water in the Aragon region by 0.5 % (Tremlett, 2000).

Case study 47. Malta

On the island of Malta, the local water service corporation has carried out a water-saving campaign based on the following measures:

- education on saving water (cartoons and advertising);
- designing an easier invoice format to make the content of water bills clearer to users.

Both lines of activities were promoted through the press and television, in order to make the population aware of the importance of saving water.

Case study 48. Various initiatives from the UK

The UK water industry provides 19.5 million m^3 of water every day to 58 million people. Only 3 % of the water is used for drinking and cooking; washing and toilet flushing use large amounts. The average domestic bill for water and sewerage services is GBP 0.64/day. One glass of water costs GBP 0.0003, a bath GBP 0.10, and a shower GBP 0.04 (*Water UK*, 1998c).

In the UK, one of the government targets for environmental protection includes lower water bills to ensure that some of the improvements in efficiencies achieved by companies are passed on to customers in 2000/01. Another important objective is to develop a framework where expenditure to correct imbalances in supply and demand is largely met by changes in the bills of those customers whose demand is increasing, not by all customers.

A cut of between 10 and 20 % could be introduced between 2000 and 2005; this implies a cut of around GBP 25 on an average family's annual bill. This price review is taking place against a background of improvements in services and environmental standards, accompanied by 10 years of increases in customer bills. Average household bills will have increased by over 40 % in real terms by the year 2000 compared with 1989, when the initial price limits were set by the government (OFWAT, 1998).

During that period, customer care has improved and companies have also introduced additional services (cheaper or free optional meters, free or subsidised supply pipe repair or replacement, improved customer information, improved access to flexible, low-cost payment methods).

To discourage cost cutting at the expense of service quality, it is intended to adjust price limits to reflect companies' relative overall performance on delivering service to customers and the environment.

Companies forecast that customers' demand for water should fall, yet at the same time estimate the need to invest more. Some of this investment includes expenditure on the connection of new customers, including the provision of meters, and also intends to enhance the margin between supply and demand in order to reduce the frequency of hosepipe bans, and the frequency of emergency abstractions from rivers and streams.

Case study 49. Water and Wastewater Minimisation: The Aire and Calder Project, UK

The Aire and Calder catchment has an area of 2 055 km² and a population of over 2 million. There has been a long history of serious water pollution in this catchment. Most of the industrial wastewater was treated at sewage works. The Aire and Calder project was concerned with minimising the effluent discharged both to sewers and directly to the rivers. Through the efforts to reduce pollution, significant water savings could be achieved.

The objectives of the various institutions involved in this project were (Edwards and Johnston, 1996):

- to demonstrate the benefits of a systematic approach to emission reduction;
- to focus on procedural changes and cleaner technology;
- to collect accurate data on cost and benefits;
- to examine the utility of the Institution of Chemical Engineer's waste minimisation manual in practice;
- to act as a showcase for British expertise.

The Aire and Calder project was financed by the BOC Foundation for the Environment, Her Majesty's Inspectorate of Pollution, the National Rivers Authority, Yorkshire Water Services Limited and 10 participating companies.

The project, which commenced in 1992, was completed in 1995 and comprised four phases:

- appointment of the project contractor and recruitment of participating companies;
- intensive study of the participating companies, working with their staff to identify and implement waste minimisation opportunities;
- dissemination of the results of the project as widely as possible to stimulate the interest of others in the benefit of a systematic approach to waste minimisation;
- monitoring further progress of the companies and the adoption of the techniques by others.

The intensive study (second phase of the project) involved the following stages.

- Site environmental review: a preliminary environmental review was completed on each site to identify the major issues and develop an action programme.
- Identification of options: manufacturing processes were reviewed and opportunities for waste minimisation were identified.
- Evaluation of options: each waste minimisation opportunity was then investigated and its environmental and cost implications assessed. Some were rejected due to excessive cost or practical difficulties. Other more feasible opportunities were pursued.
- Monitoring and targeting: these were recommended to assist each site in monitoring its releases to the environment and to assess and develop future waste minimisation.

By 1994, water demand had been reduced by 659 000 m³/year (27 %). It is considered that there is the potential to achieve an overall 44 % reduction.

Case study 50. The Spanish National Plan for Irrigation

The Spanish national plan for irrigation (MAPA, 1998) includes different programmes to improve the situation of the irrigated agriculture in Spain (keep the agricultural population, improve the environment, avoid desertification, optimise irrigation water consumption). The programmes contemplate the finalisation of different irrigation projects, economic profit, availability of water resources, market demand and environmental performance. The plan foresees a total of 228 518 ha of new irrigated land.

In addition to the establishment of new irrigated areas, the objective of the plan is to modernise and improve the existing irrigated areas. According to the draft document, there are 1 129 210 ha with insufficient water resources due to network

Potential irrigated land (in 2008) and long term Table A.8.

River basin	Potential irrigated land (surface, ha) 2008	Potential irrigated land (surface, ha) Long term
Galicia Costa	0	0
Norte	0	4 528
Duero	249 503	268 097
Tajo	35 777	59 190
Guadiana	93 983	89 849
Guadalquivir	92 963	165 872
Sur	6 708	22 865
Segura	2 145	0
Jucar	75 758	55 000
Ebro	465 981	487 358
C.I. Catalunya	0	11 526
Balearics	750	0
Canaries	3 400	8 000
Total	1 026 968	1 172 285

Source: MMA, 1998.

losses, old irrigation systems, aquifer overexploitation, etc. The modernisation will affect basically the hydraulic infrastructures (water transport and distribution network and improvement or substitution of the existing irrigation and drainage systems).

The plan also contemplates the implementation of different measures to encourage measurement of water use and water saving.

Case study 51. Integrated catchment management for irrigation in Charente, France

Awareness of the serious water resources problems in the Charente catchment began in 1987, when there was a severe drought and many observations of dried-out streams. There had been a huge expansion in irrigation (mostly for maize and tobacco) throughout the 1970s and 1980s right up until the CAP reform in 1992. After 1992, an irrigation ceiling was fixed for the irrigation area and this area increased very little between 1992 and 1997. Approximate figures are:

- 2 400 ha in 1970;
- 8 400 ha in 1980;
- 28 800 ha in 1992;
- 29 900 ha in 1997.

A water committee was set up in the early 1990s which defined water management rules each winter for the following summer. In 1992, a protocol was agreed between all the concerned parties: administration, local authorities, drinking water suppliers, fishermen, farmers, industries, nature associations, water mills and canoeing associations. This process enabled the subjects of water supply/demand to be discussed openly and encouraged consultation and dialogue.

This collaboration was considered a very important factor since tensions were previously high between different users, in particular between the farmers, and communication was difficult. The consultation enabled common approaches to be developed and avoided multiplication of often conflicting actions. Another important factor was the definition of plans on a local basis, so that strategies could be adapted to local problems.

A range of strategies and actions have been adopted to improve the water supply/ demand balance:

- construction of a new reservoir to complement the existing one: a large reservoir (Lavaud) was built to provide minimum flows for the Charente river and a future reservoir is envisaged; taxes on water use finance the maintenance and functioning costs of the reservoir;
- establishment of an irrigation advice centre; training;

- agreement on restriction plans within the context of the yearly management plan adapted to each sub-catchment and revised on a weekly basis through the irrigation period;
- installation of meters to improve understanding of water resources balances;
- equipment diagnosis.

(Montginoul and Rieu, 1996; Ferrané, 1998; Pers. Comm., 1998b)