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Towards efficient use of water resources in Europe

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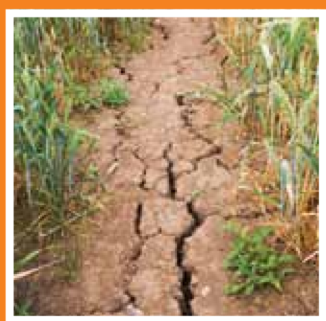

European Environment Agency

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Executive summary

Resource efficiency within boundaries of sustainability

Managing water sustainably in a 'green' economy means using water more efficiently in all sectors and ensuring that ecosystems have the quantity and quality of water needed to function effectively. Water ecosystems are vital assets, delivering essential services to our societies and economies, and thereby playing a key role in European productivity and security. It is thus essential that our use of water does not exceed ecosystem sustainability boundaries.

Although water quality has improved in recent years, water resources are over-exploited in many areas of Europe. Together with continued shortcomings in water quality and hydromorphological alterations, this has had heavy impacts on the status of Europe's water bodies.

Measures to improve the efficiency of water use offer an important tool in this context, enabling society to maximise its earnings from scarce water resources. To ensure that this relieves pressure on ecosystems, however, it is important that increased consumption does not offset efficiency gains.

Clearly, economic production cannot be sustained if it implies excessive water use and burdens natural systems. Future economic growth must therefore be decoupled from environmental impacts. And this process of decoupling requires a dual focus: on resource-efficiency innovations and instruments, and on environmental sustainability boundaries.

The Water Framework Directive defines the boundaries for sustainable water use via its 'good status' objective for water bodies. This is an essential target for impact decoupling, conveying the conditions that ecosystems require to function and support human wellbeing, health and prosperity. In this context, the 'environmental flows' concept is an essential tool for securing that aquatic ecosystems have a good quantitative and hydromorphological status. It should be more widely applied and developed.

Resource-efficiency technologies

The examples addressed in this report highlight a range of resource-efficiency measures that can enable actors at varying levels and in different sectors to reduce their water use and achieve more sustainable water management. Resource-efficient technologies in agricultural irrigation, water supply and treatment can deliver substantial water savings. In agriculture, for example, shifts to water-efficient irrigation techniques such as drip irrigation, altered crop patterns and wastewater reuse are particularly promising. Sustainable public and industrial water management depends more on innovative production treatments and processes, ecological design in buildings and better urban planning.

Resource-efficiency measures in the urban and industrial areas often offer win-win situations, with technologies that cut water use also helping to reduce energy use (for example in drinking water and wastewater treatment) and achieve more efficient chemicals use. Water utilities and water-intensive industries have an important role to play here.

In some cases, however, measures to meet water or energy needs can create problems in the other sector. The energy intensity of technologies like desalination necessitates more efficient water use and the development of renewable energy. Similarly, technologies such as hydropower should be judged in terms of their impacts on water ecosystems, which can be considerable, and in the light of their relatively limited growth potential in comparison to wind and solar energy.

There are clear opportunities to enhance the adoption of efficiency technologies. Existing measures can, however, be better applied. Once proven to be useful, new innovations should likewise be shifted from pilot applications or isolated examples to become widely accepted and applied standards.

There is also a need to address gaps in implementation of existing water legislation such as the Urban Waste Water Treatment Directive, the Drinking Water Directive and the Nitrates Directive, which are the basic measures for implementing the Water Framework Directive. Boosting resource efficiency in these areas should foster investments in the most advanced treatment and technologies — integrating water, energy and material saving objectives. Advanced wastewater treatment and treating or importing drinking water from remote (clean) sources is often energy intensive. Reducing nutrients and chemicals at source in agriculture, households and industry is therefore an important efficiency measure.

Economic instruments

Economic instruments can help incentivise efficiency measures, change behaviour and foster technological innovation.

Water pricing and market-based instruments are essential for sustainable water management and should be applied consistently to support efficient water allocation within sustainability boundaries. Water prices and tariff structures have to reflect the true costs of water — internalising all externalities, including environmental and resource costs.

In public water supply, volumetric pricing and metering need to go hand in hand and generate the revenues for utilities to finance resource-efficiency measures and upgrade aging infrastructure. Complete transparency in a utility's use of revenues and investments is a key element in communication with their consumers.

For water used in irrigation, it is essential that pricing structures provide more incentives for resource efficiency and allow more transparency in comparison to competing uses to avoid cross-subsidies from other parts of society. To remove adverse subsidies should also be a priority in future agricultural policy.

Integrating water, energy and land use

To integrate sustainable water management with resource efficiency in other areas, such as energy and land use, the WFD objectives have to be considered as a core expression of the boundaries ensuring ecosystem functioning and service provision. They should be applied in an integrated approach to define common boundaries of sustainability for the competing users in all sectors — including agriculture, energy, transport and tourism. This process demands strong intersectoral exchange, particularly in operational water management at the river basin level. Public participation under the WFD, when applied ambitiously, can provide a comprehensive tool to achieve this goal.

Communication

Consumer behaviour should be further steered towards sustainability by means of awareness-raising campaigns. Labelling and certification can play an important role in communication with users of public supplies. Metering and monitoring (and legal enforcement in cases such as illegal abstractions for agriculture) play an equally important role, boosting the transparency of consumer behaviour.

The 'Blueprint to safeguard Europe's water resources'

This report is the first in a series of five reports (four thematic assessments and one synthesis report) that EEA will publish in 2012 to provide policy-relevant information to support the development of the 'Blueprint to safeguard Europe's waters'. It focuses on resource efficiency, its role in promoting sustainable water management, and the role of technical and economic tools in this context.

Existing water legislation provides a very robust and indispensable starting point for sustainable water management and resource efficiency. Looking ahead to the 'Blueprint to safeguard Europe's water resources', the cases and examples in the present report suggest some possible priorities in implementation. In facilitating and improving resource efficiency, for example, key focus areas include water economics and strengthening policy integration and water governance across all economic sectors. Public participation and intense stakeholder dialogue at the river basin level are also effective and far-reaching tools. And there is a particular need to focus on building a shared understanding across economic sectors of common boundaries of sustainability.

To complement the present report, further EEA assessments during 2012 will:

- provide more detail on hydromorphology, as good hydromorphological status is central to implementation of the WFD;

- provide insight into the status and pressure assessments under the WFD;
- evaluate details of water ecosystem vulnerability to floods, water scarcity and droughts, providing further assessment in relation to land use and ecosystem capital accounts;
- synthesise all assessments in a summary report directly tailored to the publication of the 'Blueprint to safeguard Europe's water resources', providing information for the underlying policy principles.

1 Introduction

Clean water is a vitally important natural resource, demanding careful management. It is essential for life and integral to virtually all economic activities, including producing food, energy and industrial outputs. The availability of clean water in sufficient quantities is not only a prerequisite for human health and well-being but also essential for freshwater ecosystems and the many services that they provide.

While most Europeans have historically been insulated from the social, economic and environmental impacts of severe water shortages, the balance between water demand and availability is reaching critical levels in parts of Europe. Such water stress typically arises from over-abstraction, together with periods of low rainfall or drought. Reduced river flows, lowered lake and groundwater levels and the drying up of wetlands are widely reported, alongside detrimental impacts on freshwater ecosystems, including fish and birds. Lack of water has also had severe consequences for key economic sectors including agriculture, energy and industry. At times, Europe's citizens have also been directly affected — facing water rationing and relying on shipments of drinking water supplies (EEA, 2009 and 2010a).

In addition to the growing problem of water stress, the quality of some of Europe's freshwaters is also a concern. Pollutants from various sources can be found at levels that detrimentally impact aquatic ecosystems, degrade habitats and result in the loss of flora and fauna. Poor water quality is also a potential health threat for those engaging in freshwater or marine recreation, or consuming contaminated seafood, particularly where sanitation is inadequate or access to safe drinking water is lacking (EEA, 2010b).

Climate change is likely to exacerbate current pressures on Europe's water resources. Increasingly, much of Europe will face reduced water availability during summer months, while the frequency and intensity of drought is projected to increase in the south (EEA, 2010c). In the absence of sufficiently strong action, climate change may also detrimentally impact water quality, for example via the projected increased occurrence of toxic algal blooms.

Growing global demand for food and increasing cultivation of energy (biofuel) crops may also exacerbate agriculture's impacts on Europe's water resources. Creating a sustainable green economy requires a recognition of the interdependence of water, energy and land use, and coordinated actions under a common concept of resource efficiency.

1.1 EU resource-efficiency policy

In the European Union (EU) these goals are set out in the 'resource efficient Europe' flagship initiative (EU, 2011a) under the Europe 2020 strategy (EU, 2010). Pursuant to the flagship initiative, the European Commission has elaborated a 'Roadmap to a resource efficient Europe' (EU, 2011b) containing the following vision:

> 'By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored.'

The initiative and its related roadmap recognise water as a basic resource that supports our ecosystems and biodiversity. Water is acknowledged to be a vital element in various economic sectors and vital to the role of natural resources in underpinning the functioning of the European economy. A resource efficient Europe will allow the EU's economy to grow in a way that respects resource constraints, providing an economy which is competitive, inclusive and provides a high standard of living with much lower environmental impacts.

The European Commission plans to publish a 'Blueprint to safeguard Europe's Water Resources' at the end of 2012. The Blueprint will set out the policy process to implement resource efficiency from the water perspective and will be the water milestone on the 2011 Roadmap to a resource efficient Europe. It will review the water policy processes most important to resource efficiency: water scarcity and drought policy; the water-related part of Europe's climate change vulnerability and adaptation policy; and, most important, the state of play in the implementation of the Water Framework Directive (EU, 2000).

1.2 Resource efficiency and sustainable water management

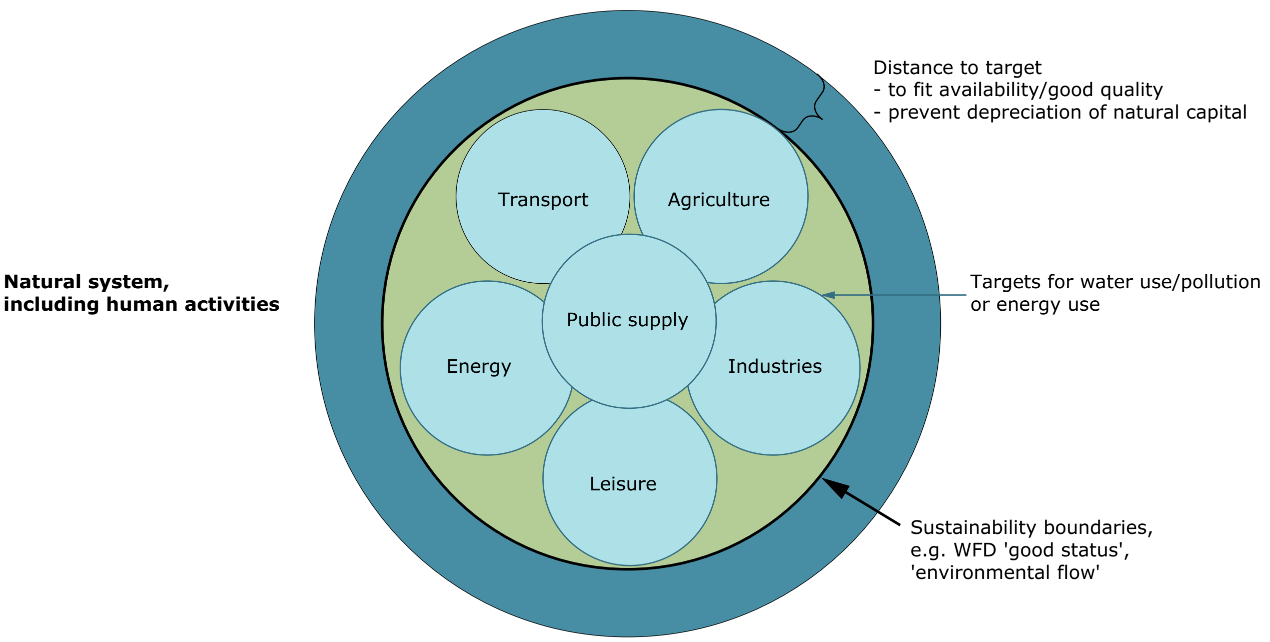
It is important to recognise what resource efficiency is and how it can contribute to sustainable resource management. Resource efficiency normally refers to the ratio of resource inputs on one hand to economic outputs and social benefits on the other. Technologies or policy tools that enhance efficiency therefore enable society to generate more earnings from limited environmental resources.

Resource efficiency is thus an important element in efforts to sustain economic development while maintaining natural systems. By itself, however, resource efficiency will not guarantee steady or declining resource use. Growing consumption can mean that resource use increases despite efficiency gains. Indeed, resource efficiency can actually contribute to increased resource use because when a sector becomes more efficient prices may drop, increasing demand and offsetting the efficiency gain (the rebound effect). Even if improved resource-efficiency results in declining resource use, it may still put excessive demands on the environment.

For these reasons, resource-efficiency policy must be grounded in an awareness not just of the quantity of resources used but the impacts on the environment, its resilience and the services it provides. As described in UNEP's report, *Decoupling natural resource use and environmental impacts from economic growth* (UNEP, 2011a), only decoupling resource use from environmental impacts — 'impact decoupling' — leads to real improvements for our natural resources.

Sustainable resource management requires that we maintain the natural capital stocks that deliver the most effective and efficient array of services. It is based on recognising and providing for the basic needs of ecosystems — including allocating sufficient water to function. This requires an awareness of the status and trends of water resources in both quantitative and qualitative terms; physical processes such as retention capacity, flow regulation and water cycling; and biological aspects such as habitat structure and functioning. It requires that society establish rules that ensure that economic activity does not exceed the boundaries of ecological sustainability (Postel et al., 2003).

Figure 1.1 Sustainable water allocations to ecosystems and competing users



Operating within these boundaries, resource-efficiency tools and instruments can contribute significantly to improving human well-being, ensuring that the allocation and use of scarce water resources generates the maximum possible value. Figure 1.1 illustrates this distribution of water resources among competing users within the boundaries of ecological sustainability. Within the economy, policies, targets and other tools are used to help achieve efficient water use, alongside other priorities such as equitable and affordable access to water to meet basic human needs.

The Water Framework Directive

In the EU those boundaries are reflected in the Water Framework Directive, which requires that Member States ensure that water bodies achieve 'good status for surface and groundwater' by 2015. This implies that the combined impacts of water use and pollution pressures are managed such that no environmental degradation occurs and sustainability is restored or maintained.

In implementing the Water Framework Directive, Member States have established objectives for good ecological status for their water bodies. This process includes specifying a 'good status' for biological, chemical, physical-chemical and hydromorphological elements. Implementing the Water Framework Directive through river basin management plans and associated programmes of measures implies closing the gap to these boundaries.

In terms of practical implementation under the WFD, 'good status' in quantitative terms is reflected indirectly as part of the hydromorphological status for surface water and the good groundwater status. The development of a more detailed expressions of environmental flows for quantitative water-resource management at the national or regional level is vital to meet the requirements of the WFD in particular in river basis with high quantitative pressures. However, wider and more stringent application by Member States is needed and the concept of 'environmental flows' still needs more attention (Box 1.1).

Interdependence of resource impacts

Sustainable water management requires more than a focus on ecosystem water needs and relevant resource-efficiency policies and tools. It also demands an awareness of interactions with other resources. Water management has serious implications for food and energy security ([1]), with efforts to enhance resource efficiency in one sector having impacts — positive and negative — on the others.

Box 1.1 Environmental flows

'Environmental flows' — water security for ecosystems — convey the quantity, quality and timing of water flows needed to sustain freshwater, estuarine and near-shore ecosystems and the services they provide. Measuring and maintaining environmental flows is important for protecting and enhancing these ecosystems and promoting sustainable water use.

The European Commission and Member States are currently developing the concept and application of 'environmental flows', for example in the context of work under the WFD on water scarcity and drought and hydromorphology. As outlined below, however, experience in the United Kingdom and France already illustrates the concept's value in meeting the objective of better, ecosystem service-oriented water management.

The Environment Agency of England and Wales has developed Catchment Abstraction Management Strategies (CAMS) at the catchment and sub-catchment scale (EA, 2010) and is using them to establish a sustainable abstraction licensing strategy. At the technical core of CAMS is the resource assessment and management (RAM) framework (EA, 2001). This framework helps to determine the catchment water-resource status and allows environmental flows to be set consistently and objectively. It calculates a water balance for each sub-catchment and allocates the total available resource between the quantity of water that can be abstracted and the amount that must remain in the river (or aquifer) to maintain desired ecological conditions (the 'in-river need'). The framework aims to integrate surface and groundwater resources; to reflect the varying sensitivity of different biota and habitats to flow status; to protect against both low flows and flow variability; and to provide a mechanism for achieving 'good ecological status' under the Water Framework Directive (Dunbar et al., 2004).

Environmental flows can help in designing restoration plans for water bodies tailored to the specific hydromorphological alterations and adverse effects on biota. They can thereby contribute to recovering good ecological status. The Rhône River rehabilitation illustrates an adaptive approach to river restoration supported by environmental flow assessment. The Decennial Rhône Hydraulics and Ecological Rehabilitation Plan (DRRP, 2000) was established with the objective of restoring a 'healthy and running river' with better ecological quality. The DRRP demonstrates what can be achieved in rehabilitating a river that has supported urban, agricultural and industrial development for a long time without due consideration to its environmental values and attributes.

Source: Dunbar et al., 2004; EA, 2010b; EA, 2001.

([1]) The 'water-energy-food nexus' was the focus of an international conference in 2011, sponsored by the Government of Germany (http://www.water-energy-food.org).

As such, the focus needs to shift from the narrow objective of sustainable water use based on greater water efficiency to an overarching objective of sustainable use of all natural resources. It is therefore important that a focus on the technologies and other mechanisms that can increase efficiency is complemented by greater understanding of the natural capital stocks and flows that drive our economies. In the water context, managing water use within boundaries of sustainability can be supported by methods and metrics that convey the relationship between economic activities and environmental impacts at the relevant hydrological unit and time period.

1.3 Aims and structure of this report

This report is the first in a series of thematic assessments that EEA is publishing in 2012 to support discussion and development of the 'Blueprint to safeguard Europe's Water Resources'. The report builds on earlier EEA reports describing the state of Europe's water resources and the pressures they face (EEA, 2009, 2010a, 2010b and 2010c). It focuses on resource efficiency and describes the opportunities for more efficient water use and avoiding pollution across all sectors, while staying within sustainability boundaries.

New technologies and innovative practices play a central role in ensuring that society can meet its need for goods and services without exceeding ecological sustainability boundaries. Chapter 2 outlines some of the new approaches available, exploring the potential for efficiency gains and linkages with energy, agriculture and industry.

Inefficient allocation and use of resources can often be understood as a result of market failure. Chapter 3 focuses on the opportunities to use markets to incentivise efficient water allocation and use, as well as the limitations that result from water's characteristics and its unique role in sustaining ecosystems, economies and societies.

Sustainable water management requires knowledge, robust data and indicators that can show the links between water management, social and economic benefits, and ecosystems services. Chapter 4 therefore addresses the need for better information to improve water-resource management and reduce environmental impacts. It presents natural capital accounts as one possible means to implement integrated environmental targets.

In sum, this report aims to introduce themes and potential solutions that may be valuable in developing the 'Blueprint to Safeguard Europe's Water Resources'. It will be complemented with further assessments in 2012, focusing on the hydromorphological quality of European water bodies, their biological and chemical quality, and updating previous state and pressure analysis with the most recent information available from river basin management plans.

Photo: © Beate Werner

2 Water-resource efficiency — measures and tools

Visualising the competition for water between the environment and economic uses (Figure 1.1) illustrates that sustainable and efficient water management demands the engagement of all sectors, and must be integrated with management of other resources, such as energy, materials and land. The goal is to ensure that society's demands on the environment — both in terms of extracting resources and emitting pollutants — are sufficiently limited that ecosystems remain healthy and provide the optimal level of ecosystem services.

This chapter therefore describes efficiency measures in the different sectors of the economy not only in terms of volume (Section 2.1) but also in non-volumetric terms of energy, nutrient and chemical use in agriculture, industries and households (Sections 2.2 and 2.3). The focus is likewise on both the quantity and quality of water resources.

2.1 Reducing water use — increasing water use efficiency

Awareness of water scarcity and the need for sound quantitative water management has mounted slowly in recent years. The European Commission conducted an in-depth assessment in October 2006 (EC, 2007a), which identified the principal sectoral water users; the extent to which water scarcity and drought issues impacted the economy, society and the environment; and possible gaps in implementing existing EU policy instruments. It subsequently issued a communication on the challenge of water scarcity and droughts in July 2007 (EC, 2007b). The supporting impact assessment (EC, 2007c) assessed the cost and benefits of the various measures to achieve water savings. This and regular follow up assessments (EC, 2009; EC, 2011a) revealed that there is considerable scope to improve current water management practices, especially in terms of watersaving potential.

Within this context, a study led by Ecologic Institute (Dworak et al., 2007) identified substantial watersaving potential in European countries based on analysis of the four main water users: public water supply (including households), agriculture, industry and tourism. The European Commission (2010) likewise estimates that Europe could decrease its overall water consumption by 40 %.

2.1.1 Water use efficiency in agriculture

Agriculture is a significant water user in Europe, accounting for around 33 % of total water use. This share varies markedly, however, and can reach up to 80 % in parts of southern Europe, where irrigation of crops accounts for virtually all agricultural water use. In many regions within southern Europe, crop irrigation has been practised for centuries and is the basis of economic and social activity. In arid and semi-arid areas of Europe, including much of southern France, Greece, Italy, Portugal, Cyprus and Spain, irrigation enables crop production where water would otherwise be a limiting factor. In more humid and temperate areas, irrigation provides a way of regulating the seasonal availability of water to match agricultural needs, reducing the risks of crop failures during periods of low rainfall or drought and thereby stabilising farmer incomes.

While enhancing the yield and quality of crops, irrigation can and does lead to a range of negative environmental impacts, including water scarcity. The detrimental effects of excessive agricultural water use are exacerbated by its relatively high consumptive use. Although some irrigation water is 'returned' to groundwater via percolation, consumption through plant growth and evapotranspiration is typically significant and approximately 70 % of water abstracted does not return to a water body (Molle and Berkoff, 2007).

Traditionally, supply-orientated approaches have ensured a regular supply of water for agriculture through a combination of reservoirs, inter-basin transfers and increasing abstraction of both surface water and groundwater. Generally, however, such practices are not sustainable in the longer term and simply exacerbate the adverse impacts of agricultural water use upon freshwater ecosystems. Fortunately, a

Photo: © Colin Brough, 2010

number of technological and management measures exist to improve the efficiency and sustainability of agricultural water use. These are described below. It should be noted, however, that the efficiency gain associated with each approach is strongly dependent upon a range of factors including crop and soil type and climate, and this must be understood fully before measures are implemented (Bio Intelligence Service, 2012).

Improving irrigation efficiency

Irrigation efficiency consists of conveyance efficiency and field application efficiency. Conveyance efficiency refers to the percentage of abstracted water that is delivered to the field. There are large differences in conveyance efficiency depending on the type of irrigation network. In Greece, for example, average conveyance efficiencies are estimated at 70 % for earthen channels, 85 % for lined channels and 95 % for pipes (Karamanos, 2005). The conversion from open channels to pressurised pipe networks can, therefore, be an important watersaving measure. In the Cote d'Azur region in France, such a conversion has helped save around 300 million m^3 annually (Dworak et al., 2007). Across the EU, potential water savings from improving conveyance efficiency are estimated at 25 % of water abstracted (WssTP, 2010).

Field application efficiency is the ratio between the water used by a crop and the total amount of water delivered to that crop, indicating how well an irrigation system performs in transporting water to the plant roots. A strong contrast is apparent when comparing furrows with sprinkler and drip systems, with the former having an efficiency of around 55 %, sprinklers 75 % and drip systems 90 % (Dworak et al., 2007).

More efficient irrigation systems are gradually being implemented within Europe. In Spain, between 2002 and 2008, the area irrigated by gravity (flooding) methods decreased from around 1.4 million hectares to just above 1 million. Over the same period, drip irrigation increased from 1.1 million hectares to 1.6 million hectares (MARM/BPIA, 2009).

Increased irrigation efficiency can, however, result in either no change or even an increase in water used if the efficiency gains simply drive an expansion of the irrigated area. For example, García (2002) reports that subsidised drip irrigation technologies in the Valencia region of Spain did not lead to reduced application rates, while Candela et al. (2008) report a tripling of irrigation area following efficiency improvements. Research in Crete has revealed that the technical efficiency of some farmers using drip irrigation systems is low and they are not fully exploiting the potential water-resource savings (OECD, 2006). Any installation of improved irrigation systems needs, therefore, to be accompanied by advice to farmers.

Modification of agricultural practices

Crops vary in their resistance to drought and their water requirements. Careful crop selection, together with irrigation management and soil moisture conservation can all reduce crop water use. Crop tolerance to drought depends partly on the depth of root systems. Crops with deep root systems such as grapes, alfalfa and sorghum are able to draw on moisture deeper in the soil than those with shallow roots (e.g. maize and pea) and so cope better during periods of water stress. Crops also vary in their timing of peak water demand. Water demand for maize, for example, is concentrated in the summer months when water stress is at a maximum. In contrast, the cropping calendar of rape, winter wheat and winter barley is centred on the autumn and winter months when there is more water available. The timing of the cropping calendar can also be used as a technique to reduce irrigated water use. Early sowing, for example, can help capture winter rains so that the need for supplementary irrigation is reduced. Early sowing also helps avoid the extreme evapotranspiration rates typical of Mediterranean summers.

Aside from economic considerations, changing from water intensive crops to those that demand relatively little water (and are drought tolerant) is an obvious option for reducing irrigation water requirements. The success of such a change is, however, highly dependent on market prices.

In addition to changing to less water intensive crop types, there is also potential for returning irrigated land back to traditional rain-fed practices, particularly in regions where water stress is acute. While such a wholesale change in the approach to farming would clearly affect water use, it raises socio-economic issues and, seen in the context of global markets and prices for agricultural products, may not be economically feasible in some locations.

Deficit irrigation is a technique that aims to reduce the amount of water applied to below the 'theoretical irrigation need' on the basis that the substantial water savings realised outweighs any reduction in crop yield. The approach takes advantage of the fact that maximum production does not necessarily lead to maximum profitability. Deficit irrigation has been shown to have more success with tree crops and vines than field crops (Fereres and Soriano, 2006). For grapevines, a reduction in water use ranging from 16.5 % (rainy years) to 53 % (dry years) produced no significant impact on the grape yield or the quality of the must (Battilani et al., 2007). Contrastingly, the water stress sensitivity of maize means that it does not respond well to the practice (Bio Intelligence Service, 2012). A number of factors must be accounted for when considering deficit irrigation, including the crop type, its phenological phases, and monitoring of soil water content.

Improving the timing of irrigation so that it closely follows crop water requirements can lead to significant water savings. The approach does require, however, that farmers are well trained and familiar with issues such as temporal changes in crop water demand and estimating soil moisture. In Crete, for example, the irrigation advisory service informs farmers by phone of when and how to apply water to crops, based on estimates of daily crop evaporation that account for crop type, growth stage, soil type and rainfall. Water savings of 9–20 % have been achieved (Bio Intelligence Service, 2012), reducing costs to farmers.

Reusing wastewater

In areas where water is scarce, treated wastewater provides an alternative source of water for irrigating crops. The practice is growing within Europe and is particularly well established in Spain, Italy, Cyprus and Greece (MED-EUWI, 2007; Aquarec, 2006).

For islands and coastal regions, water recycling allows extended and thus more efficient use of freshwater by avoiding discharge to the sea. The contribution of water recycling to meeting agricultural water demand can be substantial. In Gran Canaria, for example, 20 % of water used across all sectors is supplied from treated wastewater, including the irrigation of 5 000 hectares of tomatoes and 2 500 hectares of banana plantations (MED-EUWI, 2007). In Cyprus, the reuse targets for 2014 equate to about 28 % of the agricultural water demand in 2008 (WDD, 2008).

The quality of reclaimed water, in terms of chemical and bacterial loads, must be considered and properly managed. Regulations in force in several EU Member States aim to achieve this but more unified guidance on regulating and implementing water recycling in agriculture would support further uptake and intensification of the practice.

Following a comparative analysis of desalinating seawater, importing water and reclaiming wastewater on the Aegean islands, Gikas and Tchobanoglous (2009) concluded that the latter imposes the lowest cost and energy requirements. Reclaiming wastewater is recommended as part of a longterm strategy for managing water resources sustainably across the islands and has various potential uses, including agricultural irrigation.

In 2010, the UN Food and Agriculture Organization (FAO) launched a report about an 'economic framework for the assessment of the use of reclaimed water in agriculture, as part of a comprehensive planning process in water-resource allocation strategies to provide for a more economically efficient and sustainable water utilisation' (FAO, 2010).The Llobregat site (Barcelona, Spain) has proven to be a 'win-win' project, where farmers exchange their current entitlements to freshwater against use of reclaimed water thereby making the natural resource of freshwater available for drinking water demand. The project is delivering agricultural and environmental benefits and demonstrates efficient water-resource allocation in integrated water management.

Tackling illegal water use

While reliable quantitative information on the issue is scarce, it is clear that illegal abstraction of water, particularly from groundwater and often for agricultural purposes, is widespread in certain areas of Europe. Illegal water use may involve drilling an unlicensed well or exceeding a consented abstractable volume from wells that are licensed. In addition, it can occur from surface waters using transportable pumping devices. Addressing illegal water use is crucial but represents a major political and technical challenge. Monitoring is required to detect illegal wells and authorities have to follow up detected cases with fines or penalties sufficiently severe to deter further illegal abstraction. Surveillance is also required to ensure continued compliance.

In Spain, for example, illegal water abstraction represents a major threat, particularly at times of drought. While Drought Management Plans curtail irrigation in order to ensure that priority needs are met, farmers resort to illegal groundwater abstractions to protect their crop against drought. Drought risk translates into groundwater depletion risk (Gómez and Pérez, 2012).

2.1.2 *Water use efficiency of public water systems and industry*

Approximately 20 % of water abstraction across Europe supplies public water systems, although significant variation exists between countries. Public water not only includes the supply to households but also to small businesses, hotels, offices, hospitals, schools and some industries. The key drivers influencing public water demand are population and household size, income, consumer behaviour and tourist activities. Technological developments, including watersaving devices and measures to address leakage in public water supply systems, also play an important role.

Box 2.1 Zaragoza: watersaving city

Zaragoza, a city in north-east Spain, provides an example of successful management of urban water demand. The city reduced overall water use by 1 600 million litres on average each year between 1995 and 2008 despite significant population growth.

A local non-governmental organisation, Ecodes (Foundation for the Environment and Development), was founded specifically to help reduce water usage in Zaragoza, and worked closely with the municipality to inspire and support watersaving initiatives. Water quality also improved.

Importantly Ecodes enjoyed the full support of the municipality and managed to secure the engagement and support of the public through a clear and well structured publicity campaign. Water saving became a matter of civic pride disassociated from party politics, and consequently survived several changes of government.

Successful measures included the adoption of a range of watersaving techniques by industry such as re-circulating cooling systems and improvements in cleaning methods and maintenance regimes, combined with the introduction of water meters. In addition, following public awareness campaigns, the behaviour of the general public changed.

The government also drew up a municipal order to save water, to be incorporated in the Municipal Building Code. Finally, a workable water tariff system that aims to be fair to all consumers was introduced following a stakeholder consultation. The campaign was so successful that initial targets were achieved two years ahead of time, allowing even more ambitious targets to be set.

Source: Shirley-Smith et al., 2008.

A number of measures can potentially reduce the use of public water supplies. These can be broadly grouped into the broad categories of watersaving devices; greywater re-use and rainwater harvesting; behavioural change through awareness-raising; metering; and leakage reduction in distribution and supply networks.

Photo: © Fleur Suijten, 2005

Watersaving devices and products

The water efficiency of modern large electrical appliances such as washing machines and dishwashers, and numerous other household products including toilets, taps, showers and general plumbing, has greatly improved over recent decades. Even as these innovations become standard in new buildings, considerable scope exists for a greater uptake and use of these modern appliances across much of Europe.

Toilet flushing accounts for about 25–30 % of total domestic water use. As such, savings of 30 litres per property per day (Waterwise, 2010) can be achieved by using dual flush and low flush toilets. Cistern replacement devices (for example 'hippos') are a simple and cheap means of reducing flush volumes, typically by about 1 litre per flush. They are particularly useful in older toilets with large cistern volumes. Water can also be conserved with a delayed action inlet valve, which prevents the cistern refilling during the flush. Without such a valve, the water released is greater than the cistern's capacity — by 17 % according to one study cited in a UK Environment Agency report (EA, 2007).

Many older urinal installations do not have controls and so flush continuously, wasting significant volumes of water in public and commercial buildings. A number of flush control devices are now available that provide significant water savings. These are typically timer-based or else detect the presence of people using infrared sensors.

Installing water efficient showerheads can save about 25 litres per property per day (Waterwise, 2010). Water use by showers can be reduced considerably by aerating the water flow, which helps to simulate the feel of a power shower but without requiring high volumes of water. Such aeration can also be applied to water flowing through taps. Thermostatic mixing valves in both showers and taps maintain selected temperatures and have been shown to result in considerable savings of both water and energy. Taps with infrared sensors provide water only when an object is detected beneath them, resulting in water savings of 70 % or more.

Bio Intelligence Service (2011) identified a potential to reduce water use in buildings by 10 % using horizontal measures such as metering and pricing strategies. A further saving of more than 5 % was possible using product and building-level policies such as labelling and rating/auditing. Overall, there is a need for improved incentives for broader application of improved ecodesign.

Reuse of greywater and rainwater harvesting

'Greywater' refers to all household wastewater other than that from toilets, i.e. wastewater from baths, showers, washbasins, kitchens and washing machines. In the most simple re-use systems, greywater is stored and subsequently used, untreated, for flushing toilets and watering gardens (other than edible plants), thereby reducing the use of potable water. Greywater from baths, showers and washbasins is generally preferred to that from kitchen sinks and dishwashers since it is less contaminated. The microbial quality of greywater raises public health concerns, however, particularly when it has been stored for some time. Immediate use of greywater is therefore preferred, although approaches also exist to minimise the contamination of stored water.

Rainwater flowing from a roof or other impermeable surface can be transferred via guttering or piping to a receiving container and subsequently used for activities such as gardening and car washing. Rainwater harvesting therefore reduces household use of treated public water supplies where it is used to supply, for example, washing machines and

Photo: © Giacomo de Stefano

toilets. Perhaps even more important in countries with abundant water resources, it can also reduce the load on urban drainage systems during heavy precipitation. Fiscal arrangements to compensate those who install such arrangements may increase incentives for the local management of storm water.

Harvesting systems can range markedly in scale and complexity from a simple garden butt to community systems. In Berlin, for example, rainwater falling on 32 000 m^2 of roofing associated with a large scale urban development — the Daimler Chrysler Potsdamer Platz — is collected in a 3 500 m^3 tank (UNEP, 2011b).

While harvesting and reuse yield water savings, for some systems the energy used in manufacturing, installing and maintaining the necessary infrastructure yields a greater greenhouse gas emission than using mains water. Scope exists, however, to improve the design of such systems to reduce their carbon footprints, including with respect to storage tanks and pumps (EA, 2010a).

Box 2.2 Treated wastewater supports water efficiency

The recently completed Olympic Park in London receives non-potable water derived from the treatment of wastewater. Londoner's wastewater from an outfall sewer is turned into water suitable for irrigation, flushing toilets and as a coolant in the Park's energy centre. This water is pumped into the Park's network of pipes, which are separate from those supplying drinking water to taps. This recycling of 'blackwater' produces 574 m^3 of water per day for the Olympic Park.

Source: Defra, 2011b.

Reducing leakage

Leakage in public water systems is a common problem, undermining water-resource efficiency. Although eliminating leakage entirely is an unrealistic goal because of the costs involved, optimising leakage reduction is a crucial part of water demand management.

Leakage in public water supply systems results in loss of purified drinking water but also means wasting the energy and material resources used in abstraction and treatment. In cases where supply pressure drops, leakage can also imply a potential risk of bacterial contamination from surrounding ground.

Quantifying the combined 'distribution loss' in a water supply network, which includes water used for flushing pipes, unbilled consumption (e.g. fire fighting) and illegal consumption, can only be calculated indirectly as the difference between drinking water produced and end-user metering (or some other estimate of consumption).

Leakage is usually the largest component of distribution loss, according to the European Benchmarking Co-operation (EBC, 2011), which reports distribution losses of about 5 m^3/day/km of mains in the supply network. There is considerable variation, however, among the approximately 40 utilities participating, mainly from Europe.

Currently leakage rates are not subject to regulation other than management decisions by utilities. These are often based on considerations such as consumer health and the economic return period for investments in infrastructure maintenance. If such cost calculations do not include externalities and other consequences of expanding water supply using energy intensive and material resource intensive technologies, these decisions will produce suboptimal outcomes for society.

Leakage in sewerage systems will result in either infiltration or exfiltration depending on the local groundwater tables. Exfiltration of wastewater may result in contamination of groundwater and thereby compromise groundwater resources in cities for human consumption. Infiltration contributes to diluting wastewater and leads to roughly proportional increases in pollution loads into the environment.

Large infrastructure maintenance projects in cities aimed at reducing water leakage often have long timespans and must be integrated with city planning for projects in other sectors, such as transport, telecommunications, gas and heating. A forthcoming European Commission study to be published in 2012 will provide more information on the feasibility of further leakage reduction in Europe (EC, 2012a).

Raising awareness

Awareness-raising campaigns aimed at domestic and business water consumers play an important role in conserving water. Such campaigns encompass a number of different approaches, including websites, education programmes in schools, local authority and water company leaflets, advertising stands at live events and the use of general media outlets (i.e. television, radio and newspapers and, increasingly, social media). Typically, the larger the geographical reach of the campaign, the simpler its content. Awareness-raising can address behaviour, such as time spent showering or water use in gardening, as well as focusing on the benefits of installing water efficient appliances and products.

Metering

Metering is a very important tool for raising awareness about water use, providing factual information and feedback to every user. But fully implementing metering for all users is also a key control and governance measure. It is a precondition for a volumetric pricing, which is an important element in the water tariff structure (see Box 2.3).

Box 2.3 Water metering in England and Wales

Over recent decades, water stress has increased in England and Wales, due both to an increase in water demand resulting from population growth and changing lifestyles, and reduced water supply (decreasing environmental base flows).

To address this challenge, water companies are allowed to replace current water charges based on the value of residential property with volumetric water charges (Walker, 2009). Water meters are needed to implement volumetric charges and their use has expanded hugely. According to OFWAT (2010) 'Whereas only 3 % of residential customers had meters in 1992–1993, by 2010 that proportion had risen to 40 %.'

Customers were free to decide whether or not to install a meter and be charged based on their actual water use. The roll-out of meters was largely facilitated by public awareness campaigns and discussions, and cooperation between OFWAT, the Environment Agency and the water companies. In areas that the Environment Agency declared to be 'water stressed', water companies could require consumers to install meters. So far, four out of the nine water companies in water stressed areas have announced compulsory water metering (EA, 2008a).

Source: Zetland and Weikard, 2011; OFWAT, 2010.

2.2 Water and energy sector linkages

In the sustainable development context, efficient water use is closely linked to efficient use of other resources such as energy, chemicals, materials and land. Water is used in energy and food production; energy and materials are needed for water treatment; energy, food and industrial production are important drivers for water pollution and over-abstraction. Protecting water resources requires a focus on both water quantity and quality.

2.2.1 *Water used producing energy; energy used producing water*

The water-energy link is multifaceted. Energy production can affect water quality, while energy is used in water treatment and to reduce pollution. Similarly, hydropower — producing energy from water — and desalination — producing freshwater using energy — both play a important role in economic growth by supplying large and secure amounts of 'green' energy or water where it is a scarce resource.

Hydropower

In 2010 hydropower provided 16 % of electricity in Europe and 67 % of all renewable electricity (Eurelectric, 2011). More than 85 % of hydropower energy is produced by large hydropower plants. The share of hydropower in electricity production is generally high in the northern and Alpine countries.

In the context of the EU's Renewable Energy Directive (EU, 2009a), hydropower is an important measure for increasing the share of renewable electricity. Depending on its management, however, hydropower can impact water bodies and adjacent wetlands.

The national renewable energy action plans (NREAPs) elaborated pursuant to the Renewable Energy Directive indicate that between 2005 and 2020 the largest predicted increases in annual electricity output from renewable sources will derive from wind (424 TWh), solid biomass (99.8 TWh) and solar photovoltaics (81.9 TWh). As Figure 2.1 illustrates, the anticipated expansion of hydropower is comparatively small. Micro-hydro (< 1 MW capacity) is expected to produce an additional 1.3 TWh in 2020, compared to 2005; small hydro (1–10 MW) will produce another 6.3 TWh, and large hydro (> 10 MW) will provide an extra 14.7 TWh (Beurskens et al., 2011). The pumped storage capacity is also expected to almost double, from 23 400 MW in 2005 to 39 500 MW in 2020.

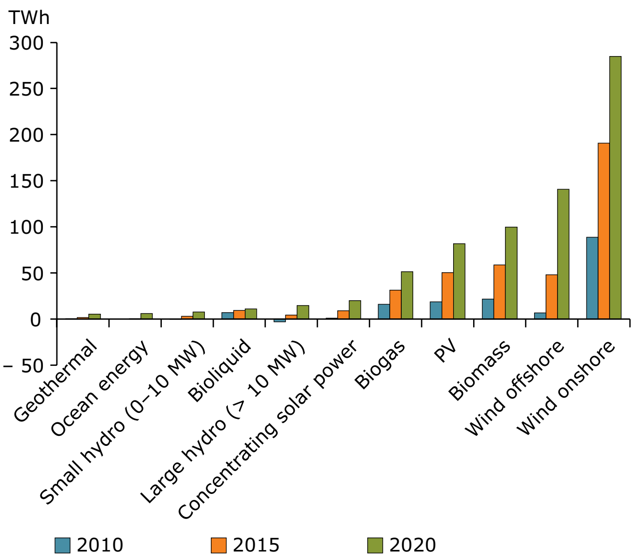
Although small hydropower schemes make up a relatively small proportion of total capacity growth, the number of installations will be far greater than large hydropower schemes. Member State plans indicate many thousands of new installations across the EU. There is a risk of increased environmental impacts from new small hydropower developments, unless particular care is given to effective impact mitigation.

Hydropower installations have potentially large environmental impacts. Structures such as hydropower dams or river-run hydropower have resulted in significant hydromorphological modifications — physical changes — to many of Europe's rivers and lakes. Hydropower can affect the hydrology of freshwater systems, obstruct upstream and downstream migration, and change the water flow and sediments. Hydropower plants have altered the seasonal or daily flow regimes in many European rivers, resulting in significant impacts on ecosystems (EEA, 2010a; Jansson, 2006; Sørensen, 2000).

New hydropower installations could conflict with the WFD objective of achieving good ecological (including good hydromorphological) status. Refurbishing and upgrading existing hydropower installations might also conflict with good ecological potential in cases where a water body is already modified (EC, 2004). However, the potential reduction of existing hydroelectric generation due to WFD implementation is so far assumed to be only around 1.5–5 % (Kampa et al., 2011).

Decisions that balance the goal of maximising growth in renewable energy capacity against the goal of minimising environmental impacts need to be assessed case by case at the regional level, within e.g. strategic planning (optimising the selection of locations). The impact of existing small and large hydropower schemes should be evaluated, and hydropower's impacts should be compared to those of other renewable energy technologies such as solar and wind. Only then will resource efficiency be understood in a manner that integrates energy, water resources and the functioning of ecosystems. It may be easier to expand the capacity of other renewable energies with less environmental impacts. Unfortunately, assessing the relative efficiency of alternative energy sources in terms of their impacts per unit of energy produced or stored is challenging. So far there are no agreed methods and indicators to evaluate this impact in a harmonised way (Melin, 2010).

Figure 2.1 Potential growth in renewable energy relative to 2005



Source: Beurskens et al., 2011.

Photo: © Giacomo de Stefano

Box 2.4 Subsidies for sustainable hydropower in Germany

In Germany, the 2000 Renewable Energy Sources Act (EEG) is the main instrument promoting renewable energy. It guarantees a defined remuneration per kWh of electricity produced from renewable sources, which exceeds market prices.

Since its amendment in 2004, the EEG has also set environmental requirements for hydropower plants to be eligible for increased subsidies. These ecological conditions are applicable for all of Germany's 7 500 hydroelectric power stations. The most important measures required for water bodies in the area of influence of hydropower plants relate to establishing migration possibilities for fish upstream, fish protection measures for migration downstream, and ensuring minimum water flows (Naumann, 2011).

First assessments of implementation of the EEG report that about 10 % of existing hydropower plants use equipment that assists upstream migration of fishes and/or ensures minimum flow conditions. About half of the upstream migration provisions have been financed by the increased subsidies available under the EEG (Anderer et al., 2011).

Source: Mattheiß, 2011.

Desalination

Desalination is widely discussed and increasingly used to meet freshwater demand in water scarce regions. The greatest desalination capacity (including both installed and projected facilities) is found in the Middle East and North Africa, which account for more than 70 % of global capacity. Europe holds some 10 % of global capacity, with Spain the biggest user of desalination with a capacity of 1.6 million m³/day. The capacities of other EU Mediterranean countries are rather smaller, with some 240 000 m³/day in Italy, 100 000 m³/day in Cyprus and 30 000 m³/day in Greece. Turkey's capacity is much less at about 10–15 m³/day (Lattemann and Höpner, 2008). Spain is currently discussing increasing its capacity dramatically, with 20 new installations planned.

The rapid expansion of desalination capacity is focusing attention on its environmental impacts. One key issue is the discharge of salt (either brine or solid waste from the desalination process). Brine effluents and waste also include other chemicals used during pretreatment and membrane-cleaning in the desalination process. Brine is heavier than normal sea water and spreads along the sea bottom, threatening organisms sensitive to salinity, for example the sea grass *Posidonia oceanica* (USNRC, 2008; WWF, 2007; Lattemann and Höpner, 2008).

Another important concern is desalination's energy consumption and carbon emissions. Southern Europe's planned investments in desalination to address water scarcity could jeopardise the reductions in energy use planned under the EU's climate and energy package (EC, 2009a). As has been widely discussed (Elimelech and Philippe, 2011; Semiat, 2008; Lattemann and Höpner, 2008), desalination plants have significant energy needs. Separating water from salt demands theoretically 1.06 kWh/m³ and further energy is needed for pretreatment and processing. Unless the energy use is off-set by renewable energy sources directly at the plant or in the region, the sustainability of desalination has to be questioned when considering the EU's combined targets for of water and energy sustainably, and reducing carbon emissions.

One way to address the energy implications of desalination might be to employ renewable energy sources. In recent years research has sought to identify technologies that allow water and energy production at a reasonable price (Blanco et al., 2009; Fernandez-Lopes et al., 2009). Spain has research programmes to foster solar- and wind-powered desalination (Fernandez-Lopes et al., 2009). In the case of the solar technologies, there is some appeal in the fact that the same climatic conditions that cause water scarcity (in part by boosting agriculture and tourism) also enable the provision of water to meet the needs of these sectors.

A further innovative way to deal with the negative environmental impact of desalination is to combine the brine discharge of desalination plants with the discharge of wastewater treatment plants, as is currently done in Llobregat (Spain) (Box 2.5).

Box 2.5 Desalination in Barcelona — moving towards environmentally friendly practices

Barcelona constructed a 200 000 m³/day desalination plant following an extended drought, which had forced the city to import drinking water via boat. Fully operational since July 2009, the plant satisfies 20 % of Barcelona's drinking water needs.

In 2010, the Barcelona Llobregat desalination plant was recognised as 'Desalination plant of the year' at the 2010 Global Water Awards for its efforts to reduce the environmental harm of desalination. Key measures have included steps to decrease harmful environmental impacts by diluting brine with wastewater from the nearby Baix-Llobregat wastewater treatment plant before discharging it into the sea. Energy recovery was also boosted by applying PX Pressure Exchanger® (PX®) devices, enabling energy recycling at up to 98 % efficiency.

The Barcelona (Llobregat) desalination plant is said to be 'one of the most well designed, modern desalination facilities in the world' (Energy Recovery Inc., 2012).

At present, the technologies for mitigating desalination's impacts are still in their infancy. As a result, desalination should only be considered an option after all other water efficiency measures have been implemented. The possibility of linking water supply with renewable energies should be seen as a chance for investments in innovative technologies, driving further growth in often marginal areas.

2.2.2 *Energy use in drinking water supply*

Drinking water supply includes abstraction, treatment and supply via the pressured network for use by customers in households and industry. The energy used depends greatly on local geographical and hydrogeological conditions and raw water quality. This ranges from clean water resources transported by gravity from mountains to urban areas or abstracted from deep aquifers by pumping, to intake from rivers, which are affected by many upstream pollutant discharges and therefore need more advanced treatment to meet drinking water quality standards.

The energy required per m^3 of drinking water is very site specific. It may therefore be more useful to evaluate energy efficiency trends over time at individual utilities, rather than to compare the efficiency of utilities in significantly differing local conditions.

The European Benchmarking Co-operation (EBC) records the power consumption at some 40 utilities, mainly in Europe, with different water source and supply conditions. According to EBC (2011), the mean value for pumping water is 0.56 kWh per m^3, varying between 0.3 kWh/m^3 at the 10th percentile and 0.9 kWh/m^3 at the 90 percentile. This corresponds to an estimated average energy use of 0.64 kWh per m^3 for producing and distributing drinking water to about 22 million people in the EU (Suez Environnement, 2012).

From the demand management side, there may be greater potentials for saving energy by reducing water use and making infrastructural investments in leakage control.

In considering the source of drinking water, the most cost-effective and energy saving solution is to obtain clean freshwater from a nearby source. If nearby sources are heavily polluted, e.g. by agricultural contamination with nitrates and pesticides or industrial pollution by chemicals, several possibilities exist to provide customers with the expected quality. One option is to source fresh, good quality water from more remote, mountainous areas, although this implies higher costs and energy demands for transport. If more distant freshwater sources are also scarce or the transport distances are too great then more intense treatment is necessary, such as ion exchange to remove nitrates and activated carbon to remove pesticides. Both are relatively energy intensive.

In the situations where drinking water demands cannot be met from available freshwater sources, a final means of increasing supply is desalination but this consumes more energy. Roughly speaking, the electricity consumed in producing drinking water with seawater desalination by reverse osmosis is around 4 kWh per m^3 higher than the energy needed for traditional treatment of freshwater from a river or a lake Suez Environment, 2012), less is needed if produced from brackish water. As noted above the energy need for the traditional treatment even including distribution is only 0.64 kWh per m^3.

Box 2.6 Improving water quality at source reduces drinking water costs

Upstream catchment management is increasingly viewed as a sustainable approach to improving the quality of water abstracted for drinking. By reducing the need for 'end-of-pipe' water treatment, it also cuts treatment costs.

In the United Kingdom successful implementation of this approach has involved partnerships between water companies, NGOs such as rivers trusts, and local farmers. For example, South West Water's programme of environmental improvement, 'Upstream thinking', helps farmers and land managers to keep peat, soils and natural fertilisers on the land, and improve slurry management. Strong benefit-to-cost ratios are projected.

Similarly, Yorkshire Water is pursuing a land management solution to a growing raw-water colour problem arising from moorland. Tackling the problem at source reduces the need for expensive carbon intensive treatment solutions and supports other ecosystem services that the moor provides such as carbon storage and biodiversity.

Water discolouration is also the focus of a United Utilities sustainable catchment management programme in north-west England, where a partnership approach is improving land management and water quality and restoring peat vegetation, thereby also supporting carbon storage.

Sources: Defra, 2011a and 2011b; Rivers Trust, 2012.

Photo: © sxc.hu/Dave Millet, 2010

Kenway et al. (2008) report that in Australia, which already faces widespread water scarcity and drought problems, urban water supply and wastewater services currently account for a small fraction of total energy use in Australia but this is expected to triple by 2030. Unfortunately, understanding of the important linkages between water, energy and the economy is currently limited but the concept of urban metabolism potentially offers a framework for analysis (Kenway et al., 2011a and 2011b).

2.2.3 *Energy use and recovery in wastewater treatment*

Wastewater treatment consumes energy, mainly in the form of electrical power. Suez Environnement (2012) reports an annual weighted average power consumption of 47 kWh/y/pe (based on 18 million people served in the EU). Similarly, BMU (2011) reports values of 32–75 kWh/y/pe for urban wastewater plants in Germany serving populations ranging from less than 1 000 persons to more than 100 000 with the lowest specific consumptions at the bigger plants. In comparison, in 2008 the average annual energy consumption of each European citizen was about 5 000 kWh.

Usefully, the chemical composition of wastewater and the heat it contains also enable energy recovery. By converting organic matter into a methane-rich 'biogas' using sludge digestion, this renewable energy source can generate power and thereby reduce or eliminate a plant's dependence on conventional electricity. Energy savings can also be achieved by improving process performance e.g. using up-to-date instrumentation, control and automation (ICA). Wastewater collection also consumes energy, although normally much less than wastewater treatment.

Based on a review of some 40 utilities using different forms of wastewater treatment, mainly in Europe, the European Benchmarking Co-operation (EBC) calculated a median energy recovery for those using energy recovery technologies of around 7.5 kWh/y/population equivalent (pe). In comparison to a median power consumption of 33 kWh/y/pe this represents a good efficiency gain (EBC, 2011).

Energy consumption and recovery data from different sources are not always comparable due to the use of different units and mixing of electricity and heat energy without considering exergy levels. This problem can be overcome by analysing the carbon footprint for the energy balances, as is practiced in, for example, Australia and New Zealand (Kenway et al., 2008).

A zero carbon footprint can be obtained by carbon off-setting and co-digestion of organic waste with sewage sludge as a synergy between the two sectors. The Amsterdam Westpoort (Netherlands) and Hagen (Germany) wastewater treatment facilities, for example, are today considered carbon neutral in their infrastructure and operation. For future comparisons, however, a clear terminology and methodology for calculating carbon footprints from wastewater treatment plants is needed.

As another example, biogas can be used as a fuel for vehicles. Stockholm's Vatten sewage treatment works, for example, is a net supplier of energy, producing 4.1 million m^3 of biogas annually, which is used as a fuel for several of the city's buses, taxis and private cars. Additionally, heat is extracted from the treated wastewater and used in Stockholm's district heating systems (Stockholm Vatten, 2012).

Several plants have reduced electricity consumption by more than 15 % without compromising effluent quality by investing in instrumentation, control and automation (Thomsen and Önnerth, 2009). Reducing the number of mixers in the biological treatment process can also deliver energy savings, as demonstrated by the 0.75 GWh reduction in annual energy consumption achieved at the Avedøre wastewater treatment plant in Denmark, which serves 260 000 citizens plus industry (Sharma et al., 2011). The latter study demonstrates the potential benefits of reconsidering design standards based on experimental investigations.

Photo: © Giacomo de Stefano, UWWTP, Strasbourg

Tertiary wastewater treatment is now the norm in northern and central Europe (EEA, 2010d). However, the 6th Implementation Report of the Urban Waste Water Directive (EC, 2011b) states a implementation gap which will require big investment in the future. With the current development of wastewater infrastructure e.g. in eastern and south-eastern Europe, there is an opportunity to integrate modern design and operation practices that achieve both optimal energy use and higher treatment levels and use those investments to increase efficiency.

2.3 Water quality and resource efficiency

The water quantity/water quality link requires the full consideration of the 'water-energy-food' nexus. Where Section 2.2 focused on the water-energy relation the following expands further to look in addition to the aspects of pollution and efficient use of land and material. An important aspect here is to further reduce emissions to help protect water resources (and the reduce energy for their treatment), but also to use land and material more efficiently.

2.3.1 Recovery of nutrients in wastewater treatment

Technological innovation is helping to achieve a more sustainable approach to wastewater treatment. It is shifting the conventional view of municipal sewage from a waste to be treated and disposed of, to a resource that can be processed for the recovery of energy, nutrients, and other constituents.

Regarding Nitrogen the European Nitrogen Assessment (Sutton et al., 2011) advocates that an ambitious long-term goal should be to recycle Nitrogen from wastewaters, utilising new sewage management technologies and by that means reduce energy for producing new Nitrogen fertiliser. In the case of Phosphorus, for example, another essential plant nutrient, applied to agricultural land worldwide in fertilisers derived from phosphate rock the situation is even more urgent as phosphate rock is a non-renewable resource, which is being steadily depleted. Some estimates suggest that global commercial phosphate reserves will be depleted within 100 years at current rates of extraction (Smit et al., 2009). Other studies indicate that the global peak in rock phosphate reserves will occur around 2035 (Cordell et al., 2009) after which mining and processing will become increasingly uneconomical.

While the timing of such a peak and the lifetime of remaining reserves is subject to continuing debate, there is a general consensus that the quality of remaining reserves is declining, phosphate layers are becoming more difficult to access and costs are increasing (Smit et al., 2009). Ultimately, cheap phosphate fertilisers will become unavailable. Unfortunately, phosphorus has no substitute in food production and the European Union is almost entirely dependent upon imports, with China, Jordan, Morocco, South Africa and USA controlling 85 % of global phosphate reserves (Smit et al., 2009).

The continued depletion of phosphate rock reserves is likely to incentivise more efficient use of phosphate fertiliser on agricultural land. However, significant amounts will continue to enter water bodies. Virtually all of the phosphorus that humans consume in food is excreted in urine and faeces, with an estimated 3 million tonnes produced globally each year (Cordell et al., 2009). Phosphorus in detergents is likewise disposed of via domestic wastewater.

As part of an efficient solution, reducing phosphorus used in detergents at source would help address the increasing depletion of stocks, as well as the disposal problem. The regulation restricting the use of phosphates and other phosphorus compounds in consumer laundry and automatic dishwasher detergents recently adopted by the European Council can be seen as a useful step forward in this direction (EU, 2012).

Within Europe, domestic wastewater is typically directed to an urban wastewater treatment plant. Depending on the level of treatment, effluent from such plants discharges some phosphorus to receiving waters, increasing the risk of eutrophication. The phosphorus not discharged within effluent is retained within treated and nutrient-rich sewage sludge (also known as biosolid).

According to Milieu et al. (2012) about 40 % of the about 10 million tonnes of dry solids of sewage sludge produced in the EU-27 is recycled to agriculture. The proportion could be even higher if there were not major concerns about heavy metals, organic micro-pollutants and emerging hazardous substances accumulating in soils and in the food chain. In the EU sewage sludge contributes less than 5 % of the total amount of organic manure used on land (most of which is of farm animal origin), and sludge is applied to less than 5 % of agricultural land in the EU.

Milieu et al. (2012) anticipate that in the future there will be a general phasing out of sending sludge to landfill. Instead, there will be more treatment of sludge, using anaerobic digestion and other biological treatments such as composting, before recycling to land. They also foresee a possible increase in restrictions on the types of crops that can be cultivated using treated sludge, increased attention to recovering organic nutrients and, in densely populated areas, incineration with energy recovery.

The ability to recover phosphorus from sewage to make fertiliser is a relatively new technological breakthrough. Several technical, economic and management approaches are available for recovering nutrients from wastewater streams (IWA, 2009). Phosphorus can be recovered from wastewater and sewage sludge as well as from the ash of incinerated sewage sludge, with recovery rates from the latter two reaching up to 90 % (Cornel and Schaum, 2009). Experimental trials have demonstrated the value of a range of recovery techniques (Valsami-Jones, 2004) including thermochemical technology developed within the sustainable and safe re-use of municipal sewage sludge for nutrient recovery project (SUSAN, 2009).

In the Netherlands, a sewage sludge treatment company delivers approximately 6 000 tonnes per year of phosphorus-rich sludge ash to a phosphate producer for further purification. The producer integrates this into the output of pure phosphorus to be sold for a wide range of applications (Schipper and Korving, 2009).

Recovering the mineral struvite (ammonium magnesium phosphate) from sludge offers a double benefit. First, struvite is a high quality fertiliser; as a crystalline product, struvite releases phosphorus slowly, while avoiding the concerns about heavy metals and organic micropollutants that arise if applying sludge directly to agricultural land. Second, struvite can form scaling in sewage pumps, valves and pipes, so struvite recovery helps prevent clogging (Marti et al., 2010).

Increasing phosphorus prices directly are affecting the economic feasibility of struvite recovery technologies. Dockhorn (2009) states that the cost of recovering nutrients from wastewater for struvite production is EUR 2–11 per kg of phosphate for the precipitation step alone, depending on the phosphorus concentration in the centrate. This is comparable to market prices for rock phosphate, which have risen from about EUR 1 per kg to about EUR 3 per kg in recent years. Bearing in mind also the need for scaling prevention, struvite recovery is likely to become more widespread in coming years.

2.3.2 *Efficient use of fertilisers and pesticides in agriculture*

To achieve the objectives of the Water Framework Directive it will be essential to further reduce the emissions of pollutants to water bodies. This must be accompanied by more efficient wastewater and drinking water treatment, which reduce the use of energy and chemicals as far as possible. Reducing pollution at source becomes an increasing priority.

Despite improvements in some regions, pollution from agriculture remains a major cause of the poor water quality in parts of Europe. In particular, nutrients — nitrogen and phosphorus — from fertilisers, pesticides and their metabolites,

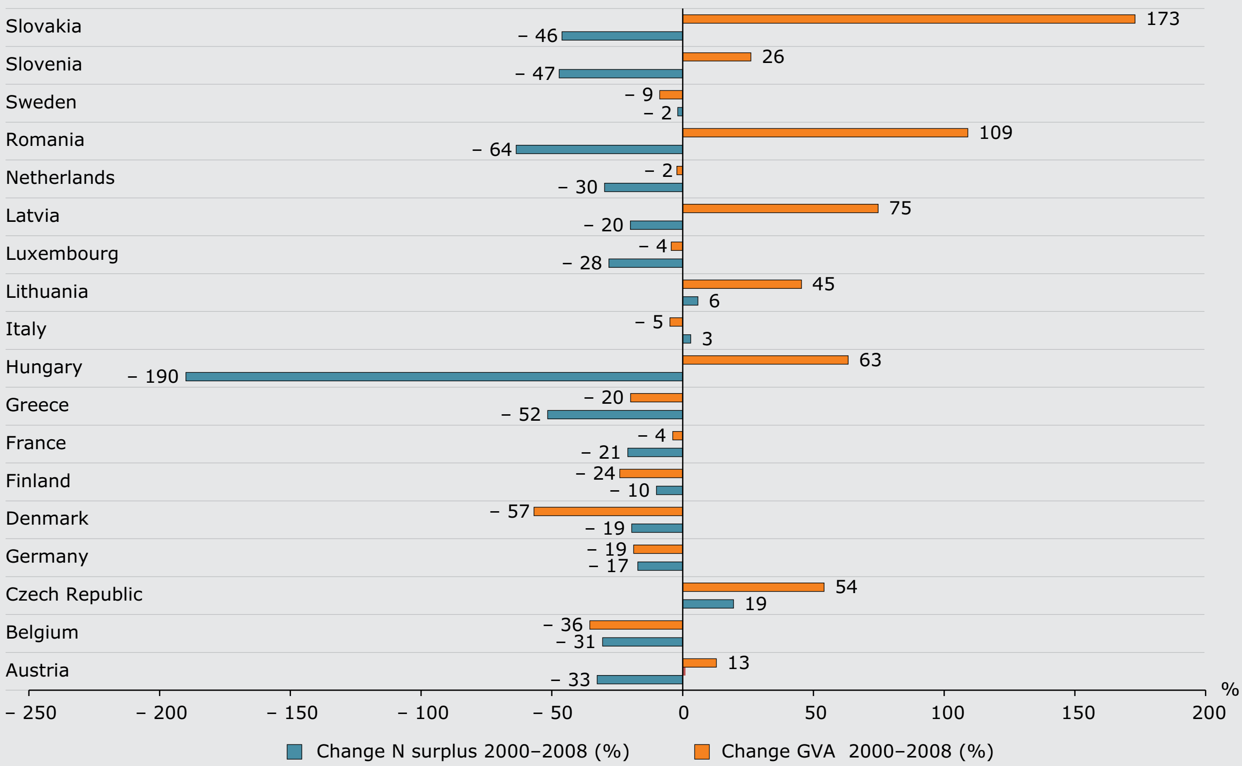
Box 2.7 Decoupling the nitrogen surplus on agricultural land from the sector's economic output

The nitrogen surplus estimates the potential surplus of nitrogen on agricultural land by calculating the balance between nitrogen added to an agricultural system and nitrogen removed from the system per hectare of agricultural land. It is currently the best indication of agricultural pressures on water environment, taking into account problems of eutrophication and high nitrate concentration in ground water.

In the period 2000–2008, six EU Member States recorded an absolute decoupling of the nitrogen surplus from economic growth in the agricultural sector (Austria, Hungary, Latvia, Romania, Slovakia and Slovenia). Relative decoupling occurred in the Czech Republic and Lithuania.

In Belgium, Denmark, Finland, France, Germany, Greece, Luxembourg, the Netherlands and Sweden economic output of the agricultural sector declined alongside a shrinking nitrogen surplus. In France, Greece, Luxembourg and the Netherlands, the surplus decreased more than the agricultural GVA.

Figure 2.2 Trends in nitrogen surpluses on agricultural land and gross value added (GVA) of the agricultural sector in 18 EU Member States



Note: The availability of data on GVA and N-surplus allowed the indicator to be calculated for only 18 EU Member States. In the other nine Member States either the data on GVA or N-surplus were unavailable.

Source: Eurostat.

sediment, pathogenic microorganisms excreted by livestock and organic pollution from manure are regularly detected in water bodies at levels sufficient to impact aquatic ecosystems (e.g. through eutrophication) and require treatment where water is abstracted for drinking (EEA, 2010). Many of these problems can be alleviated, however, by employing a range of cost-effective on-farm measures to use inorganic and organic fertilisers and pesticides more efficiently. The result is better water quality.

Legislation is likely to continue to drive the adoption of such measures in Europe. The Pesticides Directive (EU, 2009b), for example, requires EU Member States to establish national action plans to reduce hazards, risks and dependence on chemicals for plant protection. Source control measures have been identified that will reduce pesticide use. These include encouraging low-input or pesticide-free cultivation, prohibiting aerial spraying under certain circumstances, and defining areas of significantly reduced or zero pesticide use such as water catchment areas for drinking water abstraction, in line with measures taken under, for example, the Habitats Directive (EU, 1992).

In addition, there is potential to reduce harmful active substances by shifting to safer alternatives. Substantial reductions in pesticide use have been achieved with little or no impact on profitability or productivity through, for example, modifying crop rotations and sowing dates, selecting more pest-resistant crop varieties, and designating buffer strips along water courses (Arora et al., 2010).

Driving forces other than legislation will also make the agriculture sector more resource efficient. As described above, phosphorus is becoming scarce and efficient use and recovery of phosphorus from waste streams is paramount within Europe. It will also help to reduce detrimental impacts on aquatic environments, particularly as phosphorus is the primary cause of freshwater eutrophication (Correll, 1998).

Various on-farm measures can improve the efficiency of phosphate fertiliser use. In some cases these measures control use 'at source', for example, by reducing phosphorus inputs in fertiliser onto agricultural land where phosphorus levels in soils have built up over time to levels sufficient for plant growth. Romer (2009) suggests that 70–80 % of European soils have average to high levels of phosphorus and that yields could be maintained for several years without further phosphorus fertilisation. Such an approach could reduce phosphorus emissions substantially and at no cost (Defra, 2003).

Reducing phosphorus in animal feeds has also been shown to cost very little (Jacobsen et al., 2004; Malmaeus and Karlsson, 2010). Other low-cost measures include restricting fertiliser use in high-risk locations (e.g. near water bodies or on steeply sloping land) and at high-risk times, for example when soils are saturated, since under these conditions a significant proportion of the fertiliser applied can be washed away to the nearest water body.

2.3.3 Reducing water and chemical use in industry

Sustainable water management is recognised as a priority for several industry sectors and associations. It is vital to reduce water and energy use as well as emissions of chemicals. The European Water partnership, for example, has initiated a Water Stewardship Programme (EWP, 2012) with corresponding management standards.

Several industry sectors with high water consumption have improved their water management by employing on-site treatment and re-use of water, and improving chemical re-use. The result has been higher production yields and minimised waste.

Data on water use in industry, sourced from public water supplies, self supply or other sources, is collated via the OECD/Eurostat Joint Questionnaire on Inland Waters and published in Eurostat's water statistics (Eurostat, 2012). The data coverage is, however, only partial and typically covers about half of the 34 countries with agreements to report water statistics.

Despite Europe's comprehensive chemicals legislation, the ubiquity of chemicals in society is a major risk to aquatic ecosystems. Emissions of hazardous substances to the environment, including fresh and marine waters, can occur at all stages of the product life cycle. Private and public demand for consumer goods is a fundamental driver of production and, therefore, of the release of hazardous substances to the environment.

Promoting more sustainable chemical consumption patterns in the future may be achieved most effectively through a mix of policy responses, involving regulation, economic incentives and information-based instruments, including awareness-raising campaigns (EEA, 2010d;

Photo: © sxc.hu/Cre8inator

EEA, 2011). A more sustainable approach to consuming and producing chemicals would benefit Europe's environment and reduce impacts in other parts of the world that export goods to Europe.

Wider implementation of 'green chemistry' will be one important approach. It involves developing new processes and technologies that maintain the a product's quality but reduce or eliminate the use and generation of hazardous substances. Adopting sustainable, green chemistry techniques has been shown to generate financial benefits and hence provide competitive advantages (EEA, 2010d). Currently, however, there is no comprehensive EU legislation on sustainable chemistry (EEA, 2011).

With support from the EU's LIFE Programme — a financial instrument that supports environmental and nature conservation projects throughout the EU and in some neighbouring states — the textile industry has implemented more sustainable production practices. For example:

- One project (LIFE03 ENV/E/000166) enabled dye baths to be reused by installing a laser spectroscope to determine dye bath colour content, thereby enabling precise calculation of additional pigment requirements. Significant reductions in water use were achieved (72 %) and corresponding cuts in releases of sulphates (or sodium chloride) and surfactants. Energy savings of 20–25 % were also secured because it was no longer necessary to reheat the baths.

- In the PROWATER project (LIFE04 ENV/IT/000583), wastewater treatment and reuse using conventional physical-chemical pre-treatment and advanced post-treatment (crossflow ultrafiltration and ozonation) removed 62 % of surfactants and 98 % of colour. Freshwater use was cut by 40 %. Investment costs were recovered in roughly five years (EC, 2012b).

- The SuperWool project (LIFE05 ENV/D/000195) employed an innovative AOX-free plasma technology for fine wool products at large scale. Treating wool tops with low-temperature plasma and alternative resin systems is considerably better for the environment than the conventional Chlorine-Hercosett process, which uses chlorine gas. The new approach not only leads to an

AOX- and wastewater-free process but also drastically reduces the felting tendency of the material and improve occupational health and safety (EC, 2012c).

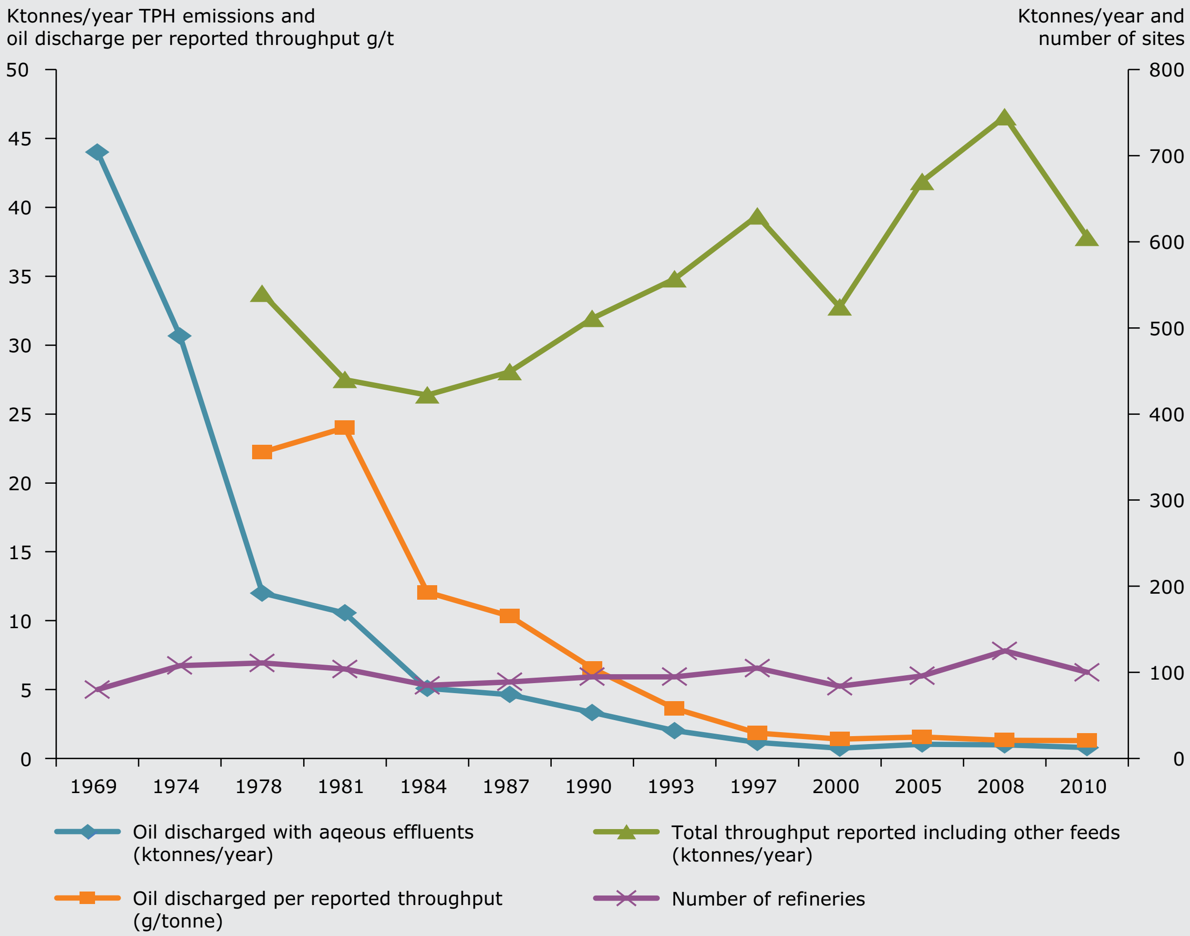
According to the FP7 project AquaFit4Use, the European textile industry consumes 600 million m^3 of freshwater annually (AquaFit4Use, 2012). This project, to be concluded in May 2012, has focused on sustainable water use in the pulp and paper, chemical, food and textile industries. It has aimed to make industries more independent of fresh drinking water supplies and obtain water qualities tailored to product and process demands and quality standards.

Box 2.8 Effluent quality improvement in the European refining industry

Since the Second World War, Europe has achieved significant economic development and improved living standards. Greater wealth and technological advances made the car available to the general public, leading to increased demand for motor fuels. Expanding air traffic likewise intensified the need for kerosene. The refining industry has partly met this demand using new technologies that enabled more sustainable use of crude oil, optimising production to meet current demands. Total European throughput of crude oil has also increased significantly, however, from some 600 000 kT in 1969 to some 740 000 kT in 2008.

Despite the economic growth and expanding fuel demand, the refining industry has a long history of reducing direct emissions to water. As Figure 2.3 shows, total petroleum hydrocarbons (TPH) emissions have been cut from 45 000 tonnes in 1969 to only 933 tonnes in 2008, which is approximately 1.3 g/tonne of crude oil processed.

Figure 2.3 Trends in TPH discharges from the refining industry in Europe



Source: CONCAWE, 2011.

3 Using markets to enhance water-resource efficiency

Markets and economic instruments have a central role to play in maximising society's returns from scarce water resources. This chapter will explain the advantages and limitations of market-based approaches, discuss the importance of pricing and cost recovery, and present the economic instruments available to correct prices and address market failure.

3.1 Water allocation mechanisms

A variety of mechanisms are available to allocate water resources among competing uses. These range from complete government allocation, to a mixture of market and government allocation, to predominantly market allocation. Some degree of government intervention is always necessary, however, even in a predominantly market-based approach.

In the past water has often been allocated with little regard to economic efficiency, and cost recovery has often been neglected (World Bank, 1997 and 2006). A range of factors have encouraged governments to address environmental concerns using regulatory mechanisms. These include inexperience with economic approaches, the practical challenges of using economic instruments, the prioritisation of policy objectives other than cost-effectiveness, and opposition from business interests to increased financial burdens. With increasing water scarcity, however, and acknowledgement that 'water has an economic value in all its competing uses and should be recognized as an economic good' (UN, 1992), European governments are increasingly turning to market allocation approaches.

Dinar et al. (1997) distinguish between four different allocation mechanisms:

- public (administrative) water allocation, whereby the state decides how much water is allocated to different uses;
- user-based allocation schemes, e.g. farmer-managed irrigation systems;
- water markets, i.e. trade in water rights;
- pricing, i.e. water use is charged.

The latter two mechanisms are market-based approaches, distributing scarce water resources of a certain quantity and quality among economic actors (Zetland, 2011). The economic agents using water can be agriculture, industry, services or household water users.

Advantages and limitations of market allocation of water

Which allocation method is preferable? In many case, of course, it is simply not feasible for governments to assume responsibility for the innumerable decisions about resource allocation in an economy. A distributed system of allocation is needed and that is exactly what markets provide. An example from Australia is given in Box 3.1 describing the development of water markets in Australia. But markets also have another important advantage. Society normally benefits most when resources are allocated to their most productive use — the use that generates the greatest earnings. Market allocation often furthers this goal because the users generating the highest returns will bid most for the resource.

For these reasons, society will often gain if resources are allocated through the market. In the case of water resources, however, there may be important reasons why market allocation is undesirable or impractical. These difficulties result in part from water's fundamental importance in sustaining biological, social and economic systems. Ecosystems require water to function properly and provide services. Humans need water to survive and prosper. Simply allocating water to the highest bidder is potentially deeply problematic if humans or ecosystems are unable to meet their basic needs.

Another difficulty with using market allocation is that water's characteristics often complicate efforts to create competitive markets. To function

Box 3.1 The development of water trading in Australia

In Australia's Murray Darling Basin, water trading is a key tool for ensuring that ecosystems are allocated sufficient water, while also incentivising innovation and maximising the efficiency of water allocation within sustainability boundaries. The development of water entitlement and the allocation systems necessary to support water trading has been a long journey. Reforms have been developed in an iterative, adaptive manner to meet local needs.

Today, markets exist for farmers to buy or sell irrigation licenses and to trade their seasonal water allocations. The key concept underpinning the trading regime is that one water user can only access more water if they could find someone who agrees to take less. This was made possible by an early commitment to meters and strong governance arrangements that prevent people from using more water than is allocated to them. An essential element in the scheme's success is government knowledge about the 'hydrological reality' — the amount of water that must be set aside to sustain ecosystem functions. Finally intense Stakeholder dialogue and risk management arrangements are necessary to ensure that all water users and relevant stakeholders understand the complexity of the hydrological system

The result has been a swift, market-driven increase in water use efficiency and, as a result, a rapid increase in the value of water licences. As this has occurred and to facilitate the further development of the markets, formal water entitlement registers and bank-like allocation systems have been established. Today irrigators can register a mortgage over an entitlement, trade allocations over the internet and review how much water is left in 'their' account online.

Source: Young, 2010.

effectively markets require a variety of criteria to be in place, including fully assigned, exclusively held, transferable and enforceable property rights. But water's ubiquity, its mobility via the water cycle and the enormous diversity of water uses make this difficult. Water is unusual in the sense that, depending on the context and use, it can have the characteristics of a public good, a private good, a common pool resource or a club good (Perman et al., 2003). This can create significant obstacles to sustainable water management.

In the absence of fully functioning markets, water prices will not reflect water use's environmental impacts and opportunity costs (i.e. the maximum value that could have been generated by using it for another purpose). The result is market failure: misallocation of resources and a suboptimal balance between economic activity and the pollution that it produces. For markets to allocate water in a way that maximises society's benefits, the price for water users must reflect the true value and costs of water. The full cost comprises three elements as also set out in the WFD (EC, 2003):

- **Environmental costs:** 'the costs of damage that water uses impose on the environment and ecosystems and those who use the environment, e.g. a reduction in the ecological quality of aquatic ecosystems or the salinisation and degradation of productive soils.'

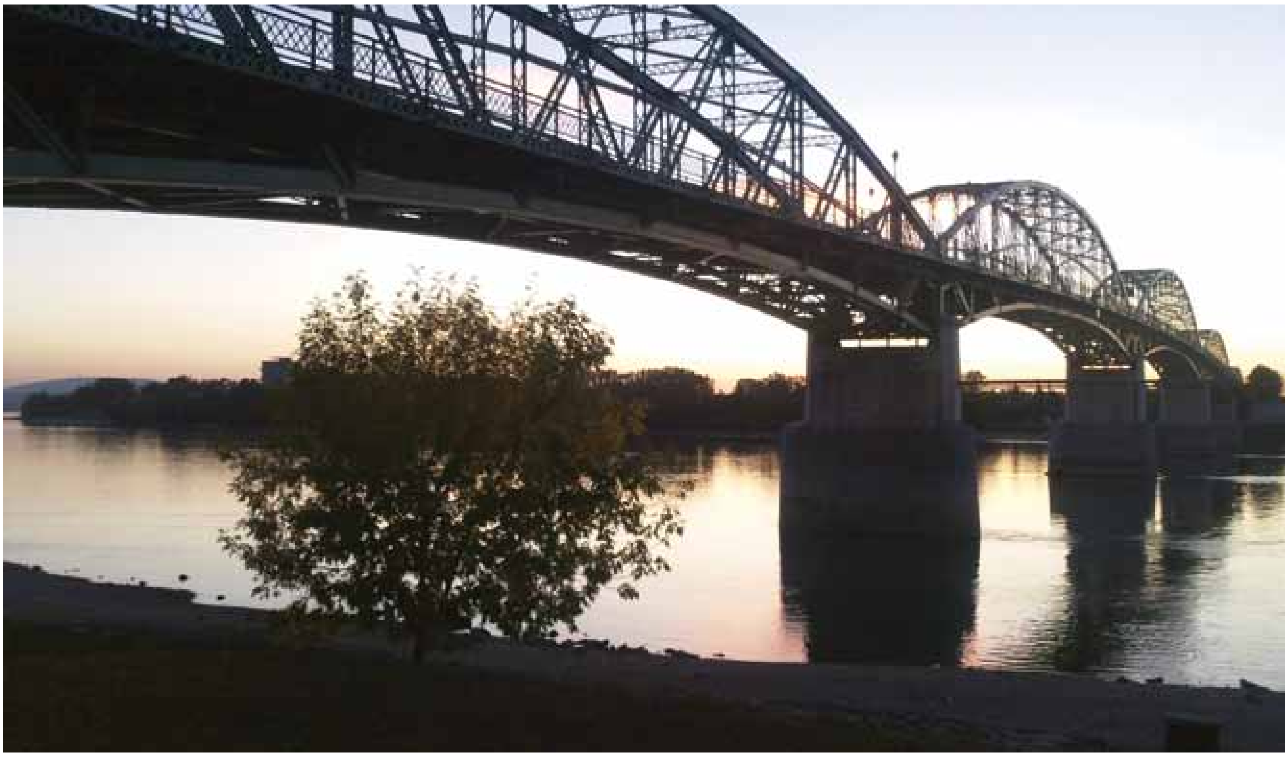


Photo: © Giacomo de Stefano

- **Resource costs (opportunity costs):** 'the costs of foregone opportunities which other uses suffer due to the depletion of the resource beyond its natural rate of recharge or recovery, e.g. linked to the over-abstraction of groundwater.'

- **Financial costs:** 'the costs of providing and administering these services. They include all operation and maintenance costs, and capital costs (principal and interest payment), and return on equity where appropriate).'

Faulty pricing means that economic agents make decisions based on erroneous information. If prices are too low then demand for water and pollution of water will be excessive. If they are too high then activities requiring water abstraction or pollution may not take place, unnecessarily reducing economic output and social well-being (World Bank, 1997). Contrastingly, where prices reflect the full costs of resources, it creates the incentives for production and consumption patterns to shift towards the social optimum (EEA, 2009; OECD, 2010). No less important, it also motivates the development and adoption of more efficient technologies and practices (OECD, 2009).

Market failures are not the only problem. 'Government failure' occurs where state interventions such as subsidies, taxes, price controls and regulations distort the market — exacerbating rather than correcting market failures. If governments want to promote sustainable development they have to make sure that prices and incentives are correct.

3.2 Economic instruments to correct market failure

Economic instruments such as tariffs, taxes and tradable permits provide a means to correct market prices and deliver efficient outcomes. The OECD (2011) defines economic instruments as 'policy tools which influence behaviour through their impact on market signals rather than explicit regulation or 'command and control'.' As such, economic instruments for sustainable water management are designed and implemented to induce some desired changes in the behaviour of all water users in the economy (individuals, firms or collective stakeholders) and to make a real contribution to collectively agreed water policy objectives (Zetland et al., 2011).

Market-based approaches potentially have the advantage of applying to users equally, encouraging the allocation of water resources to their most productive use in an adaptive way. They 'frequently offer a more effective means of achieving environmental policy objectives than traditional environmental policy instruments such as direct regulation of polluting activities' (EC, 2000). Economic instruments such as taxes or tradable permit schemes create the incentives for allocating resources to their most productive use and for reducing pollution most cost-effectively. They can also create dynamic incentives for continuing to improve efficiency and pollution abatement via innovation and industrial restructuring.

The term 'economic instruments' covers a broad variety of different tools. Some (tariffs, taxes and subsidies) operate by establishing or modifying the market price of goods and services in existing markets. Others (tradable permit systems and liability or compensation schemes) create new markets.

- **Tariffs or charges** are designed to cover part or all of the costs of providing environmental services and abatement measures. As such, water tariffs comprise the price that water utilities charge customers for treating, storing and supplying water storage, and collecting and treating wastewater.

- **Environmental taxes** alter prices, changing the behaviour of producers and consumers, and raising revenues to finance investment, e.g. in wastewater treatment facilities. Taxes are 'compulsory, unrequited payments to general governments', implying that the tax payment is not directly related to the benefit received. In contrast tariffs or charges constitute (required) payments for services (OECD, 2000).

- **Environmental subsidies** are 'current unrequited payments from government to producers, with the objective of influencing their levels of production, their prices or the remuneration of the factors of production' (European Commission, 1996). They are often used to stimulate the development of new technologies, help create new markets for environmental goods and services, encourage changes in consumer behaviour through green purchasing schemes, and temporarily support achieving higher levels of environmental protection by companies (Box 2.4 illustrates their use in the hydropower context).

- **Tradable permits schemes** define the aggregate permissible amount of resource extraction or pollution. Permits are distributed among economic agents and subsequent trading ensures that the resource use or pollution delivers the maximum earnings for society. Although most commonly used to cap emissions (notably of air pollutants), the Murray Darling Basic in Australia provides an example of trade in water allocations.

- **Liability and compensation systems aim** to ensure adequate compensation for damage resulting from activities dangerous to the environment and provide a means of prevention and reinstatement.

Clearly, economic instruments have their limitations. Establishing and enforcing such approaches often involves significant transaction costs. Furthermore, market failures will often persist for numerous other reasons: the existence of subsidies, market structures (monopoly buyers or sellers), information asymmetry or incomplete information, and so on. Regulations and labelling also have advantages in some situations. For example, regulations can be particularly important in instances where there is a need for rigid limits on resource use or emissions (e.g. where ecosystems or humans require a minimum amount of a resource to survive, or where pollutants emissions are dangerous over a threshold or accumulate in environment).

Economic instruments are also unlikely to deliver the optimum resource allocation or pollution abatement if they are not designed with those aims in mind. As noted in Box 3.2, policymakers appear in some instances to focus primarily on the revenue-raising function of economic instruments, at the expense of other policy goals.

Box 3.2 Economic instruments merely as financing mechanisms

To tackle diffuse source pollution from agriculture, in 1988 the German state of Baden-Württemberg introduced a regulation restricting standard agricultural practices, along with compensation payments for farmers (SchALVO). To finance these payments, the state introduced a water abstraction charge at the same time. When subsequent investigations concluded that earmarking revenues from the abstraction charge was illegal the two policy instruments were legally separated, with the water abstraction charge designated as a tool to incentivise sustainable water management

Despite the purportedly revised objective of the abstraction charge, evidence suggests that it still functions as a financing mechanism for the compensation payments to farmers. The government ensures that expenditures for compensation payments do not exceed the revenues from the abstraction charge. In addition, interviews demonstrate that stakeholders paying the abstraction charge — predominantly the energy sector and water supply companies — still believe that they are financing the compensation payments.

While the introduction of the abstraction charge arguably intends to internalise the resource costs, the link to the compensation payments can be seen as a reversal of the polluter pays principle.

Source: Möller-Gulland and Lago, 2011b.

3.3 Water pricing and cost recovery in Europe

Historically, Europe's water prices have rarely reflected the full costs of resource use, causing pollution and water scarcity and thereby harming the environment and society. The general public, for example, typically bears the cost of treating drinking water contaminated by agriculture or industry. Such outcomes can often be avoided if governments play a more active role in helping markets to function properly.

The Water Framework Directive (EU, 2000) makes an important contribution to better water pricing in Europe. Article 9 of the Directive includes specific provisions on the concepts of cost recovery, the polluter pays principle and incentive pricing:

- The principle of '**recovery of the costs of water services**' requires that water prices reflect the financial, environmental and resource costs of supplying water. The Directive calls for an 'adequate contribution of the different water uses, disaggregated into at least industry, households and agriculture, to the recovery of the costs of water services'. Member States can also 'have regard to the social, environmental and economic effects of the recovery as well as the geographic and climatic conditions' ([2]).

- The '**polluter pays principle**' requires that the polluter should bear the cost of measures to reduce pollution, based either on the extent of the damage done to society or the extent to which an acceptable level of pollution is exceeded (OECD, 2001).

([2]) The requirement that water users make an adequate contribution to the full costs of supplying water is often termed the 'user pays' principle (EC, 2007a).

- '**Incentive pricing**' involves implementing water pricing policies that 'provide adequate incentives for users to use water resources efficiently, and thereby contribute to the environmental objectives of this Directive'.

The cost recovery provisions in Article 9 of the WFD only concern '**water services**'. Article 2 defines water services as 'all services which provide … abstraction, impoundment, storage, treatment and distribution of surface water or groundwater', in contrast to '**water use**', which comprises 'water services together with any other activity … having a significant impact on the status of water'. This distinction between 'water services' and 'water use' is important for the design of water pricing schemes, especially in calculating the appropriate price level.

The external costs of water services which include environmental and resource costs as introduced earlier are, by nature, much more difficult to define and quantify than financial costs. An OECD study (2010) found that they are seldom reflected in current water tariffs. In the EU, the Commission is currently assessing the compliance of Member State pricing policies and water economics in river basin management plans with the WFD requirements. Initial results suggest that there is wide discrepancy between full cost recovery and actual prices. During 2012 the final results will guide final recommendations on better implementation of water economics and cost recovery.

3.3.1 Tariffs and metering

The structure and price of water tariffs are crucial factors in securing the optimal level of cost recovery and ensuring sustainable use of water resources through incentives and investments in watersaving technologies, metering and the design (OECD, 2009).

The impact of water pricing on water consumption depends on the price elasticity of demand. Demand for water is 'elastic' if changes in price have a relatively large impact on the quantity demanded (and vice versa for inelastic demand). Price elasticity can be influenced by complementing practices, such as awareness campaigns.

Photo: © BMLFUW, Austria

Box 3.3 Average drinking water and wastewater bills including cost recovery rates for selected EU Member States

Ascertaining the degree of cost recovery in water pricing can be difficult because the maintenance and replacements costs for new investments are deferred, subsidies are not always transparent (OECD, 2009), and the average prices and cost recovery rates depend significantly on capital investments to improve the level of services.

For example, a recent study by the BDEW (2010) analysed the average drinking water and wastewater bills in six selected EU Member States: Austria, France, Germany, the Netherlands, Portugal and the United Kingdom (only England and Wales). The analysis adjusted the tariffs to take into account any subventions made from the regional or national administrations to the utilities and differences between the levels of service provided in the countries. With the exception of Portugal, where price levels are generally lower, the average annual drinking water tariffs were EUR 66–92 per capita. Annual wastewater bills were EUR 93–122 per capita. After the two-step adjustments, however, the corresponding numbers for drinking water were EUR 83–109 and for wastewater they were EUR 119–170. The tariffs also included widely varying value-added tax rates in the countries.

In general, it is also unclear how far environmental and resource costs are internalised in water and wastewater prices. Most EU Member States have introduced water abstraction charges to internalise environmental and resource costs related to water abstraction. Some countries, such as Germany, have also introduced effluent taxes to internalise the externalised costs of discharging polluted water.

In sum, direct comparisons of water tariffs across Europe (or internationally) can provide information about the relative burden on consumers. It would be misleading, however, to draw conclusions about the relative efficiency of operations or the sustainability of water management.

Clearly, if price changes are to influence the quantity of water demanded, it is essential that pricing policies link water charges to the amount of water used (EC, 2007). Linking water tariffs to the volume of water consumed requires metering of water use.

Water efficiency gains can also be realised across all sectors using relatively new and innovative approaches to pricing. These include setting price levels to reflect water scarcity (Cave, 2009) or, similarly, implementing seasonal price variations.

At present, pricing structures sometimes fail to establish a clear relationship between the water used and the tariff paid. The most common pricing approaches include:

- flat rates, where the charge is unrelated to the quantity of water consumed;
- volumetric rates, where a fixed amount is paid for each cubic meter of water consumed or polluted, often in combination with a fixed access charge;
- increasing block tariffs, where the volumetric rate increases with the amount of consumption or pollution (blocks can be applied uniformly or differentially);
- decreasing block tariffs, where the volumetric rate decreases with the amount consumed (OECD, 2010).

3.3.2 *Water pricing in agriculture*

Agriculture provides for some of society's most basic needs but often has detrimental effects on the water environment (EEA, 2009, 2010a and 2010b). Historically, the water charges imposed on the agricultural sector have rarely reflected water scarcity or other environmental and resource costs. The Common Agricultural Policy (CAP) bears part of the responsibility, having in some cases provided subsidies to produce water-intensive crops using inefficient techniques (EEA, 2009).

Irrigation accounts for most agricultural water use. Where irrigation water is provided by public or private sector suppliers or via collective irrigation systems, tariffs are typically set to cover only the operational and maintenance costs (Molle and Berkoff, 2007) with governments often subsidising capital costs (OECD, 2010). The pricing structure for irrigation water varies considerably across Europe, however, and can differ within a single Member State.

The challenges of water pricing in agriculture include cost recovery issues such as the generally high financial costs of setting up irrigation schemes, as well as difficulties monitoring groundwater use and unauthorised water abstraction (ARCADIS, 2012; World Bank, 1997; OECD, 2009).

Including cost recovery for agriculture is very complex. The magnitude and diversity of agricultural production's effects on the water environment mean that including external costs fully would imply a considerably larger burden on the sector than the financial costs alone. Not including the full costs into water prices means, however, that agricultural water use and impacts are cross-subsidised by the rest of society because farmers do not pay the full price associated with their water use (Jordan, 1999).

Although it has been discussed extensively, the Commission and some Member States still disagree on whether agricultural irrigation or self-abstraction should be considered as a water service under the Water Framework Directive, implying application of the principle of cost recovery (requiring that prices include environmental and resource costs). In their assessment of draft river basin management plans, Dworak et al. (2010) determine that cost recovery is only rarely applied in agriculture.

Achieving cost recovery for groundwater use is generally difficult and a significant amount of groundwater abstraction takes place without being registered or monitored by any water authority (EEA, 2009). Self-supply, usually via on-farm abstraction of groundwater, often involves licences and other regulatory instruments. The costs of enforcing compliance are high and illegal abstraction therefore remains a challenge. Tackling the problem of excessive water abstraction requires controls such as abstraction fees (as used in Denmark, France, the Netherlands, and England and Wales), set at prices that reflect full cost recovery. Evidence shows, however, that increased groundwater charges alone do not necessarily lead to reduced abstraction; efficient monitoring systems are also crucial (OECD, 2009).

The approach to water pricing in agriculture varies across Europe. In some locations, predominantly in southern Europe, flat rate charges are still applied and hence provide little incentive for farmers to use less water. A combination of fixed fee and volumetric pricing is common in several countries, while volumetric charges are implemented in Malta, Cyprus and Luxembourg. In generation, implementation of the 'user pays' principle (EC, 2007) is limited, although some EU Member States report increasing implementation of metering in agriculture (EC, 2011a).

While increasing irrigation water prices to meet full cost recovery would maximise water use efficiency, social considerations and implementation issues pose practical limitations. A key challenge lies in establishing water pricing in agriculture that minimises impacts on farm income but incentivises water conservation and recovers a larger share of costs, including those related to environmental degradation. The process needs to reflect local

Box 3.4 Crop productivity and water use in Spain

Spain was the first country in the European Union to include water footprint analysis into its river basin management plan (in 2009). The analysis included questions on when and where water footprints exceed water availability, how much of a catchment's total water footprint is used in producing exports, and the volume and value of crops produced per unit of water (WFN, 2012).

The concept of virtual (or embedded) water conveys the water used in producing a good or service, including agricultural products. Expressed in terms of crop water use per tonne of yield, the concept can help achieve more efficient allocation of water resources in agriculture and inform crop production and trade decisions.

Coupling virtual water with economic information describing the production value of a crop can further strengthen agricultural water management. 'Water economic productivity', expressed in terms of crop market value per cubic meter of water used, has been derived, for example, for the Mancha Occidental region, Spain (Aldaya et al., 2010). That study distinguished 'low virtual water, high economic value' crops from 'high virtual water, low economic value' alternatives, in a semi-arid region characterised by irrigated agriculture. The findings showed that 'high virtual water, low economic value' crops such as cereals are widespread in the region, in part due to the legacy of earlier CAP subsidies.

An expansion of low water consumption and high economic value crops such as vines was identified as a potentially important measure for more efficient allocation of water resources (Aldaya et al. 2010). Pricing can play a role in this respect, as a tool to allocate water to those crops that generate the highest economic value at low water demand (Bio Intelligence, 2012a).

Box 3.5 Irrigation subsidies in Spain

Valsecchi et al. (2009) report that in Spain irrigation water subsidies affect the amount of water extracted or used for irrigation, as low prices tend to encourage inefficiency. This can in turn lead to wastage, groundwater depletion, pollution (particularly due to increased concentration of nitrates), soil salination and biodiversity loss.

Spain's irrigation subsidy is successful in transferring income to its intended recipients: farmers. But it has clear environmental impacts and deserves further scrutiny to assess whether reforming or removing it would benefit the environment. Removing the subsidy would be likely to produce significant positive environmental effects and negative economic effects.

Reforms of the CAP have now reduced the link between subsidies and agricultural production, leading to improved water use efficiency. Studies in the province of Cordoba, Spain, for example, have shown that following the decoupling of subsidies from production, cotton irrigation efficiency increased by approximately 40 % (Lorite and Arriaza, 2008).

and regional circumstances and incorporate broad stakeholder consultation to help establish prices that are socially and politically acceptable. There is also a need to address situations where price increases do not lead to reduced agricultural water use, for example when alternative crops or irrigation practices are not available due to technical, social or economic constraints.

3.3.3 *Water pricing for households, services and industry*

Volumetric pricing of water use and wastewater management for households, services and industry is normally based on the metered quantity of water supplied. Exceptions are made for certain industries, for example where they provide for their own water supplies or wastewater treatment and discharges into receiving water, or in cases where a high percentage of the water supplied becomes part of the product, for example in the beverage industry. In these situations, local regulations may define quality criteria or require the use of best available technique for connecting industry wastewater to public sewerage systems. This may lead to requirements on pre-treatment before the discharge.

Wastewater treatment costs must reflect environmental impacts, including the build-up of contaminants in sewage sludge and the discharge of pollutants in treated effluent to receiving waters. Appropriate pricing levels and tariff structures should encourage industries that send high concentration wastewater to a municipal plant for treatment to undertake greater on-site treatment, including recycling and reusing water and chemicals.

A uniform price of wastewater treatment per m^3 based on the amount of water supplied would not cover the wastewater utility's full treatment costs, implying that other customers bear the burden. This is clearly at odds with the polluter pays principle. Utilities therefore often apply special tariffs for high concentrations of e.g., chemical oxygen demand, nitrogen, phosphorus or heavy metals, with local conditions influencing the extra treatment costs.

Box 3.6 Effects of water metering in Denmark

Since 1992, urban water prices in Denmark have been based on full cost recovery — covering the supply cost of water via tariffs and covering the environmental and resource costs via taxes. All urban water users are metered and charged according to the volume consumed. Affordability for low income households is ensured by a separate social policy.

Investments in improved water supply and wastewater infrastructure and the introduction of environmental taxation have resulted in higher costs for utilities, leading to substantial rises in Danish water prices. Between 1993 and 2004 the real price of water (including environmental taxes) has increased by 54 % and it is currently among the highest water prices in the OECD. The rise in prices has led to a substantial decrease in urban daily per capita water demand from 155 litres to 125 litres — one of the lowest water use rates in the OECD.

Source: OECD, 2008.

Germany, for example, has implemented a policy mix encompassing market-based instruments (discharge permits and effluent taxes) and regulatory measures (discharge limits) for some years. It has led to the adoption of advanced abatement measures by wastewater treatment plants and industrial direct dischargers (e.g. the chemicals industry), as well as changes in production processes (e.g. in the paper industry), which decreased the volume of effluents generated. By internalising the environmental and resource costs associated with the direct discharges of polluted water into water bodies, harmful point source pollution has substantially declined (Möller-Gulland and Lago, 2011a).

A ten-country household survey has found that households subject to volumetric pricing (based on metering) use 25 % less water (Grafton et al., 2011). The use of meters in buildings is growing steadily throughout Europe, particularly in single-family houses, although uptake in apartments is currently low due, in part, to technical challenges. In the United Kingdom, water metering is estimated to be able to achieve average water savings of around 13 % per household (EA, 2008b).

4 Improved information for optimal water-resource management

Methodologies that quantify the relationship of economic activities to water use and its environmental impacts are valuable tools in achieving more sustainable, equitable and efficient water use. Such information has applications for different actors throughout the policy cycle and at varying spatial scales. Policymakers need good information at the local, regional and European scales to identify priority issues, relevant sectors and economic activities. It is particularly important at national and more local levels that competent authorities be informed about water availability, possible risks of scarcity and drought, and polluters. Subsequently, good information is needed to evaluate the effectiveness of policy measures. All this should be integrated into the regular river basin management planning under the Water Framework Directive.

Several broad and complementary approaches to quantifying water-resource efficiency and sustainable management can be identified, involving differing criteria, contexts and purposes.

Box 4.1 Terminology

'Water productivity' is a measure of how a system converts water into goods and services (product units/m^3). It captures the ratio of net benefits derived from e.g. crops, forestry, fishery, livestock and industrial systems to the amount of water used in the production process. In general terms, increasing water productivity means increasing the volume of benefit — i.e. output, service or satisfaction — from a unit of water input. When the output per unit of water is monetary rather than physical, it is referred to as 'economic water productivity'.

'Water use efficiency' is defined as the ratio of useful economic or product output of a system or activity to its water input (m^3/product units). It is thus the inverse of water productivity. Water use efficiency would imply using less water to achieve the same or more goods and services. In statistical publications the ratio (m^3/product units) is also neutrally referred to as 'water intensity'.

Enhancing water use efficiency means maximising the value of water use and allocation decisions within and between sectors for sustainable social and economic development. It involves getting the most not only out of scarce water resources but also out of other natural, human and financial capital stocks.

These methods are presented in brief below and are scrutinised in more detail in a recent review by the water efficiency group under the UNEP International Resource Panel (UNEP, 2012).

Water balances and physical environmental accounting comprise the most basic information relating water availability to water use. Such information can be developed into indicators such as the water exploitation index, or can be used as basic input into Water Footprint Assessment and life cycle analysis. The latter, shift the focus from the macroeconomic level (used in environmental accounting) to the business level. All approaches specify water use and its impacts precisely in time and space.

4.1 The role of indicators in quantifying and evaluating water efficiency

In general, resource-efficiency indicators relate resource inputs to physical and/or monetary outputs, such as GDP. As such, they typically need to quantify sectoral water use, economic output and environmental impacts, and explore the interlinkages at the relevant temporal and spatial scales. This information, analysed comprehensively, enables ex-post evaluation of policy implementation and helps in formulating new policy at the European, national or regional level. Reliable data are indispensable.

The EU's resource-efficiency flagship initiative under the Europe 2020 strategy has the dual objective of decoupling resource use from economic growth, and decoupling environmental impacts from resources use. Resource and impact decoupling demands knowledge and data showing the links between water management, socio-economic benefits and ecosystems services over time (UNEP, 2011a).

Figure 4.1 conveys the relationship of some of these parameters. Clearly, reliable data and thorough analysis are required to construct any of these trends. Combining and interpreting the data presents several further challenges, including demonstrating their interdependence and cause-effect relationships. If constructed carefully, however, efficiency indicators provide a practical tool to track and guide our progress.

4.1.1 Broad-scale indicators and sub-indicators

Resource-efficiency indicators of the sort suggested in Figure 4.1 are highly aggregated, combining very different data from diverse sources, particularly when they span the entire economy or several sectors. A broad-scale indicator of this sort could provide a simplified representation of water efficiency's main components (e.g. water used in producing material outputs).

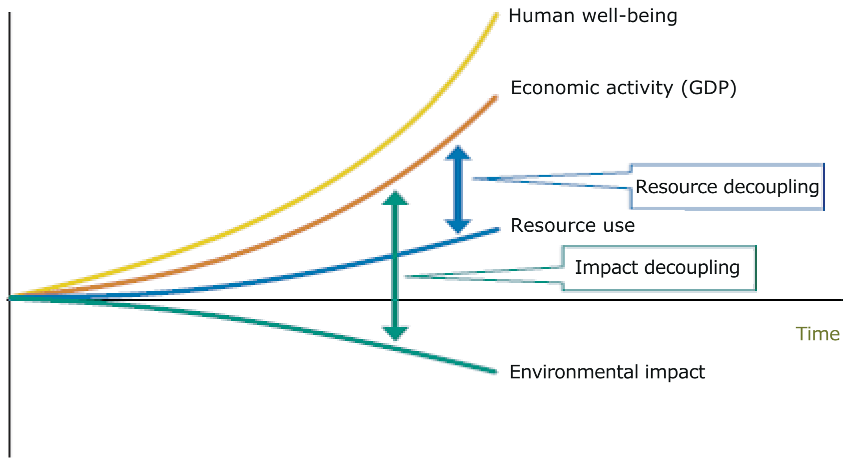
Highly aggregated broad-scale indicators of this sort can be useful for communication purposes and awareness-raising but they can lack transparency and mask important differences that exist at more refined scales, leading to misinterpretation. They may offer little to guidance for elaborating concrete measures in specific sectors. To gain such information, broad-scale analysis must be supplemented with more detailed sub-indicators that address individual elements, sectors and subregions (Saisana and Tarantola, 2002). The EEA core set of indicators uses this combination of broad-scale, main indicators and and sub-indicator assessments.

So far, no set of European indicators for water-resource efficiency has been developed, although EEA indicators monitor water quality regularly. To analyse water scarcity and drought, the Commission and the EEA have together developed the water exploitation index — the ratio of annual freshwater abstraction to long-term water availability — as the central expression for water scarcity. Figure 4.2 shows the annual WEI figures for EU Member States in 1990 and 2010.

As stressed throughout this report, however, water use and availability is bound to the hydrological reality at the catchment level and must take seasonal changes into account. The national data therefore provide only an extremely rough overview, providing no information relevant for either EU-level analysis of policy or management decisions at the regional (sub-national) level. Unfortunately, there is currently insufficient data to produce the WEI at the required spatial and temporal scales across Europe. Map 4.1 shows the level of disaggregation currently available. More refined data are being developed together with EU Member States.

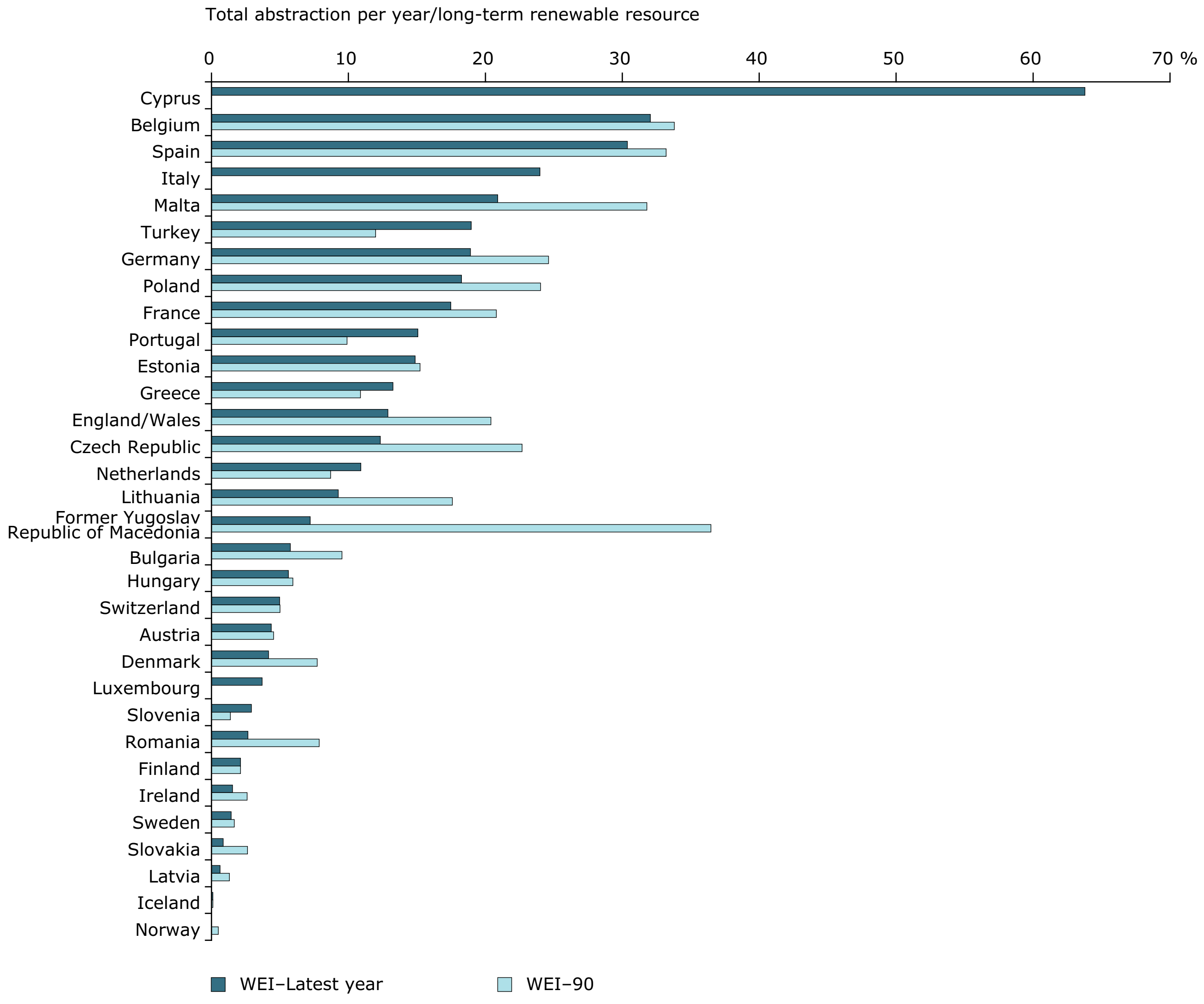
The water exploitation index only provides the broadest depiction of water use relative to general availability. It provides indirect insights into environmental impacts by describing the risk posed by over exploitation but not an ecosystem status as such. It also does not describe the development of resource-efficiency measures or their implementation.

Figure 4.1 Resource and impact decoupling



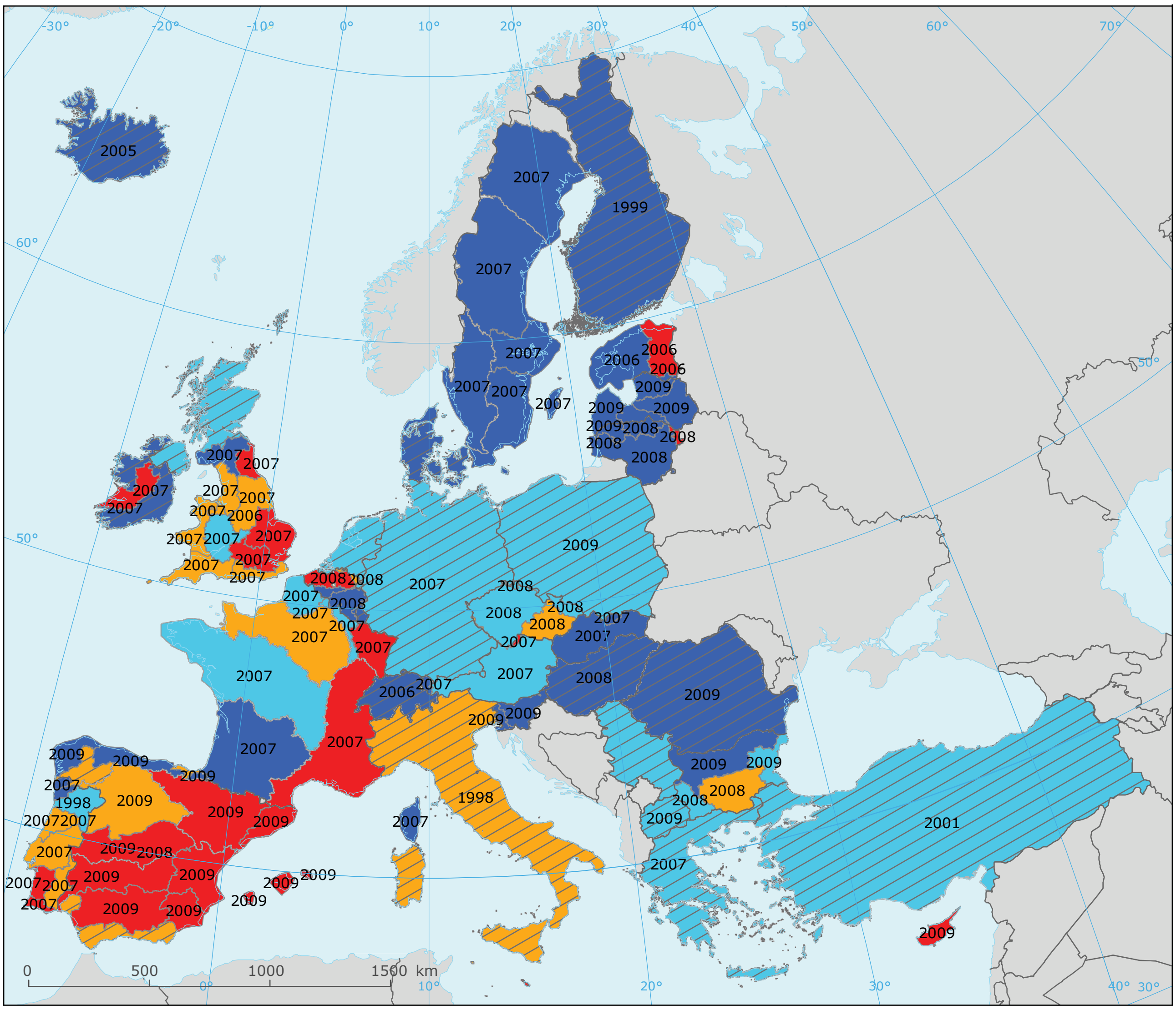
Source: UNEP, 2011.

Figure 4.2 National water exploitation index data, 1990 and 2010



Source: EEA core set indicator 018.

Map 4.1 Water exploitation index — towards a regionalised approach



Water exploitation index (%)

0–10 No stress	11–20 No stress	21–40 Water stress	> 40 Extreme water stress

Note: The map shows the maximum current disaggregation with data available from different sources. Further refinement and gap filling for all RBDs are in progress.

Legend: full colour: RBD-level data; shaded: country-level data.

Source: Data come from multiple sources as follows:
Combination of WISE-SoE#3 and WFD: AT2000-Rhine, AT5000-Elbe, BG1000-Danube Region, BG2000-Black Sea Basin, BG3000-East Aegean, BG4000-West Aegean, SK30000-Vistula, SK40000-Danube.
Combination of WISE-SoE#3 and websources: IEGBNISH-Shannon.
Websources: ES014-Galician Coast, ES016-Cantabrian, ES020-Duero, ES030-Tagus, ES040-Guardiana, ES050-Guadalquivir, ES07-Segura, ES080-Jucar, ES091-Ebro, ES100-Internal Basins of Catalonia, ES110-Balearic Islands, ES120-Gran Canaria.
http://servicios2.marm.es/sia/visualizacion/lda/recursos/superficiales_escorrentia.jsp (Total water resources in the natural system (hm³/year) Average value for the period between 1941–2009). Reported to DG ENV for the Interim Report: PTRH3, PTRH4, PTRH5, PTRH6, PTRH7, PTRH8.
WISE-SoE#3: All other RBDs.
Eurostat JQ IWA: All country-level data.

4.1.2 *Possible resource-efficiency indicators for water*

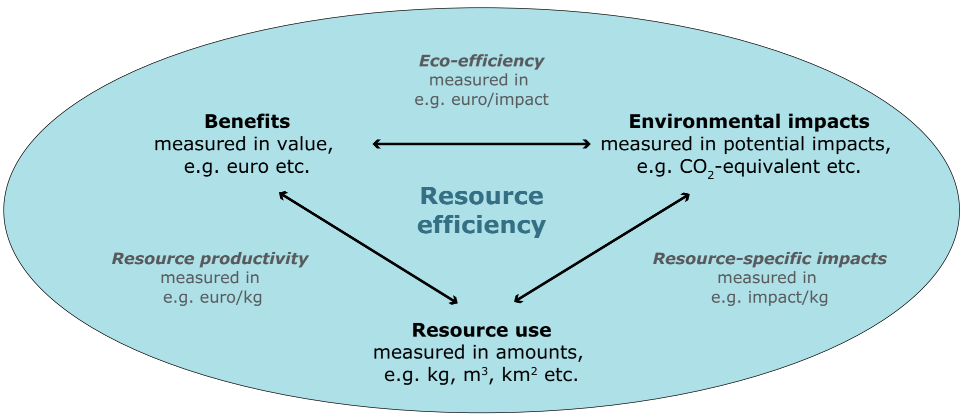
Figure 4.3 depicts the relationship of (sub-)indicators relevant to water-resource efficiency. Such indicators address specific sectors and operate at the river basin level. They can therefore cover additional issues identified by policymakers linked to specific environmental, socio-economic and ecological targets. Identifying and assessing all the interrelated factors at sufficiently refined spatial scales remains a considerable challenge. The relationship can also be expressed as resource use and benefits, reflecting resource efficiency on one hand and the environmental impact and status (ecosystem resilience) on the other.

Indicators that combine all three aspects of resource efficiency can be formulated at the international (EU level) scale or the macroeconomic (economy-wide) level. They can convey information on water productivity (e.g. in terms of GDP/m^3 water used) and environmental impact intensity (e.g. in terms of tonnes of emissions to water/GDP). Their formulation enables multidimensional issues to be summarised, supporting decision-making at the national and international levels, facilitating ranking and cross-comparison of countries and regions, attracting public interest and promoting accountability. The high level aggregation means, however, that they can result in misinterpretation and overly simplistic conclusions (Saisana and Tatantola, 2002).

Figure 4.4 provides an example of broad-scale resource-efficiency indicators, illustrating some EEA member countries' water productivity (GDP/m^3 of water abstracted), water abstraction per capita and GDP per capita. Luxembourg records the highest water productivity, with the highest GDP per capita and the second lowest abstraction, while Bulgaria has the lowest water productivity as a result of a low GDP per capita and high abstraction. It can be observed that despite the clear dependency of increasing water productivity from falling abstraction in increasing GDP, the relationships are not clearly linear. The variance in water productivity and per capita abstraction rates among countries with similar GDP per capita shows the need for more detailed assessments to explain the differences.

Water productivity alone does not provide an indication of the environmental impacts and sustainability of economic activities. Further insights into relationship between water productivity and environmental impacts can, however, be derived by evaluating water productivity alongside the water exploitation index. Figure 4.5 presents this for selected EU river basins and river basin districts. Interestingly, water stressed areas tend to have low water productivity, while areas with low water exploitation have greater water use efficiency. When annual per capita abstraction exceeds 500 m^3 (or roughly 1 400 l/cap/day), water productivity is often low (below EUR 30/m^3).

Figure 4.3 Schematic representation of the relationship between indicators relevant to efficient water use



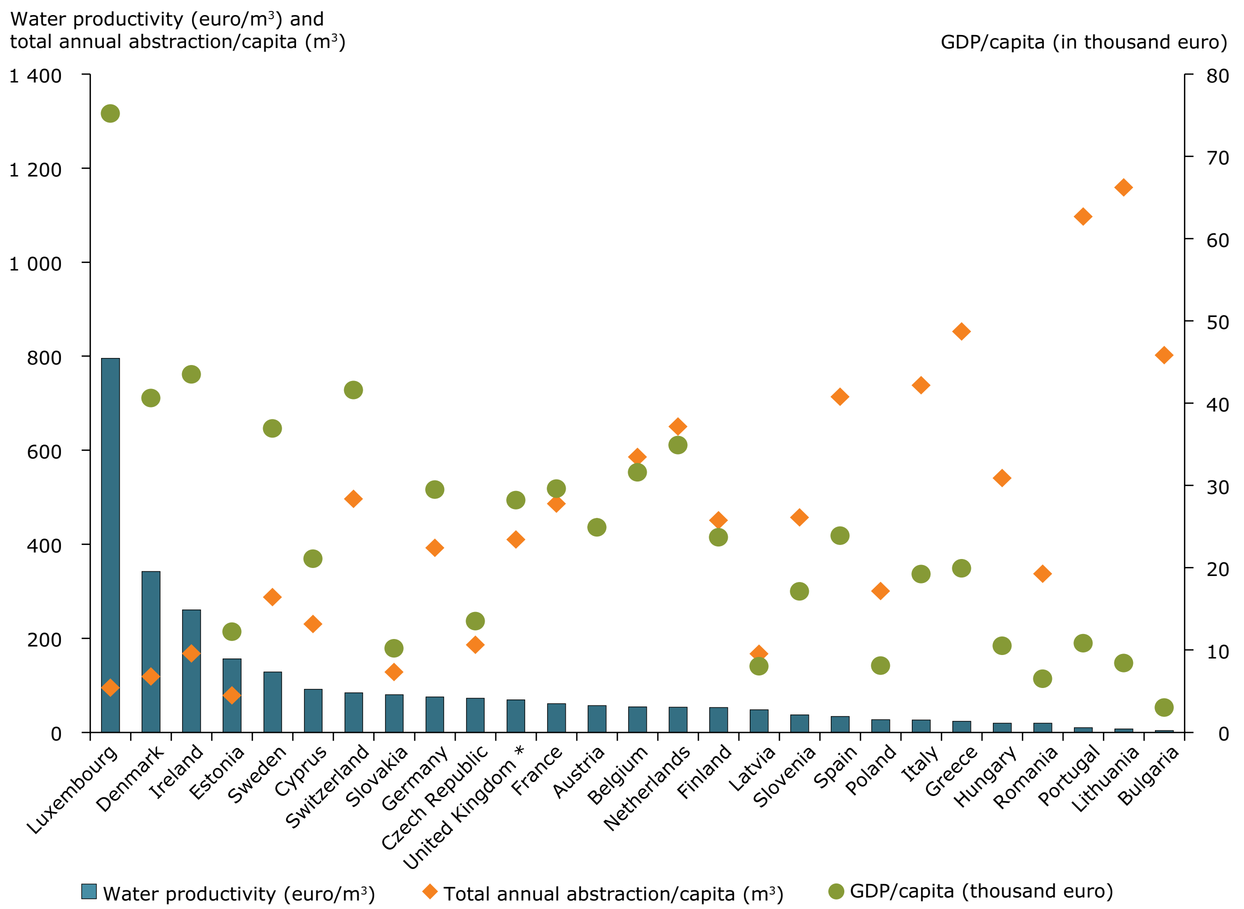
Source: Bio Intelligence Services, 2012b.

The data supporting Figures 4.4 and 4.5 are still being developed in discussion with countries. It must also be stressed that the scope for inferring concrete policies or actions from these indicators is limited unless they are complemented with more concrete sub-assessments that explain more about the reasons for e.g. high or low productivity, the economic activities driving water abstraction, and how these activities relate to the regional economy.

Management decisions are ideally based on small-scale analysis. For example, information on water productivity of different crops in a river basin provides a sound basis for local decisions on water allocation.

When seeking information on environmental impact intensity and the extent of water pollution resulting from economic activity, it is interesting

Figure 4.4 Water productivity, economic output per capita, and water use per capita in EEA member countries

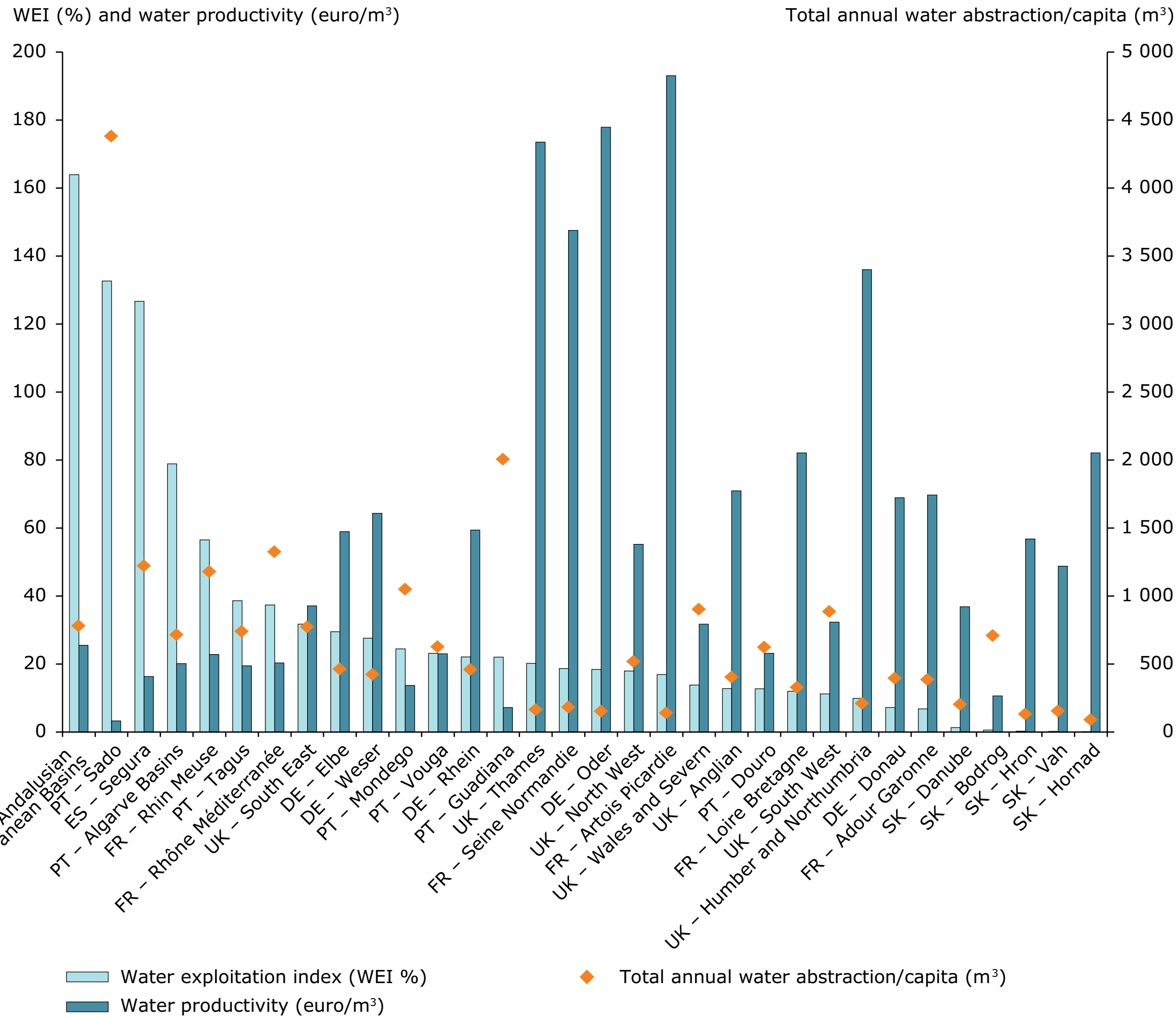


Note: The above data have been obtained for the latest available years as follows: 1998 for Italy and Portugal; 1999 for Austria and Finland; 2001 for the United Kingdom; 2005 for Bulgaria; 2007 for Belgium, France, Germany, Greece, Ireland, the Netherlands, Slovakia, Sweden and Switzerland; 2008 for Estonia, Hungary, Romania and Spain; 2009 for Cyprus, Czech Republic, Denmark, Luxembourg, Poland and Slovenia; 2010 for Latvia and Lithuania.

* The United Kingdom represents only England and Wales.

Source: ETC/ICM. The data on population and GDP (euro at current market price) are from Eurostat. The water abstraction data are from the WISE-SoE3 reporting for Austria, Bulgaria, Denmark, Estonia, France, Latvia, Lithuania, the Netherlands, Romania, Switzerland, the United Kingdom, and from the Eurostat JQ IWA for Belgium, Cyprus, Czech Republic, Finland, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Poland, Portugal, Slovenia, Slovakia, Spain, Sweden.

Figure 4.5 Water productivity and water exploitation in EU river basins and river basin districts, 2007

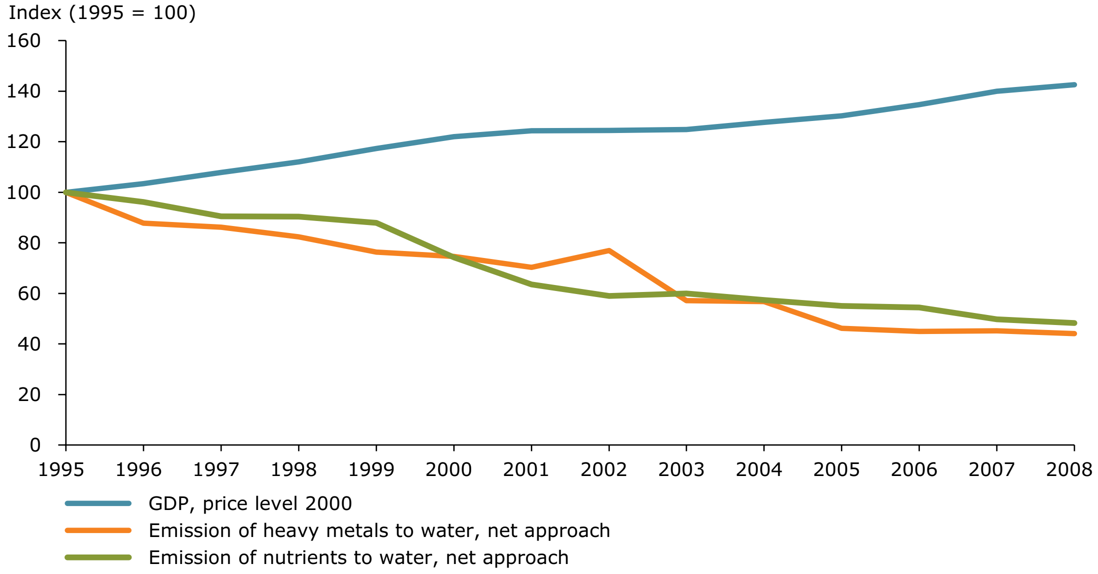


Source: ETC/ICM. The water exploitation index was calculated by the EEA (2009) based on data submitted to the European Commission. Total annual water abstraction per capita was calculated based on the same data, while GDP data (current euro) are from Eurostat.

to relate economic growth to emissions to water. Figure 4.6 shows that while the Dutch economy grew by 43 % in the period 1995–2008, heavy metal emissions from point sources decreased by 56 % and nutrient emissions from point sources decreased by 52 %. As such, emissions of both forms of pollution decoupled from economic growth in absolute terms during that period.

The aim of efforts to measure and improve water use efficiency is to maximise socio-economic benefits and welfare, while minimising adverse impacts on the environment (i.e. deterioration of the quantitative and qualitative status, functioning of the ecosystems). To achieve this we need interrelated indicators to monitor these parameters, based on a recognition that resource efficiency cannot be limited to water but also embraces energy and land resources. Box 4.2 provides examples of more detailed analysis of specific water-intensive industries at the river basin scale in Spain and Sweden, including also the environmental costs.

Figure 4.6 Economic growth and emissions of nutrients and heavy metals to water in the Netherlands, 1995–2008



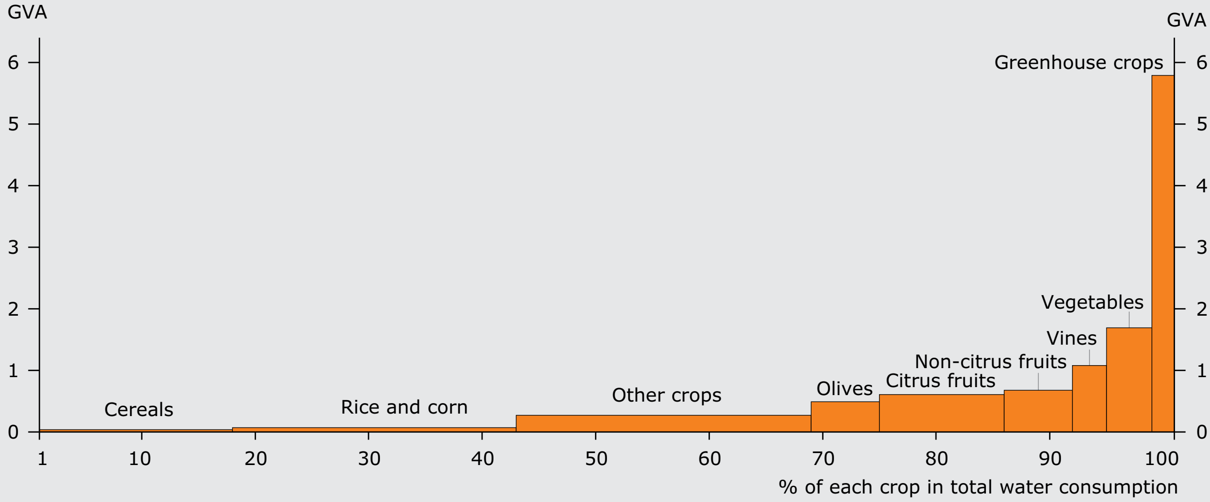
Source: Statistics Netherlands, 2010.

Box 4.2 Sub-indicators to monitor efficient use of water in agriculture and industry

Agriculture

Crops grown in Spain vary significantly in terms of water productivity. For example, 75 % of the value added generated in irrigated agriculture consumes just 9 % of irrigated water. Crops that generate limited value added relative to their water needs (such as cereals) are generally associated with low efficiency irrigation, i.e. more extensive irrigation techniques that supply more water to the land than the crops require (such as flood techniques). By contrast, high value added crops achieve efficiency rates of 90 %. This situation is also likely, to some extent, to reflect the incentives generated by quantity constraints and the limited role of prices: incentives to raise the technical efficiency may therefore only be strong when the value added generated by additional water input is high. More reliance on market signals, such as cost-reflective water pricing and water trading, would generate incentives to use water-saving technology in all agricultural production.

Figure 4.7 Gross value added of water consumed in irrigated agriculture in Spain, 2001–2002



Note: The y-axis measures GVA (euro) per m^3 of water consumed. Each rectangle area is proportional to the share of each crop in the value added of irrigated agriculture.

Source: MMA, 2007.

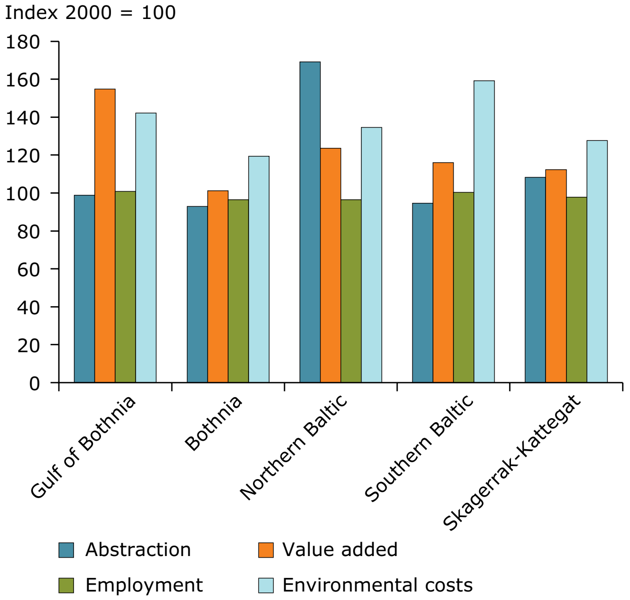
Figure 4.8 shows the evolution of water productivity in the agricultural and service sectors in Cyprus from 1998 to 2008. Agriculture (which accounts for up to 60 % of total water use) contributes only about 2 % to GDP, making this water use highly inefficient in terms of economic output (with water productivity of 2 EUR/m³). By contrast, the service sector has become progressively more efficient, decoupling water use from economic output. The sector's GVA has increased sharply, accounting for 60 % of GDP, while water use (30 % of the total water use in Cyprus) has remained more or less constant.

Industry

In **Sweden** the water intense industries achieved a clear decoupling of economic output from water use in the River Basin Districts of Gulf of Bothnia and Southern Baltic in the period 2000–2005. Water abstraction remained constant or even decreased, while value added increased significantly.

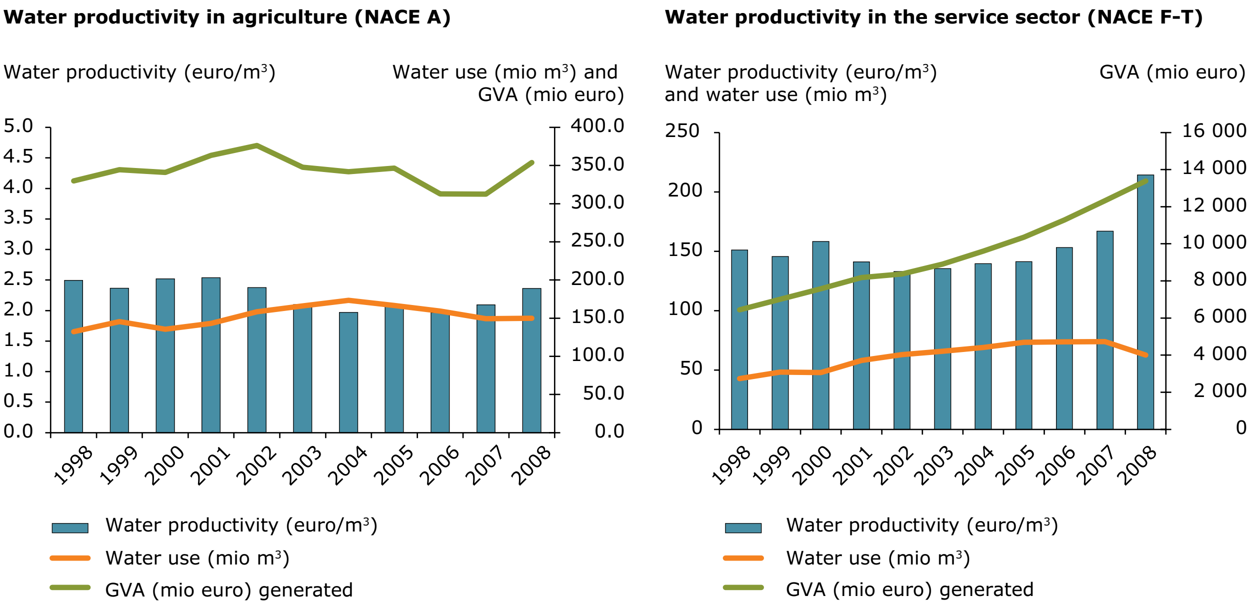
By contrast, water abstraction increased significantly (60 %) in the northern Baltic, while value added increased by only 22 %, indicating a continued strong link between water use and economic activity in the water-intense industries there. Decoupling can be seen to a lesser extent in the river basin districts of Bothnia and Skagerrak-Kattegat. Investments for treating and preventing environmental impact increased most in the southern Baltic.

Figure 4.9 Evolution of water abstractions, value added and employment in water-intensive industries in Sweden's river basin districts, 2000–2005



Source: Sweden Statistics, 2007.

Figure 4.8 Water productivity in Cyprus per economic activity, 1998–2008



Source: ETC/ICM. Data on water use are from MS reporting to WISE-SoE#3. GDP data are from CYSTAT, 2012.

4.2 Water accounting as a framework for understanding linkages between water resources and the economy

4.2.1 *The UN System of Environmental–Economic Accounting for Water*

Capturing the multifaceted character of the water sector requires a broad variety of resource-efficiency indicators. Quantitative and qualitative aspects require equal consideration, across all relevant sectors. The choice and scale of indicators must also reflect the local nature of water management needs.

The UN's System of Environmental–Economic Accounting for Water (SEEA-W) could serve as a central framework for arranging data from different data sources (such as hydrological services and statistical agencies) and generating a comprehensive picture of the natural hydrological cycle and its links to the economy.

The SEEA-W (UNSD, 2007) was adopted as an interim standard framework subject to further revision. It encompasses physical supply and use tables, which analyse the origin of the water abstracted by economic sectors, transfers within the economy, and returns to land and rivers. The framework links physical and monetary information on water, enabling environmental and economic policy issues to be analysed together.

Although the SEEA-W concept is relatively simple, implementing it is far from straightforward. It requires collecting a wide range of data — often the outputs of national or regional modelling work — from numerous actors and stakeholders. Unfortunately, European data flows have developed over time in rather diverse ways in the different national systems and are neither fully coherent nor fully consistent with the SEEA-W concept and its terminology. Compiling them must therefore be done with caution and harmonisation and normalisation steps are often needed.

The SEEA-W data must also be disaggregated in several directions. Downscaling is needed to provide information at meaningful and representative spatial and temporal resolutions. Modelling techniques are also required to match analysis of water stress at the river basin level (i.e. the physical micro-system) with economic analysis (i.e. the socio-economic macro-system), bearing in mind the diversity across Europe. Such analytical work can deliver water accounts that can serve multiple purposes for different European bodies, ensuring full consistency between the indicators and water policy assessments developed by each. This approach can also enable water to be incorporated as a component of wider

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ecosystem accounts, linking it to other aspects of natural infrastructure such as biomass production.

4.2.2 *Ecosystem capital accounts for water*

Although comprehensive in its approach, the SEEA-W 2007 focuses on physical supply and use tables, which analyse the origin of the water abstracted by economic sectors, transfers within the economy, returns to land and rivers and final uses. As such the approach does not relate to hydrological units as the natural physical basis, nor does it integrate environmental constraints such as 'environmental flows'. Water assets and quality issues are not fully developed.

Pursuant to a decision of the United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) in June 2011, water assets and quality issues will be addressed in the second volume of the SEEA-W. Water will be measured in natural capital accounts, focusing on the water provisioning service, security of access for human and environmental use based on long term probabilities, and impacts of water use on ecosystem services and environmental infrastructure. The EEA is currently developing this approach and will deliver its findings to the European Commission to support development of the 'Blueprint to safeguard Europe's Water Resources' in summer 2012.

The elaboration of the SEEA-W is part of a wider cross-media process of developing ecosystem capital accounts (EEA, 2011c). As an extension of the SEEA-W, ecosystem capital water accounts (ECWA) record the same basic flows but in a different way. Whereas SEEA-W reports for economic sectors, ECWA reports for inland ecosystems.

Ecosystem capital accounts aim to measure the capacity or potential of an ecosystem to deliver provisioning, regulatory and cultural services and the impacts of over-use or misuse which degrades natural capital. Water is recognised as a component of a broad range of valuable ecosystem services: supplying resources for ecosystems, society and the economy, supporting ecosystem regulation and maintenance and providing cultural services. Ecosystem capital accounts will also link water resources to other aspects of natural infrastructure such as biomass production and landscape integrity, which are covered by land use accounts.

The main ecosystem services involving water can be listed using the common international classification of ecosystem services (CICES) under discussion in the context of the SEEA revision. As shown in Table 4.1, all the services addressed in SEEA-W so far (UNSD, 2007) are 'provisioning services' (marked in blue text). There are also many important regulatory and cultural services supported by the water cycle (marked in red text) which are so far not fully covered in the SEEA-W.

Quantifying and comparing stocks and flows (supply and use) is not sufficient to identify impacts on ecosystems and resulting degradation. Because water is the socio-ecological system's vital fluid, ecosystem capital accounts must address a variety of questions, including:

1. Is there enough water of the appropriate quality available at the right place when needed?

2. Are human uses (abstraction, management, transfers, pollution, irrigation) compatible with expected risks of drought periods? Is human water use safe?

3. Is current water use compatible with environmental constraints and society's needs?

ECWA will organise the accounting balance around the concept of 'accessible water'. This comprises total available water minus the amount to be reserved for environmental requirements. The term is used following the 'Human Appropriation of Renewable Fresh Water' (HARFW) approach (Vitousek et al., 1986). ECWA differs from HARFW in several respects, however, in particular in recording returns of water and water stored in dams as accessible even though it has been 'appropriated'.

ECWA delivers a variety of useful indicators. The first is the **Total Ecosystem Accessible Water (TEAW),** which summarises the various positive and negative changes in the water resource: flows and stock changes. TEAW can be computed by ecosystem units and river sub-basins and basins and aggregated at the level of administrative regions and countries, as well as according to any geographical or climatic zoning.

TEAW will vary according to factors such as precipitation (influencing TEAW either positively or negatively); spontaneous evapotranspiration by crops or tree plantation (negative); additional evapotranspiration by irrigation (negative); storage in reservoirs (positive) and additional evaporation by reservoirs (negative); salination of groundwater (negative); pollution of rivers (negative); and transfers of water received (positive) or supplied (negative).

The TEAW aggregate is not sufficient to assess water's accessibility completely. The temporal variability of meteorological conditions needs to be taken into account, reflecting the succession of wet and dry periods and possible temporary severe stress that may result for people, agriculture and nature.

ECWA could capture this risk using a stress coefficient based on the number of days when plants cannot access any water in their growing season (EEA, 2011c). **Net Ecosystem Accessible Water** is obtained by multiplying TEAW by the water stress coefficient. On that basis, a headline indicator derived from ECWA is the **Ecosystem Accessible Water Surplus** index, which compares withdrawals of water (abstraction, diversion to electricity turbine, net storage in reservoirs) to Net Ecosystem Accessible Water.

EEA will publish first results of the Ecosystem Capital Water accounts during 2012 with the aim of linking hydrological and economic aspects of assessing water-resource management. In the discussion around appropriate target setting, integrating water with other media (land, biodiversity) and other sectors (energy, agriculture), this will be a vital support for the development of the Commission's 'Blueprint to Safeguard Europe's Water Resources'.

Table 4.1 Water and ecosystem services in the draft common international classification of ecosystem services (CICES)

Theme	Class	Group
Provisioning	Nutrition	Terrestrial plant and animal foodstuffs
		Freshwater plant and animal foodstuffs
		Marine plant and animal foodstuffs
		Potable water
	Materials	**Biotic materials**
		Abiotic materials
	Energy	**Renewable biofuels**
		Renewable abiotic energy sources
Regulation and maintenance	Regulation of wastes	Bioremediation
		Dilution and sequestration
	Flow regulation	Air flow regulation
		Water flow regulation
		Mass flow regulation
	Regulation of physical environment	Atmospheric regulation
		Water quality regulation
		Pedogenesis and soil quality regulation
	Regulation of biotic environment	**Lifecycle maintenance and habitat protection**
		Pest and disease control
		Gene pool protection
Cultural	Symbolic	**Aesthetic, heritage**
		Religious and spiritual
	Intellectual and experiential	**Recreation and community activities**
		Information and knowledge

Note: All the services addressed in SEEA-W so far (UNSD, 2007) are 'provisioning services' (marked in blue text). There are also many important regulatory and cultural services supported by the water cycle (marked in red text) which are so far not fully covered in the SEEA-W.

Source: EEA, 2010e.

4.3 Water Footprint Assessment and Life Cycle Analysis

In addition to resource-efficiency accounts at broad scales such as regions, river basins or districts, companies require assessments at the product or service level in order to measure the water use efficiency of their production cycles. This is the domain of Life Cycle Analysis (LCA) and Water Footprint Assessment (WFA). Both are also relevant to labelling and certification, as detailed in the next section.

LCA and WFA originate from different methodological contexts and have different purposes. They also have similarities, however, and are based on the same hydrological balance data. The two approaches are described below, and a more detailed comparison is presented in a forthcoming report prepared jointly by the EEA and the UNEP International Resource Panel (UNEP, 2012). LCA and WFA are currently being developed further to enhance their compatibility in the water area.

In a policymaking context, both LCA and WFA can be useful planning tools for environmental authorities, regulators, utility managers and water-intensive industries aiming to comply with the requirement for sustainable water management. Research and methodological development is under way on both sides to integration of all resource aspects, including water quantity, water quality, material use, energy consumption and carbon footprints.

Photo: © Giacomo de Stefano

4.3.1 Water Footprint Assessment

Water Footprint Assessment (WFA) is a volumetric approach, defined as the total volume of freshwater used to produce goods and services. It was originally introduced to indicate and value the direct and indirect water use of a consumer or product, using a rather simplistic approach (Hoekstra, 2003) with the main purpose of awareness-raising. The approach was further developed in recent years to better capture water quality aspects and reflect local issues and possible water management measures in the catchment where water is originally abstracted (mainly for agricultural purposes at the beginning of the supply chain) (Hoekstra et al., 2011).

WFA distinguishes three water components: blue, green and grey water. The blue water footprint relates to the amount of surface and groundwater used in production, while the green water footprint relates to the use of rainwater that does not become run-off (Falkenmark, 2003). The grey water footprint is distinct from the concept of grey water described above in Chapter 2. It comprises the volume of freshwater required to dilute and assimilate pollutants in the light of natural background concentrations and existing ambient water quality standards (Hoekstra et al., 2011). The blue, green and grey water footprints are now also evaluated in a sustainability assessment to determine environmental, social and economic sustainability (Hoekstra 2011). Case studies on this are under way.

In calculating the water embedded in products, WFA highlights the large water requirement of raw agricultural products and the often substantial transfers of water between the locations where products are produced and the locations where they are consumed (Hoekstra and Mekonnen, 2012). To assess the impacts of internationally traded products, however, WFA must consider all three forms of water footprint (blue, green and grey) at the catchment where the water is actually needed and used, and also account for water availability with sufficient spatial and temporal precision.

In its simplicity the water footprint has had great value in raising awareness, drawing public and consumer attention to the water use involved in different production processes. However, for precise information to guide policy decisions at the catchment level, accounting methodologies are needed that include precise modelling of the input and output balances and account for quality aspects throughout the whole life cycle.

Box 4.3 Virtual water assessments

Building on Water Footprint Assessment, the virtual water concept captures the volume of freshwater used to produce goods that are traded internationally. As such, it conveys the water embedded in traded products and the 'virtual' movement of water between remote catchments via those products (Allan, 2003).

An analysis of the virtual water in exported and imported crops (Velázquez, 2007) showed that the Spanish region of Andalusia uses large amounts of water in its exports of potatoes, vegetables and citrus fruits, while importing cereals and arable crops with lower water requirements. The study concludes that the agricultural sector will need to modify its water use greatly if it is to achieve significant water savings and environmental sustainability.

This example from Spain suggests that the virtual water concept can highlight instances when the choice of crops grown in a catchment areas do not support sustainable water management. However, a report prepared for the Victorian Department of Primary Industries (Frontier Economics, 2008) highlights some of the concept's limitations, in particular its failure to convey the impacts of water use and assumptions about the availability of water for alternative uses. As such, it concludes that the concept offers no guidance to policymakers in ensuring that environmental objectives are being met.

Australia's National Water Commission came to a similar conclusion (NWC, 2008). In its view measuring virtual or embodied water does not provide a useful or reliable benchmark for allocating a nation's scarce water resources. In practice, analysis of opportunity costs is seen as the most important determinant of allocation.

In the context of reviewing LCA methods, Berger and Finkenbeiner (2010) suggest that the original WFA approach can be integrated into LCA calculations by adding a weighting factor. Such an approach would have drawbacks, however, because the intuitive, volumetric approach to quantitative assessment is turned into a combination of quantitative and qualitative assessments. This achieves greater complexity but loses the awareness-raising element that explained much of WFA's original appeal.

4.3.2 Life Cycle Analysis

Life Cycle Analysis (LCA) is an ISO-standardised (ISO 14040/14044) tool that evaluates the environmental performance of products and services across their life cycle (ISO, 2006). LCA assesses the various environmental impacts by quantifying all inputs (e.g. extraction and consumption of resources) and outputs (e.g. waste and emissions), and then evaluating the contribution of these inputs and outputs to impact categories such as climate change, ecotoxicity and ozone depletion.

The full life cycle of a product or service, 'from cradle to grave', comprises numerous stages: extracting materials from the earth; processing, production and assembly procedures required to create the finished products or services; transportation; consumer use; and ultimately disposal of the products or waste materials (UNEP, 2002). The cycle is driven by society's needs and uses, which in a globalised market normally involve numerous locations and actors at each stage producing specific environmental impacts.

Water-related Life Cycle Analysis comprises four stages. In the inventory phase, input-output balances are set up based on hydrology and water uses, similar to basin wide water accounts. Next, in the impact assessment phase, categories of environmental impacts (e.g. climate change, ecotoxicology, acidification) are selected. The results from the hydrological input-output analysis are then assigned to the categories. These classifications are transformed into common units with characterisation factors to obtain an environmental profile of the product expressed in a common metric. This allows the integration of different metrics like volume, concentration or energy use for a certain process to be normalised and used in one common evaluation scheme for the product or service. LCA can therefore encompass water consumption, emissions of pollutants to receiving waters, and the energy needed for treatment processes equally .

LCA has been used to assess the efficiency of depollution and links to energy consumption in the area of wastewater treatment (Larsen et al., 2007; Larsen et al., 2010; Clauson-Kaas et al., 2004; Høibye et al., 2008). Subsequent studies by Foley et al. (2010) and Rodriguez-Garcia (2011) have provided systematic results across a broad range of different wastewater treatment typologies. The analysis in Foley (2009) illustrates the benefits of using the broad-spectrum LCA approach — highlighting the potential for an overall environmental downside in pursuing advanced biological nutrient removal.

A large number of other LCA studies look at optimising the efficiency of various components of the wastewater system, such as sewage sludge treatment and disposal (e.g. Hong et al.m 2009; Hospido et al., 2010; Johansson et al., 2008; Peters and Rowley, 2009), phosphorus removal and recovery (e.g. Coats et al., 2011; Johansson et al., 2008; Remy and Jekel, 2008), and different technologies to facilitate wastewater recycling (e.g. Munoz et al., 2009; Pasqualino et al., 2011; Tangsubkul et al., 2005).

LCA has also been applied to the comparison of different drinking water supply technologies, with the most recent examples including Bonton et al. (2012), Munoz et al. (2010) and Vince et al. (2008). Other studies (e.g. de Haas et al., 2011; Lundie et al., 2004; Munoz et al., 2010) have applied LCA across integrated (water supply and wastewater management) systems, thereby providing a broader perspective on the trade-offs identified in the studies looking to optimise specific sub-components of the water system.

Although LCA has primarily been used in assessing water pollution, rather than water use (Koehler, 2008) some approaches focus on integrating quantitative and qualitative aspects. Examples in the water area relate to car manufacture (Warsen et al., 2011) and food production (Ridoutt and Pfister, 2010; Ridoutt et al., 2009).

4.4 Labelling and certification, standards and stewardship

Certification and labelling schemes enable consumers to express their environmental and social values through their purchasing decisions, making the production and supply chain values of the product more transparent. In doing so, they provide assurance that specified minimum criteria, characteristics or production methods have been complied with. In certified schemes, a third party normally evaluates the chosen criteria; in contrast labelling schemes are mainly voluntary and producers will use a particular label or logo without any certification mechanism. By responding to consumer preferences, such standards can be powerful tools for influencing business practices. Such practices can include encouraging water efficiency or water management more generally.

Schemes that focus on water consumption can be problematic, however, if they inadvertently cause other aspects of production, such as the wider environmental, social or economic burden, to increase. Customers are not only interested in water use and impacts when making purchasing decisions. Schemes that include more sustainability criteria may be of more value, therefore, although greater complexity may make it harder for consumers to comprehend different schemes. A 2010 inventory of voluntary schemes in relation to agricultural products and foodstuffs, compiled for the European Parliament, identified over 400 schemes (RPA, 2011). Producers, especially small- and medium-sized enterprises may likewise find it very difficult to prove their compliance with a proliferation of complex standards.

A report for DG Environment (RPA, 2011) found that stewardship was a favoured basis for certification, rather than volumes of water used; and consumer education was preferred over consumer-aimed labelling. It would appear that certification of water stewardship activities would be more appropriate, and this is the focus of a range of industry driven initiatives, both within the EU and aimed at creating more global certification standard. For example, the Alliance for Water Stewardship (AWS) is developing performance standards which can be used globally to certify water users who voluntarily practice sustainable water management (AWS, 2011). Aimed at water utilities and companies that use significant quantities of water in their operations, the scheme is being developed with stakeholder involvement and will have stringent standards on water stewardship. A key aspect is likely to be tools to measure the water consumption, which may take the form of the water footprint, and setting standards that reduce the size and impact of the footprint.

The European water stewardship scheme (EWS), developed for Europe by the European Water Partnership (EWP), addresses operational evaluation of sustainable water management, including issues such as impacts on local river basins, integrated response solutions and risk management. The EWS defines sustainable water management response strategies at the river basin scale for European water users, including industry and farmers. The EWS includes a guideline/standard and checklists for private water users to guide them towards sustainable water use, management and governance. It is highly complementary to water accounting tools, rewards sustainable practices and takes into account EU policies, including the Water Framework Directive.

Box 4.4 Water footprinting as a tool for water stewardship in the supply chain

Because most water footprint assessments have not addressed the environmental impacts of water use, corporate organisations are increasing moving away from water footprinting alone (and in some cases at all) towards water stewardship approaches. The UK retailer, Marks & Spencer, uses a three-tiered approach, drawing on the water footprint methodology (Marks & Spencer, 2011):

Tier 1: standards	Marks & Spencer defines criteria that their suppliers have to meet.
Tier 2: risk	Marks & Spencer tries to use information on water risk in its supply chains to identify which products are from areas at risk of water stress. This has included using both Water Footprint Assessment and other tools.
Tier 3: influence	Using the information on water risk in their supply-chain, Marks & Spencer identifies which suppliers to target with its water stewardship approach. Marks & Spencer is not simply targeting suppliers located in areas at risk of water stress — after all, a supplier may be working sustainably even if located in a high risk area. Sustainable suppliers are given an award for sustainable practice. Marks & Spencer is also working with WWF and the Food Ethics Council to foster stakeholder engagement.

Source: RPA, 2011.

Box 4.5 'Naturemade' labels promoting sustainable hydropower

In Switzerland, a green hydropower standard was established in the late 1990s. The Association to Promote Environmentally Friendly Electricity (VUE) was founded to develop a broadly accepted standard of quality for green electricity. In summer 2000, the 'Naturemade' label was publicly launched.

The green labelling scheme has two main objectives. First, the economic objective is to have a reliable and objective certification scheme that trusted by consumers and ensures fair market competition. Second, the ecological objective is to improve local river conditions by creating an incentive to develop sustainable hydropower.

The scheme imposes two sets of requirements on hydropower plants. The first comprises 45 scientifically defined criteria relating to matters such as minimum flow regulations, hydro-peaking, reservoir management, bedload management and power plant design. These enable the hydropower plants to be certified independent of their age, size or operation. The second requires that a surcharge be applied to every KWh of energy sold as green hydropower and that the funds raised should be reinvested in the local river system in the form of tailored river restoration measures (EAWAG, 2001).

Currently about 3 % of Swiss hydropower plants are 'Naturemade' certified and the payments under the scheme have generated EUR 6.4 million of environmental investments to improve the environmental performance of hydropower plants in the period 2000–2009 (VUE, 2011).

Source: Dworak, 2011.

5 Conclusions

5.1 A scarce resource requires careful management

Clean water — this vital part of our daily lives, our environment and our economy — is becoming increasingly scarce due to increasing demand from different human and economic activities, and the effects of climate change. Although Europe is comparatively well equipped with water and the economic means to address water shortages and water pollution, both are still a problem in many parts of the continent. Resource-efficiency measures are therefore at the top of the water management agenda. They are needed to ensure that sufficient clean water is available at an affordable price for human needs, while the functioning of aquatic ecosystems is preserved to further provide vital goods and services. A common understanding of water's importance is essential, alongside effective communication about who needs water, where and for what purposes.

This report as the first in a series of EEA reports over 2012 supporting this communication about our water resources. It aims to provide support and information for developing the commission's 'Blueprint to safeguard Europe's water resources'. As an overarching process covering all relevant water policies, the Blueprint brings together the results of WFD's first round of implementation, the review of the water scarcity and drought policy, measures to address climate change vulnerability, and the issue of resource efficiency in the water area.

5.2 Principles of sustainable water management

Decoupling

Resource efficiency is an important and useful principle to guide policies in the context of increasing resource scarcity. It can be applied to all natural resources and is important for water, which plays an essential role in the functioning of both ecosystems and the economy. To prevent any efficiency improvements (in quantitative or qualitative terms) from being outweighed by increased consumption, resource use has to be decoupled from environmental impacts. It is essential that we preserve our natural capital and the ecosystem services it delivers. Efficiency increases therefore must enable vital ecological functions to be maintained and restored.

Common boundaries

The Water Framework Directive sets objectives, providing boundaries against which decoupling can be measured. These relate in particular to protecting water quality and aquatic ecosystems. Sustainable water-resource management, in particular regarding water quantities, can be further improved by policies on water scarcity and drought, and climate change adaptation. The development of 'environmental flows' is an important tool for implementing objectives on water-resource management and in relation to hydropower impacts

The competing water uses have to be considered in the economic nexus of 'water-energy-food', bringing together the competing water demands of e.g. agriculture, transport, energy, water utilities, industries and tourism.

Together, these competing uses should comply with targets determined by the needs of healthy ecosystems, with clean water being one essential aspect of these needs. To establish common objectives like the WFD's 'good status' requirement beyond the water area, there is an urgent need for mapping and assessing ecosystem services linked to water, land use and biodiversity. For example, the biodiversity targets for 2020 should be part of this integrated mapping process. Using or polluting water should likewise be related to energy consumption targets for mitigating climate change, and to sustainable land use. Water, energy efficiency and land use are closely related.

Sectoral integration and communication

The examples of sustainable water management and resource efficiency presented in this report show that integrating responses with all sectors competing for water use (and pollution) is vital. Environmental measures need to be implemented in the policies of other sectors, including agriculture, energy, transport and tourism. Environmental actors therefore need to highlight the importance of the hydrological cycle and aquatic ecosystems in providing services that these sectors need. This demands intense communication at the EU level and in particular at the national and regional levels of operational water management. Public participation and the process of developing river basin management plans under the WFD (the second round will be finalised in 2015) is the best entry point and tool for this.

5.3 Tools and measures

A mix of tools

The examples in this report show that to balance competing water uses and water-related activities within common boundaries a mix of tools is most effective. Technical and efficiency-related measures are needed, together with economic instruments that allocate water to its most productive use, incentivise efficiency and innovation, and generate revenues to support ecosystem management. The measures should also include normative tools, like the objectives of the WFD, to enforce ecosystem sustainability boundaries. Knowledge and information-based tools such as awareness-raising, accounting, certification and labelling are important as supporting measures, allowing flexibility and drawing on local knowledge and experience to define tailor-made solutions and to foster innovation.

Agriculture

Agriculture remains a key focus area for improving water management as it accounts for an average of 33 % of water use in EEA countries. In southern Europe this can reach up to 80 %. The great majority of water used in agriculture goes into irrigation, hence the highest opportunities for efficiency gains can be expected here. To increase the efficiency of field application, the most important measure is shifting from using furrows (with 55 % efficiency) and sprinklers (with 75 % efficiency) to drip irrigation, which is 90 % efficient.

For water used in irrigation, a pricing structure is needed that provides more incentives for resource efficiency and allows more transparency in comparison to competing uses to avoid cross-subsidies from other parts of society. The removal of adverse agricultural subsidies is necessary to facilitate the incentivising effect of pricing, charges and taxes. Furthermore illegal water abstraction needs to be tackled with more intense monitoring.

Changes in agricultural practices, including cultivating crops with less water demanding cropping patterns and shifting to more rain-fed cultivation, can reduce water demand. Wastewater reuse is another possibility to increase efficiency and avoid competition with drinking water supply.

Next to quantitative water use, agriculture is still also the largest source of nutrient pollution in water as well as a driver for hydromorphological changes. First results from the assessment of river basin management plans under the WFD show that to reach the objectives of the WFD further reduction of inputs from agriculture are urgently needed. In view of energy needed to reduce drinking water pollution or to transfer freshwater from distant unpolluted areas, reducing pollution at source is logically the most efficient approach.

A wide mix of measures is available in agricultural practice to achieve the goal of good status and to prevent water scarcity. Actions depend on the decisions at farm level, the wider framework of agricultural policy and the subsequent economic structure of the sector. Further development of the sustainability of the CAP and direct regional and local initiatives between water authorities and farmers are therefore needed to alleviate the most important agricultural pressures at the river basin scale. Good practice examples show that it is possible to develop productive and profitable farming while respecting the water environment.

Public water supply

Public water supply includes water supply to households, public buildings, small business and industries. In some southern European coastal areas, tourism alone is the biggest consumer of public water supplies. As different consumers use public supplies, a variety of reduction measures is needed and local authorities should tailor their campaigns to local needs to provide enough water of sufficient quality.

Installations of water saving devices, metering, the reuse of grey-, harvest of rain water and leakage reduction are the most important technical measures to be exploited. Investment in those technics has to be seen also as precaution for upcoming scarcity situations (climate change) as well as in connection with the energy consumption needed in the respective drinking water and wastewater treatment. The mélange of different solutions in particular in population dense urban areas needs to be integrated part of the urban development at large and adjusted to the region-specific pattern of urban metabolism.

The tariff structure and urban and industrial water management play a vital role in influencing efficiency measures and incentivising investments in water saving devices, technologies and innovative wastewater technologies. A central element is the pipe infrastructure network for distribution, which next to the treatment technologies represents a large part of the costs for utilities. Full cost recovery is obviously necessary to cover investments in infrastructure over the coming decade and to adopt innovative technologies integrating water and energy efficiency.

As water pricing is an important issue in public debate, full transparency is needed regarding the relation of prices of water services, cost recovery and investments. Water is an essential element in most human needs but providing convenient access from the tap, clean water after use and recovering externalities has a cost, which needs to be clearly communicated. Metering is absolutely essential as a feedback, communication and control mechanism. Raising awareness about the value of water and the way it is consumed by all actors is important for increasing efficiency in public water supply.

5.4 The water-energy link

Coordination between water and energy legislation is obviously vital to align water and energy efficiency and the global need to exploit renewable energies in the long term. At the regional level this applies, for example, to coordinating river basin management plans and national renewable energy action plans under the Renewables Directive (EU, 2009a). Likewise, water efficiency measures should be aligned with targets for energy reduction. Water quantity and water quality are closely connected, and reducing pollution at source is also an important efficiency measure in relation to the energy use. The water-energy link includes also the agricultural sector as the cultivation of bioenergy crops consumes a lot of water and adds to pollution. An EEA report on vulnerability of water ecosystems in autumn 2012 will focus on the interlinkages between water, land use planning and agricultural policies within the water-energy-food nexus.

The direct water-energy link is most relevant for the areas of hydropower and desalination, where each resource is used in produced the other, and in various areas linked to water quality, notably energy use in supplying drinking water supply, and energy use and recovery in wastewater treatment.

Hydropower

Hydropower is an important supplier of renewable (CO_2 neutral) energies throughout Europe, currently accounting for 70 % of the total. Its importance is also related to its ability to provide storage capacity for renewable wind and solar energy in future decentralised energy networks. As an important driver of hydromorphological alterations of water bodies, however, hydropower can negatively affect river ecology. In many Member States the hydromorphological status of the water bodies is a major threat to achieving the WFD goal of good ecological status in 2015. The main measures for abating ecosystem impacts are reducing direct damage to fish, enabling connectivity for migratory species and restoring and maintaining ecological habitats in riparian areas related to the installations, including restoring connected wetland and oxbow areas. Strategic planning and environmental impact assessments of new and refurbished hydropower installations are a key tool to implement those measures.

While hydropower capacity is currently considerable, in comparison to wind and solar energy, the potential for further increase is rather limited. This should be reflected in strategic planning. In terms of resource efficiency and taking into account all available technical measures, the environmental impacts have to be related to the energy produced or stored. In general, the hydropower schemes with the least impact per TWh at the level of the river basin plan should be chosen. This requires an evaluation of impacts in the context of the whole river basin management plan process, bearing in mind the best possibilities for exploiting renewable energy potential given the hydrological, geological and climatic conditions of the river basin. This evaluation is an important responsibility of the competent water authorities in cooperation with energy sector partners.

Desalination

For desalination there is a similarly close connection and need for cooperation between the water and energy sector, but also a high need for investments into renewable energies.. In particular in Mediterranean countries with both high agricultural water demand and intense tourism, desalination can appear to local authorities as the ideal solution to increase economic activity despite water scarcity constraints. In reality, however, there are important costs involved in desalination, which should be reflected in decision-making. In addition to environmental impacts due to brine discharges, desalination is very energy intensive, undermining regional efforts to meet EU energy reduction targets.

Although reverse osmosis technologies are more efficient than older thermal desalination technics, the thermodynamic minimum energy needed to separate H2O and salt implies desalination will always be an energy-intensive technology. As transport from remote areas is also energy intensive (see below) the first solution should therefore be reducing water use and increasing water use efficiency in all sectors in regions prone to droughts and with water scarcity problems.

Parallel development of renewable energies offers a win-win solution. Wind and solar power are both available in ample quantities in water-scarce coastal Mediterranean areas. One solution, being investigated in some promising studies but requiring much development, investment and innovation, is the direct combination of desalination with renewable energies at the same plant.

The link between water quantity, quality and energy efficiency

The energy used in treating drinking water and wastewater can be markedly reduced when pollution — in particular nutrient pollution — is avoided at source. Both the Urban Waste Water Directive and the Drinking Water Directive provide the basic measures to implement the objectives under the WFD. Further integrating targets related to energy and land use, reduction at source measures would help the implementation of those directives in a more efficient way. Further to the reduction at source, the existing implementation gap in the UWWTD needs to be closed with investments into most up-to-date efficient and effective treatment.

Energy use in drinking water supply relates to processing, treatment and pumping, and transfers from sources and customers through the distribution network. It is therefore site specific, depending on the availability of clean freshwater (from remote, e.g. alpine, areas), the pollution status, geography, relief and distances. The age and condition of the network also plays a role. Worse water quality and greater water scarcity in a river basin implies greater energy and resource use for treatment and transporting freshwater over large distances. The consequences for potential energy saving and water pricing are obvious.

Eenergy use and energy and material recovery in the wastewater treatment process is relevant for resource efficiency. The combination of electricity and heat energy in wastewater treatment, implies that the best unit to evaluate the overall energy balance of a treatment plant is the carbon footprint. There are several examples of CO_2 neutral plants that employ sewage sludge digestion to produce biogas, which is used to regain the energy used in the treatment process or for vehicles in the public transport system. More efforts and ambitions like that in urban wastewater management should be encouraged.

The recovery of phosphorous and nitrogen from urban wastewater is an important efficiency measure. Worldwide phosphorous stocks, needed in particular for fertilisers, are limited and expected to become more costly in the future. A viable option is direct recovery from the treatment process, as several examples in the United Kingdom and the Netherlands show. Direct application of sewage sludge to agricultural land is not a sustainable option, however, as it could contaminate soil with heavy metals, persistent organic pollutants, and pharmaceuticals. As a 'reduction at source measure', restricting phosphates in detergents helps to ensure efficient use of energy and materials.

5.5 The knowledge base to foster resource efficiency

A basic requirement for sustainable water management at the river basin level is knowledge about the current and future water availability, the water needed for economic activities, environmental needs and how these needs relate to availability in a relevant time span. In short, water administrators needs to know whether water use is an over-exploitation and leads to water scarcity. This knowledge is the basic requirement to take action and steer allocation in the short term and encourage efficiency increases in the long term.

The most important data relates to water availability and water use (abstraction and consumption). Such data are needed per hydrological unit (river basin district) and on a monthly basis to reflect the hydrological realities and seasonality effects. This information is to be used in indicator assessments such as the water exploitation index and water accounting approaches. In particular, ecosystem capital water accounts can support the distance-to-target analysis and help evaluate how and where objectives and targets in sustainable water management are met and are within sustainability boundaries.

Water balances are the basic information that fuels further economic assessments, whether at the macroeconomic level (natural capital accounts) or the corporate level (LCA, WFA, stewardship and certification). Assessing the economic dimension requires detailed enough information on water prices, gross value added for the different sectors, metering and the most relevant investments. One of the problems with statistical data is that aggregation is often related to administrative boundaries rather than to river basin districts. In principle reallocation and statistical conversion are relatively easy to do with disaggregated data but require a harmonised approach and streamlined development and application throughout Europe. For better data quality and improved assessments at all levels (EU and national) a better cooperation between environmental, statistical and hydrological services is urgently needed.

So far no indicator set to describe specifically resource efficiency in the water area has been developed. This might be necessary when policies in this area are further developed and integrated better with the efficiency efforts in other policy areas (materials or energy). Data and information about the economic aspects of the WFD, full cost recovery and the real cost of water need to be reflected in economic development at the regional and river basin district level, as they are vital for integrating water, agricultural and energy policies.

At the corporate level the relevance of water, its value and costs, is increasingly recognised. Consequently the interest in stewardship, water accounting, footprint assessments and water-related LCA analysis is increasing to support sustainable water management throughout all sectors. The different methodologies and their application are still being developed and transparent case studies are needed that apply the techniques across the entire supply chain, thereby reflecting the effects of European production and consumption on water scarce river basins outside Europe.

5.6 Future needs for sustainable water management

All the elements, measures and tools needed to implement more sustainable water management are contained in some form in European water legislation, namely the WFD, water scarcity and drought policy and the adaptation policy. The success of these policies in achieving their goals can only be determined in full by means of the review processes currently under way in the context of developing the 'Blueprint to safeguard Europe's water resources'. From the viewpoint of resource efficiency and in reference to the material collected in this report, some principle considerations should be included in developing further policy options.

Understand water in the ecosystem services framework and protect environmental needs

In implementing water policies, one important ambition is to base them on greater recognition that water is an essential resource in providing ecosystem services efficiently and that the objective of 'good status' needs wider policy integration to reflect this reality.

Common objectives should ensure the most efficient use of water resources in the economy, while ensuring that **environmental needs** are met and the the vital ecosystem services that support our economies and all human needs are preserved. For sustainable water-resource management quantitative provisions like environmental flows are needed and should be further developed. However a wider, more integrated setting of common objectives considering water's role alongside all other natural assets can only be implemented in a common framework based on the ecosystem service concept.

Encouraging the use of technical efficiency measures

A range of technical measures is available for energy efficient water saving and pollution reduction. To further develop and establish those measures and techniques, there is a need to boost **innovation**, for example via the Commission's innovation partnerships (EC, 2012d). With a large part of Europe's water infrastructure being up for renewal it is vital to use this opportunity for technological improvements instead of sustaining inefficient solutions. As a highly industrialised and developed region, Europe should also aim to lead global development in this area.

Incentivising the right technological developments and behaviour

After ensuring that environmental needs are met using regulatory measures (targets), **economic and market-based instruments** are needed to foster technological development, efficient water allocation among sectors, and the right behaviour from all actors to achieve sustainable water management. For that economic measures include effective water **pricing** and tariff structures, removing of adverse subsidies, and effective application of the cost recovery principle, including the internalisation of all externalities and environmental costs.

The EU and its Member States can play crucial roles in these policy areas, using public spending and grants to create and maintain necessary infrastructure, promote technological innovation and incentivise behavioural change. The **economic incentives** given by the CAP and cohesion policy need to be further scrutinised and effects on ecosystem functioning needs to be prioritised. The possibility of **water trading** within and beyond agricultural actors needs to be further evaluated, along with the possibility of a framework for inter-sectoral financing. The economic analysis under the WFD can be an entry point for an improved system of incentives at the national level. Better guidance might be needed for Member States to establish such systems effectively.

Integration between all relevant sectors

The close link between water, energy and agriculture — 'the water-energy-food-nexus' — requires full integration of policy objectives in the areas of sustainable water management, water policy, renewable energies and a sustainable agricultural and land use policy. This integration is not only the responsibility of EU-level actors but should be implemented at every practical step of implementation on the ground at the national and regional level. The public participation process under the WFD is one possibility to enter into this **dialogue between sectors**. The second round of river basin management planning is a chance to improve current implementation. Sustainable water management needs highly interconnected, open and transparent **governance**.

Communication — stakeholder dialogue

Further results from the review of WFD implementation are needed before determining the focus of future sustainable water management policy. Clearly, however, improved inter-sectoral communication and a more shared understanding of common boundaries oriented at the concept of ecosystem good and services have a role to play in the second round of **river basin management planning**. Improved communication between the water sector and other sectors will be important in efforts to balance the water use of competing economic sectors (agriculture, industry, utilities, etc.). Intense stakeholder dialogue under the **public participation** provisions of the WFD is therefore needed.

Awareness-raising and monitoring

Next to economic incentives, behavioural change and innovative investments should also be encouraged via awareness-raising and improved communication and understanding between all stakeholders. Transparency is a key element in building shared understanding of sustainable water management.

Monitoring measures like metering are absolutely vital to provide this transparency and give feedback to all relevant actors on how they use their water. **Metering and monitoring** of water use and discharges is also absolutely vital in the context of the economic incentives. In some areas, however, for example illegal water abstraction, improved monitoring procedures need to be accompanied by legal enforcement.

Improving the knowledge base

To ensure the necessary transparency and inform policies at the local and international levels the knowledge base for action needs to be improved. At the local level it is absolutely vital that competent authorities make any **water management decisions** (e.g. regarding incentives, allocations or restrictions) in full awareness of the availability of their freshwater resources at the catchment level and in full awareness of the actual needs of all actors in their jurisdiction. Appropriate accounting methodologies need to be implemented at the local level to provide this transparency and allow effective monitoring. Further guidance to Member States might be needed to better implement this knowledge in the next round of river basic management planning.

At the corporate level, **stewardship approaches** that implement input-output balances for all products and services need to be further developed. Life Cycle Analysis and Water Footprint Assessment should be further discussed in that context and integrated into the best applicable stewardship scheme.

For all improvements of the knowledge base, transparency and dissemination, **data policies** between the relevant data providers, hydrological services, statistical offices and environmental administrations should apply open exchange of data free of charge (or only charging for administration costs).

As part of the transparency efforts, better **dissemination of information** is vital. The water Information System for Europe (**WISE**) can play a more integrated role in connection with water information systems in Member States. New information technologies enable easy and more targeted information exchange and a better and faster connection with all stakeholders.

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