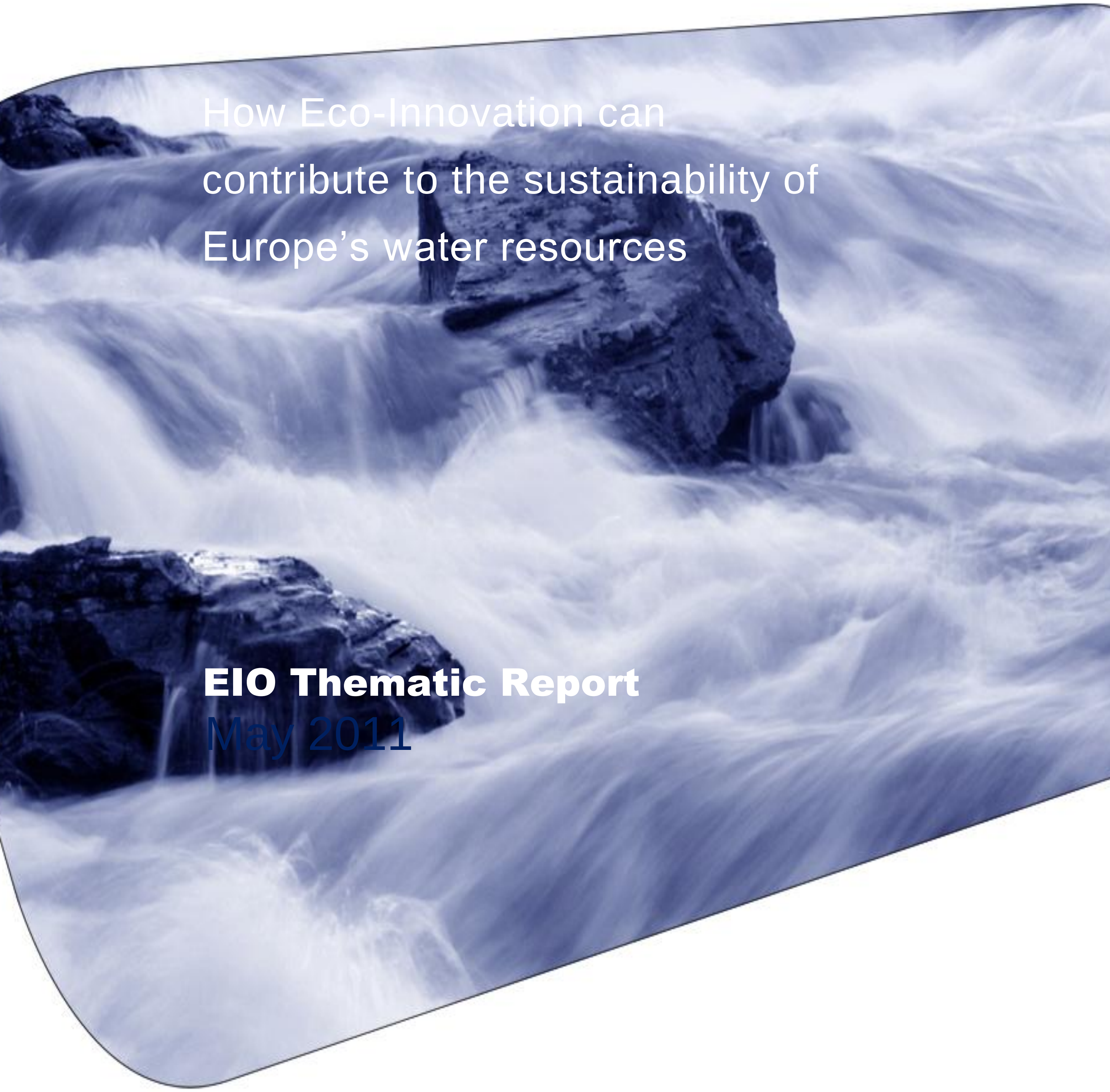
Water Innovation



How Eco-Innovation can contribute to the sustainability of Europe's water resources

EIO Thematic Report

May 2011

Eco-Innovation Observatory

The Eco-Innovation Observatory functions as a platform for the structured collection and analysis of an extensive range of eco-innovation information, gathered from across the European Union and key economic regions around the globe, providing a much-needed integrated information source on eco-innovation for companies and innovation service providers, as well as providing a solid decision-making basis for policy development.

The Observatory approaches eco-innovation as a persuasive phenomenon present in all economic sectors and therefore relevant for all types of innovation, defining eco-innovation as:

“Eco-innovation is any innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle”.

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A note to Readers

Any views or opinions expressed in this report are solely those of the authors and do not necessarily reflect the position of the European Union. A number of companies are presented as illustrative examples of eco-innovation in this report. The EIO does not endorse these companies and is not an exhaustive source of information on innovation at the company level.

Table of contents

List of Figures

List of Tables

List of Boxes

Executive Summary

Introduction

Water is an essential and central element of all human activity and when it comes to the production of food and sustaining human life there is no substitute. Although it is difficult to put precise numbers to the human requirement for water, it is estimated that each person on the planet needs 20 or more litres per day to have a reasonable standard of living. Of this, only 2 - 4 litres is consumed directly while the remainder is necessary for food production and sanitation. Yet many countries consume far higher volumes per capita. Due to cost and bulk it is not economic to transport water from wetter parts of the globe to drier, yet relatively affluent nations with relatively little water have, to date, overcome this problem by trading in water-intensive goods, such that they import 'virtual water'; in effect they export their water shortage to countries with abundant water (Hoekstra, A.Y. and Chapagain, A.K. 2008). Jordan and Egypt, for example, choose to forego food sovereignty by consciously importing as many products as possible so as to conserve their own, limited water resources.

Yet, with the rapidly increasing global population, this strategy may no longer be sustainable. As water becomes less available so it will appreciate in value. Hence there are real pressures to conserve water, to reduce the costs of treating and distributing water and collecting, treating and disposing of wastewater. Similarly, as the world looks for alternative sources of power and ways to replenish diminishing stocks of phosphate, the recovery of energy and minerals from wastewater will become ever more important. The maintenance of aging infrastructure that leaks or fails to deal with modern-day pollutant loads imposes a heavy financial burden on developed nations.

So it is that conditions for the development of new technologies and management practices in relation to water are more aligned, perhaps, than ever before. The water market is enormous and getting larger, it is inextricably linked to the energy sector and is reaching a crisis point that demands innovation.

Why Focus On Water?

In the last 100 years the global population has trebled from around 2 billion to over 6 billion (United Nations, 2007), yet global water usage has increased six fold. According to the recently published Water Disclosure Global Report 2010 (ERM, 2010), demand for water is projected to outstrip supply by 40 percent by 2030, and an estimated half of the world's population is likely to live in areas of high water stress by the same year.

Even without accounting for climate change it is apparent that the rapid increase in the human population will place ever-greater calls on fresh water. Similarly the burgeoning demographic leads to the generation of greatly increased volumes of wastewater to be treated and disposed of. In recent years, many reports have been written about these issues; from NGOs such as the WWF, through business coalitions like the 2030 Water Resources Groups, the United Nations and a broad spectrum of academics. Within Europe, the European Environment Agency has published the report 'Water resources across Europe' and The

European environment — state and outlook 2010 (SOER 2010), including a chapter devoted to water resources.

Still, it is reported (Greentech Media, 2010) that the proportion of venture capital investments in the water sector are a small percentage of the total deals done in ‘clean technologies’, with an estimated global investment of c. $150m in 2009. Globally there is only one venture fund that invests solely in water technologies and one other that employs a full-time water analyst. Other VCs see water as a minor component of their Cleantech portfolio and demand very high standards of the investee companies before committing funds.

Given this set of circumstances and the scientific and technological expertise that exist in Europe it should be the case that European companies and research organizations can benefit from the current situation. This Thematic Report will examine the drivers for and barriers to innovation, specifically in respect of water, and give examples of existing mechanisms to promote technological innovation, along with brief case studies of successful organizations.

Key Trends and Targets

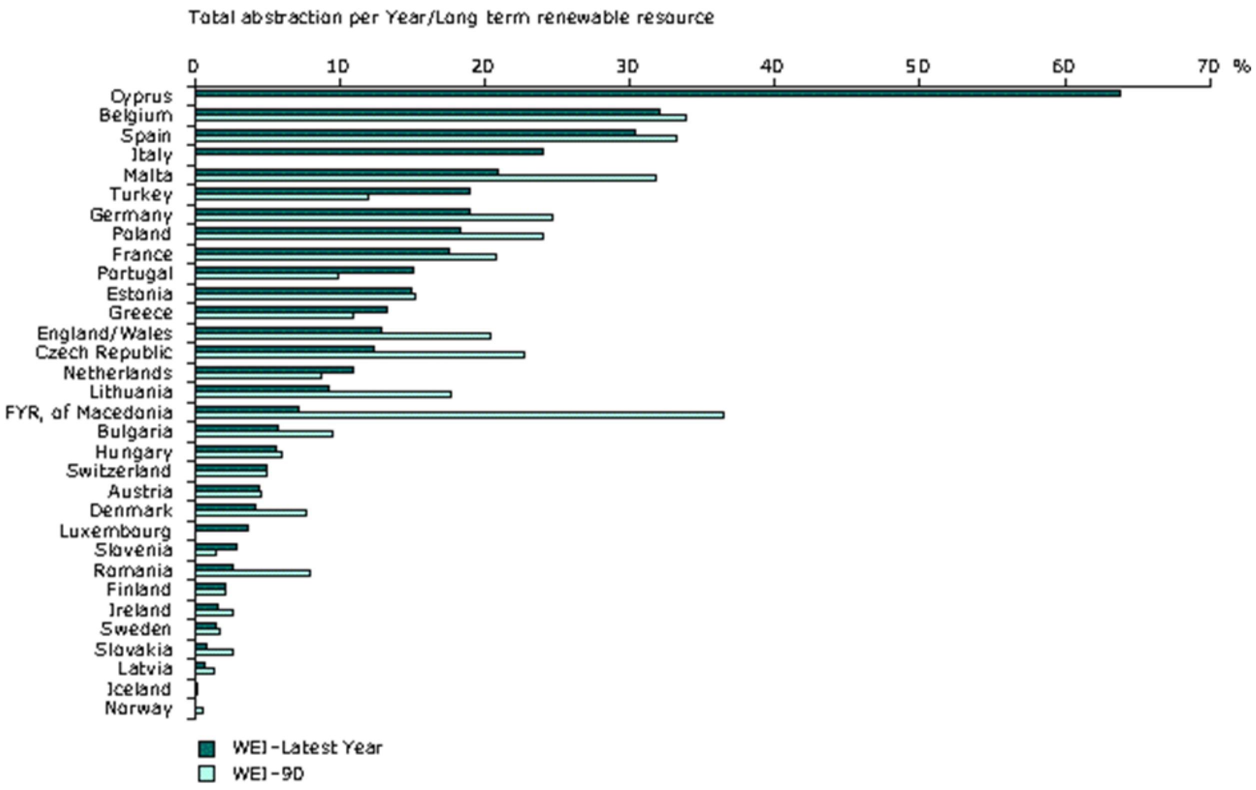
Empirical evidence shows that the quantity of freshwater use in Europe has become increasingly problematic (EEA, 2009). Over the past thirty years, droughts have dramatically increased in number and intensity in the EU. The number of areas and people affected by droughts went up by almost 20% between 1976 and 2006 (European Commission, 2007). For a rough estimate of water stress the European Environment Agency (EEA) uses the so-called Water Exploitation Index (WEI; EEA, 2003, updated 2010) which compares available freshwater sources with actually extracted amounts of water. Closely related is the Water Consumption Index which only takes into account the amount of water which is retrieved from but not returned to the system.

Figure 1 shows a comparison of European countries with regard to WEI between 1990 and the latest year available 1998-2007).

The chart shows that various countries reach the water scarcity threshold of 20% as defined by the EEA (see section 3.5.1). Cyprus has the highest ratio of water abstraction per available total freshwater resources (~64 %). Any ratio above 100% would mean that water demand has to be satisfied through withdrawals from non-renewable sources, non-freshwater sources (like desalinated water) or through imports.

In the OECD in general, water is mostly being used in sustainable ways at the national level. However, most OECD countries still face at least seasonal or local water quantity problems and several have extensive arid or semi-arid regions where water is a constraint to sustainable development and to the environmental sustainability of agriculture (OECD, 2004). In the EU, water scarcity is also manifested through increasing external water resources dependency (even EU countries that do not have an image of being water-scarce, such as the UK, Belgium, the Netherlands, Germany and Denmark, have a high virtual water import dependency) (Hoekstra, 2006).

Figure 1 | Annual total water abstraction as a percentage of available long-term freshwater resources around 1990 (WEI-90) compared to latest year available (1998–2007) (WEI-Latest Year)



Source: EEA, 2010

Increased water use that contributes to water scarcity is mainly driven by population growth, higher incomes, and changing lifestyles. In turn, these drivers lead to an increased global demand for food and feed, biofuels and other industrial uses of crops and biomass (thus increasing demand for water in agriculture). Furthermore, demand for services that require more water (toilets, washing machines, golf courses) increases, as well as pollution and climate change linked to economic activities. In its new report "European environment — state and outlook 2010" (EEA, 2010) the European Environment Agency estimates that by 2030, under an average economic growth scenario and assuming no efficiency gains, annual global water requirement will increase from 4,500 billion m3 to 6,900 billion m3, more than 40 % above current accessible reliable supply. An important economic driver behind this increasing demand is the price of water, which is often only a small fraction of what it actually costs to extract water, deliver it to users, and treat it after its use.

Performance

The organization and representation of water usage data is becoming a higher priority activity at different levels around the world however to date there is little commonality between countries and a number of projects and programmes exist which aim towards advancing methods by which economic-environmental analysis can be applied in the field of water.

Part of the problem in formalizing accounting methods is the quality of the data available. Thus while there are many datasets available work is still required in order to standardize the format and representation of the numbers that are generated, thereby ensuring accuracy and avoiding misinterpretation.

Part of the process will be to decide on how to take account of the water embodied in products, often termed ‘virtual water’. The concept of the Water Footprint has been invoked to fill this gap in knowledge and thereby relate water consumption to material use. Only with a rigorous and accurate system of accounting for water use can eco-innovation in respect of water be judged.

Key Challenges

Because water is so ubiquitous it is useful to consider key challenges in respect of the different dimensions of the water cycle. Thus we may look at the pressures on resources and how we maximize the use of what water is available. Low cost, low energy desalination is therefore a key challenge, as is the prevention of diffuse pollution and quality deterioration in large water bodies as a result of climate change. Much innovation is required in the area of treatment of water so as to use less energy and fewer chemicals. Once water has been sustainably treated to an acceptable standard the manner of its distribution must be tackled so as to minimize energy for pumping and to detect and prevent leakage, thereby saving energy and chemicals as well as water. Often the most visible element of the water cycle, that of usage requires innovation in order to devise low/no water industrial processes, rainwater harvesting and ‘grey water’ use and efficient irrigation, together with policy and regulatory innovation to address demand. Innovation in that often-overlooked sector of wastewater will allow Europe to recover resources and energy from effluent, use less energy and chemicals and reduce the infrastructure demand, whilst generating ‘secondary water’ of a quality sufficient for non-potable (or possibly even potable) uses.

The report details a number of newly-deployed or still-developing technological innovations that address each of these challenges.

Global Dimensions

While the pressures on water in Europe are not insignificant, in other parts of the world there are more immediate and severe constraints and it is clear that water is becoming one of the most important issues of our time. Countries such as Israel and Singapore, with very high levels of water stress and reliance on neighbour states have made great investments in the support of innovation in respect of water. Consequentially they have seen a growth in exports associated with water technology and also attract inward investment in their advanced research and development facilities dedicated to water. There is a potentially enormous market for products that reduce the pressures on water resources and it is important that EU countries are facilitated in their entry to that market. The mechanisms by which water-based innovation is encouraged in Europe and beyond are explored.

Driving Eco-Innovation in the Water Sector

The drivers for and barriers to eco-innovation in respect of water are explored from different perspectives. Using the findings of the Euro Barometer it is shown that those companies in the industry sector that includes water and waste water cite the key drivers as current high energy prices, expected future high energy prices and access to subsidies and fiscal incentives. The same survey revealed that those same companies considered the main barriers to innovation to be uncertain demand from the market, lack of funds in the enterprise and lack of incentives provided by existing regulations and structures.

The prevalence of below-full-cost pricing of water, regulation, ownership and governance and absence of market competition are seen as deterrents to innovate and illustrate the special nature of water as a common good as well as a commodity.

Borrowing from marketing theory, the PESTEL framework is used as a lens through which to analyse the water sector barriers to and drivers of eco-innovation. This illustrates how multi-dimensional the issue is and offers concise targets for intervention to help stimulate innovation.

The generic innovation policy measure taxonomy as applied to water eco-innovation reveals the mechanisms by which different effects might be stimulated using both supply-side and demand-side focused policies to influence the development and uptake of technologies and behaviours. This illustrates the importance of non-technological innovation, such as targeted grants, tax breaks, procurement standards and regulations in the promotion of innovation.

A variety of initiatives, from across Europe and from non-European countries to encourage eco-innovation specifically in relation to water, is explored. It is apparent that there are many different formats of support and intervention but the relative merits of the alternatives are not clear and further study of the effectiveness of the different models is encouraged so as to identify best-practice.

Future Outlook: Visions of sustainable water innovation

In order to set the eco-innovations in respect of water in context, the water status of Europe in 2050 is envisaged. The vision is largely positive and is presented as a snapshot of the future situation with indications of how that future was arrived at. The 2030 Water Resource Group estimates that in 20 years there will be a 40% deficit in water resources when the currently available sources are compared with the projected demand. Current rates of efficiency gains are insufficient to close that resource gap and so it is necessary to invoke radical innovation.

In the vision, based on a projected population roughly equivalent to the present and accounting for climate change there is somewhat less fresh water available however advances in desalination mean that irrigation using seawater in coastal zones is economically viable, reducing the stress on rivers, lakes and aquifers. Efficient irrigation and the development of glasshouses with advanced water management further alleviates the demands placed on freshwater. Still in the realms of agriculture, the continued prevalence of a meat-based diet and demand from outside the EU for good quality meat means that large quantities of water are used to grow feed crops and process meat that is exported, along with a ‘virtual water’ component, thus offsetting, to a degree, the gains made elsewhere.

Water treatment has been revolutionized by multivariate and pervasive real-time monitoring and control and the development of nano-membranes such that much less energy and chemicals are consumed. Through the promotion of water-efficient appliances, water re-use, rainfall harvesting and lifestyle changes brought about by metering and education it is necessary to treat much less water.

The water that is treated to potable standard is distributed via a renovated pipe network in which leakage has been reduced to less than 5% and energy used to generate pressure in the system is recovered as electricity which is fed into the grid. Full-cost pricing, metering and a wide range of domestic appliances that use little or no water, coupled with low and no-water industrial processes whose development has been stimulated through a variety of policy measures mean that much less water is used per-capita. Post-use, the effluent is collected in exclusively foul-water sewers such that it is not diluted by drainage and the novel technologies that have again been developed with the benefit of regulatory and financial incentives mean that it is considered a resource from which are recovered phosphates and nitrates, low-grade heat energy and metals, before the resulting sludge is co-mingled with other biological wastes and used to generate high-quality gas for use on-site to make the facility energy neutral while the excess is exported off-site or fed into generators for energy to be used locally.

The final effluent from the wastewater treatment is of such high quality that it is used directly for some applications and on being returned to the environment is instrumental in making Europe compliant with the objectives of the Water Framework Directive.

Findings

The main findings of the report are summarised in ten key messages and recommendations are made for priority actions as follows:

- Introduce full-cost pricing for water such that its true value as an economic resource is recognized widely throughout industry and society, for which it will also be necessary to;
- Engage public opinion. Make the visibility of water consumption greater, through the widespread use of information campaigns and metering of domestic properties.
- Focus measures to foster innovation activity on those industry sectors where the largest impacts can be achieved.
- Examine the water footprints of major European imports to determine where there are supply-chain vulnerabilities, which might usefully be addressed through innovation in respect of water. Engage with the agenda on the life cycle water footprint labelling of products.
- Review the European policy landscape in respect of measures encouraging water innovation, with a view to publishing a guide for legislators.
- Study carefully those initiatives (both in Europe and beyond) that have demonstrated success in stimulating innovation in the area of water technology and use so as to develop best-practice solutions for implementation in the EU.

1 | Water eco-innovation: using water better

Water is a critical resource for all societies and a combination of climate change, population growth, increased urbanization and dietary shift poses a challenge for countries around the world to manage precious and limited fresh water resources. This challenge represents a significant opportunity for the development of technology and new organisational and management solutions in addition to legislative responses.

In addition, the urgent need for Innovation in respect of water may be linked to the general need for resource efficiency, which is a European Union “Flagship” (European Commission, 2010)

This report considers how water is used, how it is accounted for and looks at the enablers of and barriers to innovation in the area of water use. It looks at key areas for development, and examines existing initiatives to promote or support innovation; both within Europe and beyond. Case studies are given which illustrate a variety of different aspects of the water cycle in which there is scope for innovative responses to existing problems. There are many different forms of initiatives in the area, including government funding, public-private partnering, purely private supply-chain networks and competitions. They are driven by increased public and governmental awareness of the potential risks associated with water scarcity, the water-energy nexus and the emerging area of corporate water risk which is leading investors to ask questions of corporations with significant exposure to water.

The report incorporates a view of the future based on the adoption of innovative technological and process developments around water. This section references the European Vision for Water (www.ewp.eu), which is now a widely accepted approach to work towards a sustainable use of water in 2030 and is endorsed by the EU DG Environment.

There appear to be ‘hotspots’ of innovation activity around water, notably Singapore and Israel. According to the report ‘Charting our Water Future’ by the 2030 Water Resources Group (World Water Council, 2009);

“Singapore aims to increase value-added contribution from the water sector by over 300 percent in less than 12 years, generating roughly 11,000 professional and skilled jobs by 2015. Israel has laid the groundwork for increased investment in water management technologies: its irrigation technology is best-in-class, and there are over 250 businesses that deal specifically with water technologies, exporting $1.4 billion worth of goods in 2008.”

It could be argued that innovation in the water sector to date has been mostly by means of incremental improvement, when compared to other sectors (e.g. ICT, Mobility) and that there is a requirement for more impactful developments in short term.

The objective of the report is to identify areas of potential growth and recommend how European innovators might best be enabled in developing the solutions of the future. The report is based upon research into currently-operating support mechanisms, both within Europe and elsewhere, combined with the Horizon Scanning exercise undertaken by the Finnish Futures Research Centre as part of the Eco Innovation Observatory project. In order to set the likely innovations in context the report includes a ‘Visions of 2050’ section.

Because water is so all-pervasive and is integral to every aspect of human activity it has been necessary to constrain the scope of the report to those innovations that have water as their primary focus, although reference is made to those areas where significant water savings might be effected as a result of other activity. It does not deal with hydropower or dwell at any length on agriculture, in spite of the great significance of these areas of research and the amount of effort being expended on them at the current time. Thus it is acknowledged that a great deal of work is being undertaken globally to breed drought-resistant crops and plant variants that are tolerant of brackish water but these are given only passing mention since it was necessary to draw boundaries around the subject, however arbitrary.

This report is an output from the Eco Innovation Observatory. As such the emphasis is not on water-saving measures per-se, which might encompass economic (e.g. taxation) and cultural (e.g. dietary changes) solutions. Rather the report concentrates on how generic influences on the process of Eco Innovation apply to the water sector and what specific influences there are, that are peculiar to water. Nevertheless it is important to recognise that innovation can be considered as applying to both demand-side and supply-side and that both have a place in promoting sustainable water resource management. This concept is a particularly important one and is central to EU COM 2007 (414) on water scarcity and droughts, which emphasises the need always to act on the demand side before addressing the supply-side of innovation. Technology alone will not address the issues but has an important role to play in the hierarchy of responses: first, use less; second, use it differently; third, reuse it; fourth, treat it differently. At each of these stages there is scope for both policy and technology innovation.

The report has been structured so as to introduce the generic challenges of water management and accounting, highlight specific issues facing the sector and the requirement for solutions to address those challenges and introduce concrete examples of novel technologies developed in response to those issues. The report then considers examples of European initiatives to promote eco-innovation in the water sector, along with country-specific initiatives and non-European examples. The drivers of and barriers to innovation are explored in the context of water and the future examined through the lens of broadly implemented innovation.

2 | Global context, challenges and trends

2.1 | Global issues in water use

2.1.1 | Key trends

Water is a vital resource. From an anthropogenic point of view water is essential not only for direct uses such as for the provision of drinking water, growing food, and the production of energy and other products, but also for ensuring the integrity of ecosystems and the goods and services they provide to humans. However, although freshwater is a renewable resource, its annual availability is limited. Annual freshwater use in many places exceeds the limit of the available water, which has resulted in river flows that are below environmental flow requirements (World Water Assessment Programme, 2009), declining groundwater levels and pollution of water bodies. A national or river basin strategy to combat those problems has shown to be insufficient to ensure secure provision of freshwater for everybody.

It is thus becoming increasingly important to put freshwater issues in a global context and to account for the interdependence of economic, environmental and social issues, even more so, as local water depletion and pollution are often closely tied to the structure of the global economy. With increasing trade between nations and continents, water is more frequently used to produce exported goods. International trade in commodities implies long-distance transfers of water in virtual form, where virtual water is understood as the volume of water that has been used to produce a commodity and that is thus embedded in it. Knowledge about the virtual water flows entering and leaving a country can cast a completely new light on the actual water scarcity of a country.

The concept of virtual water is a fine instrument for awareness raising, and to help policy makers to realize whether some choices are good ones, or whether better choices can be made in respect of water resource stewardship. However the real benefit of the application of the concept can be achieved only if the findings are somehow connected with economic / price effects, i.e. with drivers to change. Water accountancy activities help to address water resource issues in a more concrete way but accountancy is only the start of this process and is useless if not followed by improvement measures.

According to the Communication from the Commission to the European Parliament and the Council - Addressing the challenge of water scarcity and droughts in the European Union, while "drought" means a temporary decrease in water availability due for instance to rainfall deficiency, "water scarcity" means that water demand exceeds the water resources exploitable under sustainable conditions. Droughts are localised and temporal phenomena as water availability can vary during one year and between different regions within a country (Yang et al., 2003). The long-term imbalance resulting from water demand in excess of available water resources is no longer uncommon. At least 11% of the European population and 17% of its territory have been affected by water scarcity to date. Recent trends show a significant extension of water scarcity across Europe. Countries in the Mediterranean, as well as regions with intensive agricultural production, often face temporal water scarcity. But even some rivers in the UK are at long-term risk of drying out (WWF, 2010). The European Commission expects further deterioration of the water situation in Europe if temperatures keep rising due to climate change. Thus, water is no longer the problem of a few regions, but will concern an increasing share of the European population.

Outside the EU, limits have already been reached or breached in several river basins that are now “closed” because people have used all the water, leaving just an inadequate trickle for the ecosystem. Examples include important breadbaskets around the Colorado River in the United States, the Indus River in southern Asia, the Yellow River in China, the Jordan River in the Middle East, and the Murray Darling River in Australia (Molden et al., 2007). In the more arid regions of the world, water scarcity has become the single greatest threat to food security, human health and natural ecosystems (Seckler et al., 1999).

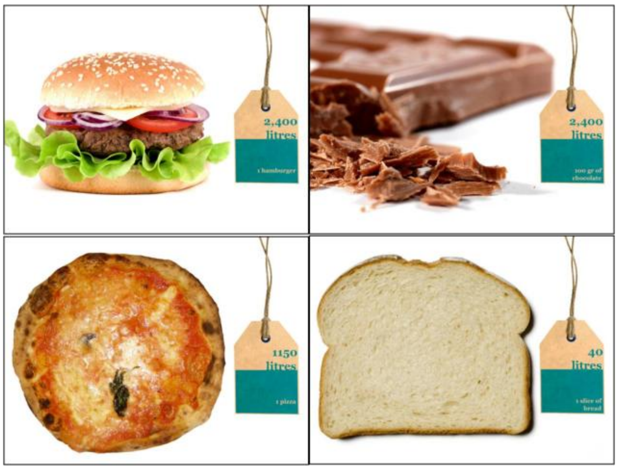
Remarking on these issues, the Chairman of the European Water Partnership, Tom Vereijken, recently observed that research has shown water consumption can be reduced by 40% with relatively easy measures. Focus on these easy measures; in policy making and awareness-raising, will require significant effort but will result in great water savings. From the perspective of those trying to encourage Eco-Innovation this observation may appear to be a negative one, however through increased awareness of the issues around water scarcity the willingness to adopt technologies that further reduce demand will be heightened. The point serves to illustrate that the problem of water constraints will be addressed through a variety of approaches: technological, social and political/legislative.

2.1.2 | Drivers of water demand

Water demand is driven by various economic and human activities, including the demand from households, industry, agriculture, the energy sector, urban amenities, tourism, etc. The quantity of freshwater used per capita is directly related to individual and industrial water consumption patterns (EUROSTAT, 2004).

Increased water use that contributes to water scarcity is mainly driven by population growth, higher incomes, and changing lifestyles. In turn, these drivers lead to an increased global demand for food and feed, biofuels and other industrial uses of crops and biomass (thus increasing demand for water in agriculture). Furthermore, demand for services that require more water (toilets, washing machines, golf courses) increases, as well as pollution and climate change linked to economic activities (Rosegrant et al., 2002; WRI and Rabobank, 2008; Yang et al., 2003). Figure 2 shows the water footprints of different products to illustrate the impacts brought about by a change in consumption habits.

Figure 2 | Water footprints of different food products



Source: Hoekstra and Chapagain, 2008

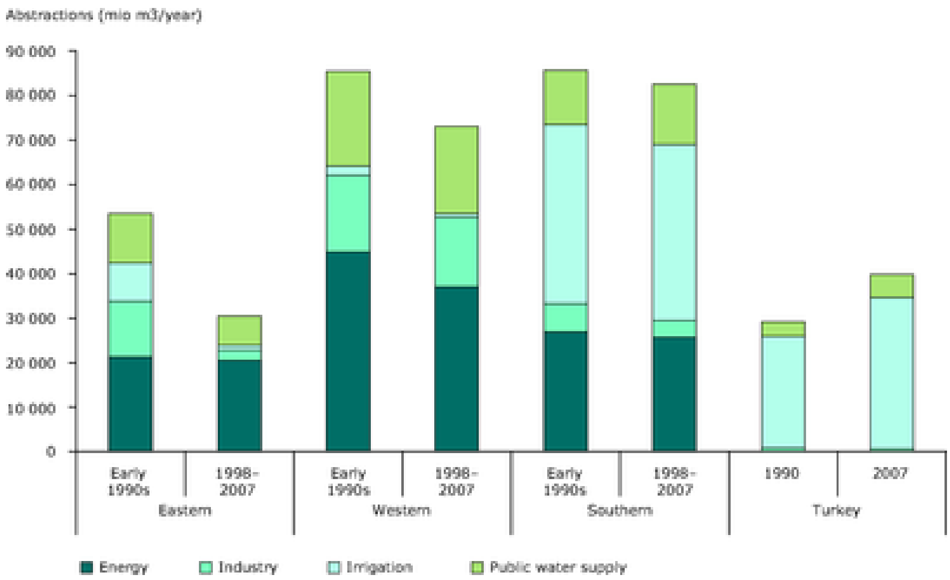
In its new report "European environment — state and outlook 2010" (EEA, 2010) the European Environment Agency estimates that by 2030, under an average economic growth scenario and assuming no efficiency gains, annual global water requirement will increase from 4,500 billion m3 to 6,900 billion m3, more than 40 % above current accessible reliable supply. These estimates include return flows, and take into account that a portion of supply should be reserved for environmental requirements. Agriculture is the biggest consumer of water. While this sector currently accounts for about 3,100 billion m3 of global water abstraction per year, without efficiency gains this demand will increase to 4,500 billion m3 by 2030. Further the estimates foresee an increase in industrial abstraction of almost 100%, and in domestic abstraction of 50 % over the next 20 years.

Interestingly, the historic rate of efficiency improvement in agricultural and industrial water use is approximately only 1% per year. Assuming that this rate is not increased in the next decades, improvements in water efficiency would meet only 20% of the supply-demand gap. These data clearly underline the necessity to foster eco-innovation initiatives, in order to ensure future supply not only for agriculture and industry but also and most important of drinking water.

An important economic driver behind this increasing demand is the price of water, which is often only a small fraction of what it actually costs to extract water, deliver it to users, and treat it after its use. One reason for this is that countries often subsidize water, especially for agricultural use. Even without subsidies, in the majority of the cases water prices do not reflect the true external costs. A more political cause of water problems is inadequate institutions (policies, laws, and organizations that influence how water is managed) (Molden et al., 2007). It is worth noting that the problem of pricing has been recognized and the Water Framework Directive, the most far-reaching and adventurous piece of European legislation relating to water, mandates that all EU countries must work towards full-cost pricing of water.

The main sectoral drivers for the increased water consumption that contributes directly to water scarcity are an increasing abstraction for energy production, agriculture, public water supply and industry (Rosegrant et al., 2002; Yang et al., 2003). On average in the EU, energy production accounts for 44% of total water abstraction, primarily (more than half of the 44%) serving as cooling water (~24% of total water abstraction); 24% of abstracted water is used in agriculture; 21% for public water supply and 11% for industrial purposes. However, these averages conceal strong regional and temporal differences as water demand can vary strongly by region and season (see Figure 3; EEA, 2009). In southern Europe, for example, agriculture accounts for more than half of total national abstraction, rising to more than 80% in some regions, while in Western Europe more than half of water abstracted goes to energy production as cooling water.

Figure 3 | Sources of freshwater abstraction by sector - European average numbers (million m³/year)

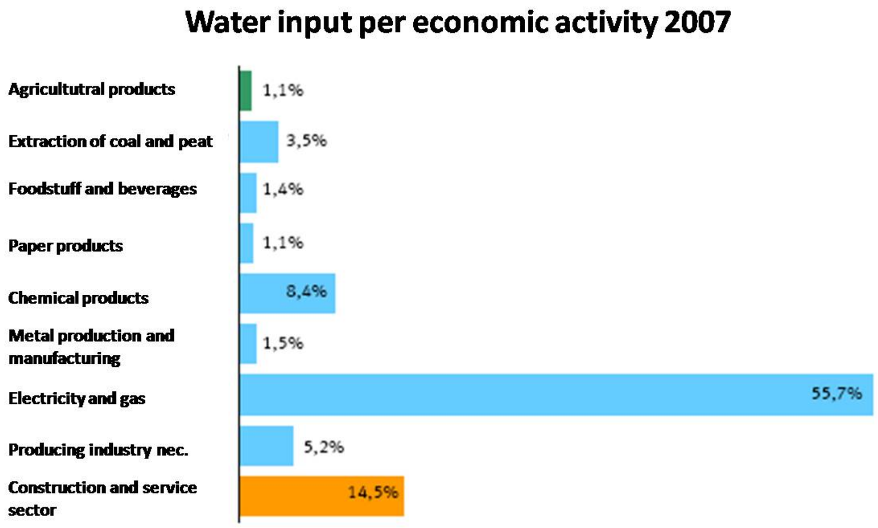


Source: EEA, 2010

Figure 4 shows water input numbers for the German economy in 2007. The total water input in all economic activities accounts for 92% of the total water input (8% goes into domestic uses). The main user of water is the electricity and gas sector where water is used for cooling purposes. 14.5% of the water input is appropriated by the construction and service sector, followed by the chemical industry (8.4%).

Much smaller water inputs flow into the metal industries (1.5%), food and beverages industries (1.4%) and agriculture (1.1%). These numbers underline that Germany is far below the EU average in terms of water input for agriculture.

Figure 4 | Water input per economic activity in the German economy in 2007



Source: Statistisches Bundesamt, 2010

3.1.3 | Relating water use to material use

Setting water use into relation to material use is not trivial; as for the majority of the products water is needed in one or more phases of the production chain of the final product or its input products. Not surprisingly, it is not possible to directly relate current material use trends with water use trends.

While the calculation of the water footprint (i.e. its virtual water content) of an agricultural product is relatively straight forward, the calculation for further processed products becomes more challenging, as in the most complex cases the processing of a number of input products results in a number of output products. Methodologically, if during processing there is some water use involved, the process water footprint is added to the water footprints of the input products before the total is distributed over the various output products (Hoekstra et al., 2009).

Hence, it becomes self-evident that in the production of goods water can be saved in two ways: by making the processes in the production chain less water-intensive as well as by using materials for the processing of which water is needed more efficient, as with decreasing material input also processing water input will decrease. Moreover, as more goods are made from recycled materials the requirement for water in the manufacture of virgin material will decrease, as will the energy generation to produce those raw materials.

In Mediterranean countries, seasonal tourism regularly inflates the population, adding extra pressure to already scarce water resources. However, available per-capita figures on water abstraction for those countries with a large tourist industry are below the EU average, as they are calculated using the normal population of the country, and do not include the massive influx of tourists each year (EUROSTAT, 2004).

Energy production, agriculture and industrial production also differ significantly in their 'consumptive' use of water. Almost all cooling water used in energy production is re-used or else restored to a water body, while the consumption of water through crop growth and evaporation typically means that only about a third of water abstracted for agriculture is returned (EEA, 2009). However, also the restored cooling water has an impact on the environment as it increases the temperature of the receiving water body and consequently changes habitat properties.

It is worth noting that the way in which electricity is generated has an impact on the amount of water consumed. A study by the US Electric Power Research Institute (EPRI, 2006) detailed the differing power generation technologies (fossil fuels, biomass, natural gas, nuclear) and the differing cooling mechanisms (closed cycle, once-through) and from those figures it is apparent that electricity produced by nuclear generation consumes 30-50% more water (water lost to evaporation from the cooling system) than fossil fuel-generated electricity (coal and oil) and roughly four times as much as electricity from natural gas-fired power stations. As such the energy mix of a future Europe will have significant implications for water resource husbandry. Those nations reliant on nuclear power will consume a great deal more water than those using natural gas or alternative energy supplies such as wind, tidal, solar or energy derived from waste materials. The ongoing replacement of older once-through systems with more advanced cooling technology, including recirculation, dry and hybrid systems is likely to drive further reductions in abstraction for energy production in the future (EEA, 2009).

2.2 | Evolving water metrics

2.1.1 | Established measurements

Water accounting – the organisation and representation of statistical water data – is gaining increasing attention within national and international (statistical) institutions around the world. The use of water is an issue with increasing policy relevance, and water accounts have already been included in some statistical systems at the national level (Olsen, 2003; Statistisches Bundesamt, 2008). These statistics mostly represent the domestic uptake of water.

In the European Union there are two, partly related, initiatives:

- The accounting requirements determined in the Water Framework Directive (European Parliament, 2000) which include specifications mainly relating to water quality data at the river basin level (the aim is to reach the good ecological status of all water bodies by 2015);

- An initiative to set up improved water accounts for EU countries pushed by Eurostat, in accordance with the EEA, National Statistical Institutes (NSIs), as well as international organisations such as the OECD as a part of the European Strategy for Environmental Accounting (ESEA; EUROSTAT, 2003). Thereby, Eurostat is developing a new set of standard water accounting tables to ensure internationally comprehensive and comparable data collection. Eurostat decided to focus efforts first on the development of physical flow accounts and to use a framework of sectoral disaggregation, so-called physical Supply and Use tables (PSUTs) constituting the most suitable conceptual approach to record all water flows entering, flowing within, or leaving the economy in a consistent way. Such an initiative is of great relevance as it also ensures a higher degree of sectoral disaggregation of the water use data, which allows for the identification of especially water-intensive sectors. Ideally, data on water abstraction for the agricultural sector can then be further broken down into different sub-sectors.

Moreover, DG Research is funding various FP6 and FP7 projects, which aim at advancing methods in the field of economic-environmental analysis, which can also be applied for the water field. The EXIOPOL project (www.feem-project.net/exiopol) has been the first comprehensive approach of combining economic and environmental data in one framework (a so-called "environmentally extended multi-regional input-output" model – EE-MRIO). The EE-MRIO approach is improved, data sets created, revised and extended, and questions of current political relevance answered within many related projects such as FORWAST (http://www.forwast.brgm.fr), WIOD (http://www.wiod.org), OPEN:EU (www.oneplaneteconomynetwork.net), CREEA, etc. An additional advantage of such approaches is that, given comprehensive data of reasonable quality, it is possible to calculate key indicators which enable to evaluate the performance of different sectors, countries or regions, and to develop specific targets at which future actions or policies have to aim. In the water field such indicators could be, for instance, water use/consumption per GVA (gross value added) or water use/consumption per production output.

At the international level, the System of Environmental-Economic Accounting for Water (SEEA-W) prepared by the United Nations Statistics Division (United Nations, 2007) is broadly the equivalent to European initiatives. The SEEA-W was developed as a response to increasing policy interest in the area of sustainable water use, methodological advances and growing experience on the level of national statistical institutes.

Following statistics of the UN, currently about 25 countries have implemented (part of) water accounts: 17 developed countries (Australia, New Zealand and 14 EU countries) and eight developing countries (Botswana, Chile, Mexico, Namibia, the Philippines, South Africa, Turkey, the Republic of Moldova) are implementing the SEEA-W, while three others have established the institutional arrangements for the project (China, Dominican Republic, Morocco). The expertise on water accounts gained in these countries, and especially in the European countries is very valuable for further work in this area.

At the international level, the AQUASTAT database (FAO, 2010) is the best available water data source. As in the case of the data on water use, data are available per 5-year period and show the most recent year data in each period for each variable. Despite the wide area coverage and long time series (1960-2010), the AQUASTAT database on water use still has significant data gaps, and there is a large potential (and, it might be argued, urgency) for improvement regarding more detailed data.

The large amount of data on water usage enables a high-level analysis of water stress and availability. This informs legislation and policy directing research funding towards sectors with the potential for large savings. The concept of water accounting, however, has yet to be embraced and the calculation methods standardised, to avoid misinterpretation and to improve the accuracy of the numbers that are generated. Moves in this direction are being made by the yet-to-be-formalised International Council on Water Stewardship though it should be noted there are a number of such initiatives globally. In developing a voluntary code of practice which can be applied outside a legislative framework it is likely that the uptake of the concept will be enhanced. Rather than legislative compliance the engagement with water accounting and water stewardship will be for a practical end and therefore more readily accepted by business, in a similar way to the reporting of (reductions in) carbon emissions. Such policy signals can indicate to innovators where future markets may lie but do not necessarily create the conditions to support innovation or overcome barriers to technology development.

2.2.2 | Virtual water and water footprinting

Indicators such as the WEI are practical in terms of data availability; however, they do not take into account very important aspects such as real water consumption, water embodied in products (which had been used along the production chain) or the difference between "blue" and "green" water (see below). The Water Footprint fills this gap, and shall be described in the following section. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce[1] the goods and services consumed by a person or a community or produced by a company (Hoekstra and Chapagain, 2008). The concept is based on the concept of “virtual water” developed by Tony Allan, which measures the amount of water embedded in the production and trade of food and consumer products (Allan, 1993). Allan argues that the rule of comparative advantage could also be applied in the context of water-rich or water–poor countries. This means that countries which face water stress should apply a strategy in which the focus is set on the import of water-intensive products (and at the same time reduce the domestic production of such products) while water-rich countries should use this advantage and export especially water-intensive products. Thereby, the footprint concept takes into account the water actually consumed (input minus output) throughout a production process.

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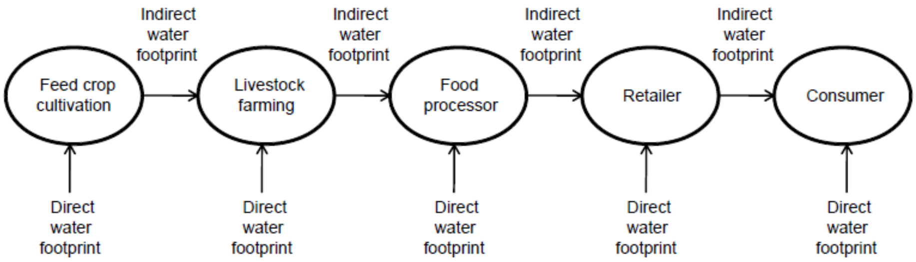
[1] *In contrast to other approaches like “water intensity” or the “water rucksack” where the whole water abstracted for a production process is taken account of (disregarding the amount of water returned to the system).*

The water footprint of a nation is defined as the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation (Hoekstra and Chapagain, 2007, 2008). The total water footprint of a country includes two components: the part of the footprint that falls inside the country (internal water footprint) and the part of the footprint that impacts on other countries in the world (external water footprint). The external water footprint of a country is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country considered. The water footprint is a quantitative measure of the amount of water consumed. It breaks down into three components: the blue, green and grey water footprint. 'Blue water' is freshwater taken from surface water and groundwater. 'Green water' is water stored in the soil as soil moisture and evaporated by plants. 'Grey water' is water that is polluted as a result of the production goods; calculated as the volume of freshwater that is no longer available to assimilate further loads of pollutants without violating ambient water quality standards.

The water accounting framework allows for national water accounts but can also be used at lower spatial levels. For several countries, elaborate water footprint accounts are now available. In Europe these are the Netherlands (van Oel et al., 2009), UK (Chapagain and Orr, 2008) and Germany (Sonnenberg, 2009). The framework allows for water accounting along supply-chains. Figure 5 gives an example of how this looks like for the case of an animal product.

Figure 5 | The direct and indirect water footprint in each stage of the supply chain of an animal product



Source: Hoekstra et al., 2009

Depending on the scale and question to be answered with this concept, data requirements, quality and availability vary considerably. The calculation of the water footprint of a specific product such as, for instance, a bottle of alcoholic or non-alcoholic beverage (Ercin et al., 2009; Hoekstra et al., 2009; SAB Miller and WWF, 2009) requires detailed information concerning the water quantities used in the supply chain as well as in the production itself (hence the distinction between the "supply chain water footprint" and the "operational water footprint"). Thus, the effort for such a calculation is very high and there is a great need for standardised concepts to properly calculate numbers that can be compared on a like-for-like basis. This would also avoid the unintentional misuse of the concept.

Water Footprint Dataset

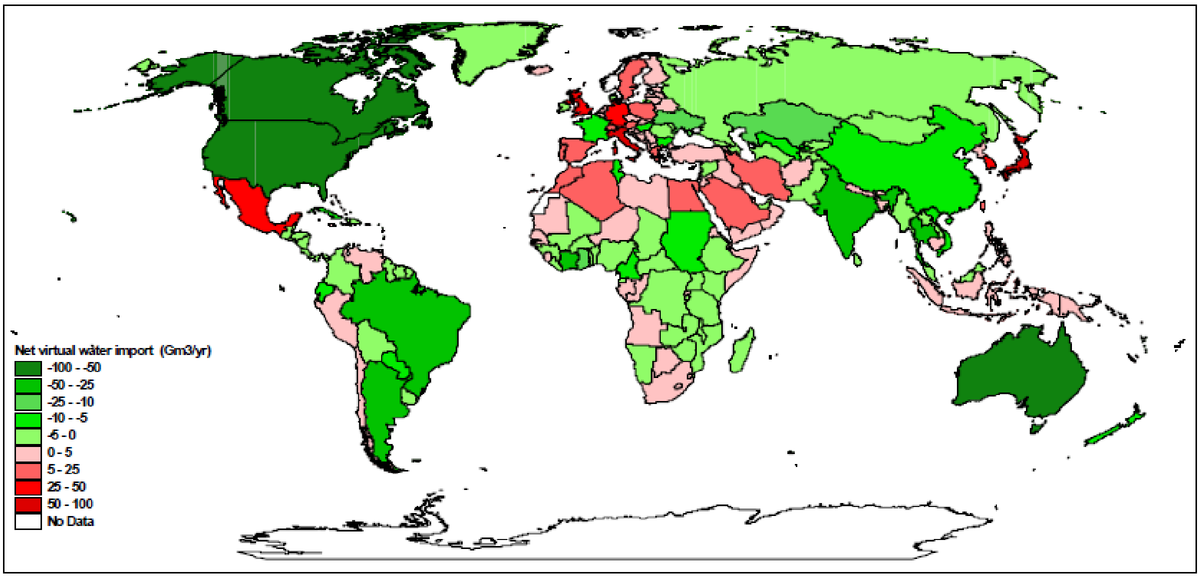
By the time of writing, the only available world-wide water footprint datasets are presented in the study "Water Footprint of Nations" (Chapagain and Hoekstra, 2004). In this study, the authors estimate the virtual water content of agricultural products and livestock products. The agricultural water footprint of 210 nations is calculated broken down into 175 crops for the period 1997-2001 based on the total volume of crop produced and its corresponding virtual water content. Figure 6 shows the resulting national virtual water balances related to the international trade of products for the period 1997-2001.

The majority of the European countries are net importers of water. A consequence of this fact is that these countries are dependent on foreign water resources necessary for the production of goods consumed by the national economy. Chapagain and Hoekstra (2004) define water import dependency of a nation as the ratio of the external water footprint to the total water footprint of a country. The study, however, does not distinguish the above-explained green, blue and grey water footprints and only a crude estimation was used for industrial products. Moreover, country averages of climate variables are used, which is particularly problematic in large countries with both humid and semi-arid areas. A database for the water footprint of products, which covers more recent years and more detailed information (based on regional data rather than national average data), is currently under construction (Mekonnen, pers comm. 2010).

The quantification of the amount of water used along the production chains of products is essential (Lutter et al., forthcoming). The water footprint concept foresees very accurate calculations on the micro level, however due to data availability and practicability reasons on the macro level the current available national water footprint accounts (Chapagain and Hoekstra, 2004) must resort to simplifying assumptions resulting in a loss of accuracy.

It seems unrealistic to expect bottom-up calculated data for all economic sectors. However a standardised and homogenously applied water accounting system could be used, in the future for a comprehensive and reliable calculation of the Water footprint of economic sectors or nations, allowing for the quantification not only of the direct but also of the indirect water inputs as virtual water of the pre-products. Such a presentation of the water data in would enable the clear communication of the “hydrological consequences” of consumption.

Figure 6 | National virtual water balances related to the international trade of products. Period 1997-2001



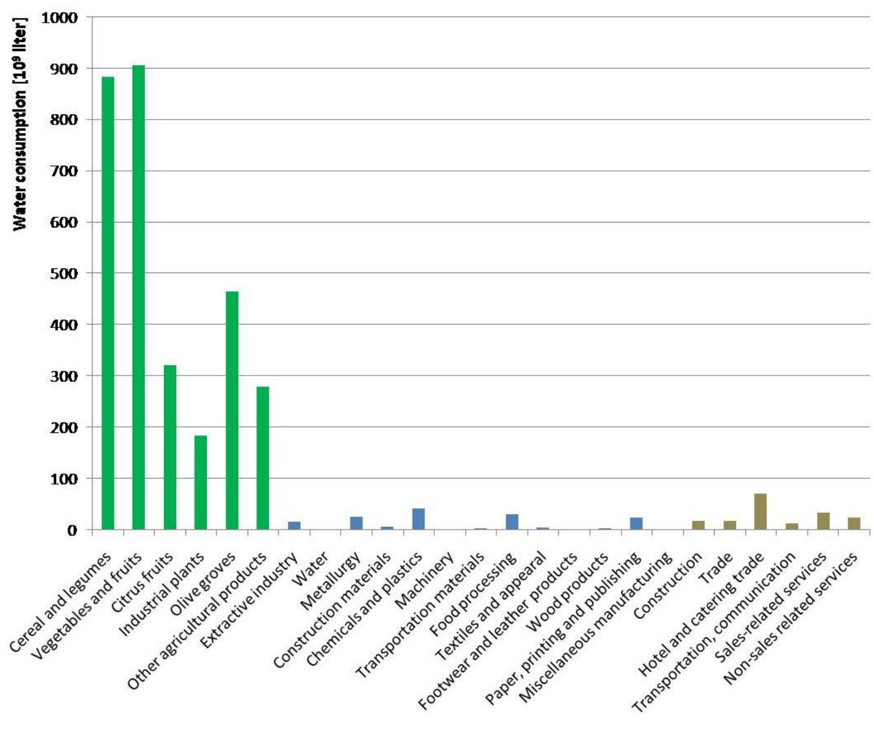
Source: Chapagain and Hoekstra, 2004

So far, the available data is rather sparse and there are only a few countries in the European Union, which produce water accounts of good data quality and with a high level of sectoral disaggregation. Especially in this context the new standard accounting tables developed by Eurostat (cf. chapter 2.2) will play an important role, as they will allow for a more precise analysis of water consumption throughout the different economic sectors.

Velázquez (2006), for example, applied input-output method in the Spanish region of Andalusia to determine which economic sectors consume the largest quantities of water. The model disaggregates 25 economic sectors, six of which are agricultural sectors. Dietzenbacher and Velazquez (2007) showed that a substantial part of water consumption in the Andalusian region is embodied in its exports to other Spanish regions or abroad, despite the substantial level of water scarcity faced in this region and the relatively low share in total added value stemming from the agricultural sector. Figure 7 shows the most water-intensive sectors in the Andalusian economy. 90% of all water consumption takes place in the agricultural cluster. The manufacturing cluster and the services cluster each account for 5% of water consumption.

Researchers work towards a detailed understanding of the ‘flows’ of water into, from and within the European Union. Such an understanding will permit the identification of those products and services that are the largest direct and indirect consumers of water, permitting resources to be directed at the reduction of embodied water, the substitution of those products or mechanisms to reduce their consumption. Although we are some way from that situation, it is evident, at the macro and meso levels, as described above, where innovation has a significant role to play in addressing water consumption, treatment and quality.

Figure 7 | Water consumption per sector in the Andalusian economy in 1996



Source: Dietzenbacher and Velázquez, 2007

2.3 | Key challenges for water eco-innovation

Water eco-innovators face diverse challenges in the areas of securing access, treatment, demand and use as well as disposal of water. New eco-innovative solutions have a potential to respond both to the social and environmental challenges as well as to become a viable business case. A number of these key challenges are briefly described below. The Water Supply and Sanitation Technology Platform (WssTP, 2010) and ACQUEAU have both published priority areas for research and innovation: these have both been taken into consideration in deriving the key challenges presented here.

2.3.1 | Resources

Cost-effective, low energy desalination

Many major cities and areas of high population are located adjacent to coastal regions. There have been well-documented examples of the degradation of coastal aquifers due to over-abstraction, leading to a diminution of the quantity of freshwater available for consumption and irrigation (e.g. Llobregat delta, Barcelona, quoted in Groundwater and Human Development, Emilia M. Bocanegra et al. (2005), Balkema). The advent of truly low-cost desalination technology would enable coastal or near-coastal communities to make use of the abundance of water (sea-water) available locally.

Diffuse pollution

Large-scale agriculture often gives rise to the deterioration of raw-water quality due to the leaching of nutrients, pesticides and herbicides, soil compaction by cattle and faecal contamination from livestock. These lead to the requirement for more extensive treatment at the water-supply works, demanding greater infrastructure, energy and chemical inputs. The appropriate management of catchments and farming practices can lead to large improvements in natural water quality with attendant cost savings. More difficult to manage out of the system are endocrine disrupting chemicals, often derived from hormone replacement products, oral contraceptives and other medicines. These demand ever greater sophistication in water treatment technologies; often based around membranes which are both expensive to procure and require high levels of maintenance.

Anoxic water bodies, algal blooms, manganese mobilization etc.

With the rise in temperature predicted by climate change it is likely that the development of algal blooms and anoxic conditions in lakes and reservoirs will increase. These conditions can take water bodies out of supply and result in the release of metals, such as manganese, from sediments into solution, requiring higher levels of treatment before the water can be distributed. The oxygenation of large water bodies by low-energy means will therefore be an important technology.

2.3.2 | Treatment

Real-time network monitoring and management

Water treatment and distribution systems are complex and multi-variate in nature. The development of low-cost, distributed monitoring networks, integrated with smart systems for measuring and adjusting parameters such as chemical dosing, flow and pumping rates, leakage detection etc. will permit the optimization of energy usage and other inputs.

Low-pressure, self-cleaning, chemical-free membrane systems

The use of membranes for the removal of fine particles and micro-organisms is common. Some membranes can be used for the removal of chemical compounds. There are many issues related to the operation and maintenance of membranes and advances in this area plus the development of 'functionalized' membrane materials offers great scope for savings in energy and chemicals.

Nearly-chemical-free water and wastewater treatment including 'synthetic biology'

Many chemicals could theoretically be removed from the water and wastewater treatment process if it were possible to replace their function by physical or biological means. The use of nanoparticles and 'superbugs' or cultures designed and bred for specific functions offers the prospect of greater efficiencies and reduced environmental impact.

Low energy UV/non-UV disinfection

At present very large amounts of energy are used to disinfect water by means of exposure to Ultra-Violet radiation. The technique, while effective, is also expensive and unsustainable due to the need frequently to replace the UV tubes. Methods to remove the need for UV disinfection or otherwise make it more energy-efficient (such as the use of light emitting diodes (LEDs) instead of traditional UV tubes) offer significant cost, material and energy savings.

2.3.3 | Distribution

Demand-driven distribution

Rather than pressurizing a distribution system to ensure a sufficient flow in all receiving properties, in future networks the use of distributed monitoring infrastructure and control software in combination with localized pumping equipment will allow utilities to supply water at a locally appropriate pressure. Since leakage is highly correlated with pressure, any reduction in pressure will not only save energy but also reduce losses and extend the asset life of pipes and valves. This approach is generally termed Demand-Driven Distribution.

Self-healing pipe materials or other non-invasive pipe repair techniques

Novel pipe materials that are more durable or can self-heal or which make easier the job of leak detection and repair have the scope to reduce the leakage of potable water to the ground. Leakage is a well-documented problem in many countries, with the result that water suppliers use chemicals and energy to treat water to a very high standard before then losing a significant percentage. Similarly, leaking sewerage pipes can result in ground contamination or else increased volumes of sewage being treated, due to ingress of groundwater.

Leakage detection

Even with reduced pressure and self-healing pipes there will be residual losses from older distribution infrastructure and other disturbances, accidental or deliberate. The ability to detect these losses and remediate them in good time will contribute to savings in water, chemicals and energy and extend the life of infrastructure networks.

Recovery of energy from distribution networks

At present much energy that is used to pump water over large distances and against gradients is lost as heat and noise generated by pressure reducing valves (PRVs). If it were possible to replace these with units, which harnessed the energy and transformed it to electric current the utilities operators would be able to recoup some of the costs of the energy and provide small-scale generation on a widespread basis.

2.3.4 | Use

Low / no water industrial processes

Many processes rely on secondary properties of water such as thermal transport (cooling) and kinetic energy (cleaning) that can be provided by other means, e.g. air. When water has been a very low-cost and plentiful input to these processes there has been no reason to look for alternative methods, however this will become more relevant as water becomes more scarce and more expensive. Similarly, those processes such as irrigation, where there is no substitute for water, will need to be less water-intensive.

Point-of-use treatment systems (UV/ozone) grey water, rainwater harvesting

Beyond the abstraction, treatment and distribution of water and the collection and treatment of wastewater there is little scope for utilities providers to effect change in the water sector. Universal metering has been shown to alter the behaviour of consumers and if metering and price signals can be used together to make domestic customers more aware of their water consumption then the market for point-of-use appliances to treat water or re-use 'grey' water will be stimulated.

Irrigation

Although it might reasonably be considered beyond the scope of a report on the water sector and more properly dealt with under 'agriculture', it cannot be ignored that irrigation is a larger consumer of water in Europe than either domestic or industrial uses. Water-efficient irrigation, irrigation on demand and irrigation using brackish water are technologies that will enable the better husbandry of more scarce freshwater resources. Technological developments in respect of irrigation will encompass sensors and communication, intelligent watering systems and high-efficiency delivery mechanisms for water and nutrients, as well as the means of incorporating all of these elements into irrigation 'packages'. A European research project called Desiras (*Addressing Desertification by Efficient Irrigation in Agriculture)*, led by the European Water Partnership, has just begun (February 2011) to develop two demonstration sites, in Cyprus and Spain to enable research and development into such integrated systems, with a view to enabling reductions of up to 45% in the volume of water required to irrigate potatoes, olives and verbena.

Household consumption

There have been many and varied studies into the volume of water used at the individual and household level. A recent OECD report, Greening Household Behaviour (OECD, 2011) on the role of public policy in greening household behaviour detailed the results of a survey with 1600 respondents across Europe, in which it was revealed that, while price-elasticity varies according to income, in general water consumption decreases in response to increased awareness of consumption (through metering) and the pricing of water on a per-unit basis. These findings correlate strongly with previous studies and on average the introduction of metering results in a reduction in household consumption of water of 20%. In addition, eco-labelling was adjudged to have a significant positive effect on the probability of investment in water-efficient appliances. As such it can be seen that non-technological innovation measures have a major role to play in the efficient management of water resources. Visibility of individual consumption, communication of the environmental impacts of excessive water usage and the ability to price water according to true-cost of collection (abstraction), treatment and distribution are therefore important tools in the reduction of water scarcity.

2.3.5 | Wastewater

Recovery of energy from wastewater
Wastewater contains significant amounts of energy in the form of calorific value of the organic solids component and also as low-grade heat energy. The further development of technologies to capture that energy will enable waste water processors to reduce their own energy requirements, reduce landfill or other disposal fees and earn revenue by charging others for the disposal of organic wastes through co-digestion of sewage sludge and other waste streams. The feasibility of such ambitious aims is already demonstrated at facilities such as Strass im Zillertal wastewater treatment works in Western Austria, which is has been energy neutral since 2005.

Recovery of resources from wastewater
In addition to energy, wastewater (sewage) contains nutrients, notably phosphates - a commodity that is essential for industrial-scale agriculture but in diminishing supply - along with low levels of various metals. Industrial effluents often contain much higher concentrations of metals. The development of efficient techniques to remove these metals will result in the recovery of valuable commodities and lower fees for discharging to the receiving environment.

Low energy aeration
Approximately 50% of a wastewater treatment plant's energy requirement is for the oxidation of effluent via air blowing equipment. The replacement of this element of the process, through more efficient compressors, novel small-bubble or passive aeration, offers significant energy savings.

Reduction in sewer loading
The use of sustainable drainage systems and separation of surface runoff from foul sewer (sewage) can reduce instances of flooding and pollution but also has the major benefit of a lower flow rate and more predictable quality of effluent received into wastewater treatment works.

Decentralised wastewater treatment
The need for decentralised treatment of wastewater is clearly developing. For Western communities, the costs of maintenance and operation of large infrastructure systems are quickly increasing to a level where it is becoming hard for them to maintain sewerage systems at the desired levels. For Eastern Europe, new systems have to be put in place, and the investment costs for large, centralised systems that collect over wide areas and convey sewage to vast treatment works are difficult to overcome. Hence there is a need for (modular) decentralised systems and a reduction in the volumes sent to sewer through reuse at household levels.

The planned European Innovation Partnership (EIP) for "Water Efficient Europe.", heralded by Innovation Union proposes a division along slightly different lines, namely; urban, agriculture, land-use and industry. This partnership, still at the proposal stage, “will bring together all relevant actors at EU, national and regional levels in order to: (i) step up research and development efforts; (ii) coordinate investments in demonstration and pilots; (iii) anticipate and fast-track any necessary regulation and standards; and (iv) mobilise ‘demand’ in particular through better coordinated public procurement to ensure that any breakthroughs are quickly brought to market.” The aim of the partnership is to streamline, simplify and better coordinate existing instruments and initiatives and complement them with new actions where necessary.

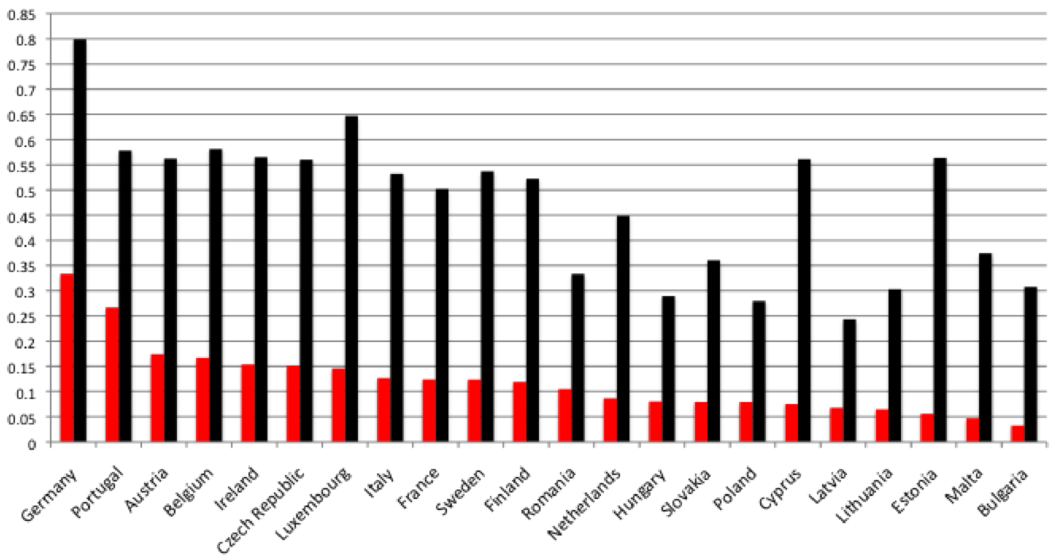
2.4 | Innovation activity in water in EU: evidence from innovation surveys

There is very little EU level evidence on business innovation activities in the field of sustainable water. The section presents a snapshot from two major surveys focussing on innovation offering a possibility to compare EU member states.

2.4.1 | Snapshot from the Community Innovation Survey

The 6th Community Innovation Survey (CIS) published by the Statistical Office of the European Communities (Eurostat) includes analysis of the relative amounts of parameters that might be termed proxy measures of Eco Innovation compared with the overall investment in generic innovation activity by countries in the EU. These 'proxy measures' include: reductions in soil, water, noise, or air pollution; use of recycled waste, water, or materials in the production process and reduced air, water, soil or noise pollution during the product use (end-user benefits). An example of the data produced by the survey is given in graphical form, below in Figure 8.

Figure 8 | Share of companies introducing innovations reducing soil, water, noise, or air pollution in the production process in EU member states



Source: Community Innovation Survey 6, ESTAT; Calculations: EIO

The figure illustrates the share of companies introducing innovations in the production of goods or services which have environmental benefits in the form of reduced soil, water, noise, or air pollution (in red) compared to the share of companies undertaking generic innovation activity (product or process, ongoing or abandoned, organisational and marketing innovation) (in black) as a proportion of total CIS population.

The countries have been ranked in order of the share of companies introducing environmentally beneficial innovations. It can be seen from the figure that there is some broad correlation between the amount of innovation investment in general and the amount of what might be termed eco-innovation but that this is not a direct relationship, with countries such as Germany and Portugal scoring relatively highly on both measures but Cyprus and Estonia recording low levels of 'eco-innovation' relative to their investment in generic innovation activity. Of course this direct comparison of two variables is somewhat subjective and hides many other factors in the countries' respective economies. It does, however, indicate that there may be some positive relationship between innovation activity in general and eco-innovation outcomes.

2.4.2 | Eurobarometer on eco-innovation

In the recent Eurobarometer study (EC, 2011), 106 companies were identified as operating within the water supply; sewerage; waste management and remediation sector, of which 25 were water collection, treatment and supply organizations and 21 operated in the sewerage sector (the remainder were waste management and remediation companies or 'other', non-specified). The results were not broken down by sub-sector and were reported for the entire 106.

Companies were asked 'Over the last 5 years, what share of innovation investments in your company were related to eco-innovation, i.e. implementing new or substantially improved solutions resulting in more efficient use in material, energy and water?' The respondents in the group containing Water and Sewerage Undertakers indicated that significantly more of those companies than in all other sectors apart from 'agriculture and fishing' had identified greater than 50% of their innovation as eco-innovation. As mentioned above the sector is not broken down further and therefore it is not possible to tell which of the companies that responded thus were associated with water and/or sewerage.

Responses to other questions relating to materials use, eco-innovative products and processes revealed similarities between the sector encompassing water and sewerage and other sectors, with the exception of the question '*How would you describe the relevance of innovation you have introduced in the past 24 months in terms of resource efficiency?*' Nearly three times as many in the 'water, sewerage, etc.' group as any other group, and five times as many as most groups, said that between 40% to 60% reduction of material use was attributable to innovation.

One interpretation of this is that the 'water, sewerage, etc.' sector is as innovative as other sectors or more so however the data are not sufficiently rigorous to draw firm conclusions and indeed the responses to other questions might be taken to contradict this view (e.g. '*During the past 24 months have you introduced a new or significantly improved eco-innovative product or service to the market?*' Fewer in the 'water, sewerage, etc.' sector responded 'Yes' to this question than most other sectors).

Perhaps most telling from the results of the survey is that fewer of the respondents in the water sector identified lack of external financing or lack of funds within the enterprise or uncertain returns on investment as very serious barriers to accelerated eco-innovation. This appears to contradict the received wisdom that access to finance and risk-aversion are significant barriers to innovation in the water sector. In lieu of more statistically significant data what we can say is that based on this survey there appears to be no overall difference in attitude to eco-innovation between companies operating in the water sector and other sectors of the economy in Europe.

3 | Water eco-innovation in practice

The following section details examples of novel technologies in some of the key areas of innovation. These technologies are indicative only and not intended to represent the best available technologies, rather they are illustrative of the wide range of innovation in the water sector. The emphasis on technological innovation is not to dismiss other forms of innovation such as organisational change or process innovation which, as shown elsewhere in this report, have the potential significantly to affect water usage. Rather, it is in keeping with the general theme of the report. Clearly, for such novel technologies to be accepted and for their use to be encouraged there need to be appropriate market conditions and these might be facilitated through the use of innovative regulations and financial instruments.

It is not intended that all parts of the water sector are equally represented, however the technologies have been roughly grouped according to the classification used above, namely: Resources, Treatment, Distribution, Use and Wastewater.

3.1 | Resources

Desalination

The ability to cheaply turn salt water (seawater) into water that is usable for irrigation or potable supply is a truly enormous goal and one that could make a step-change in human development. As such, the pioneers in this field, those who get to market first, will not only enable communities to exist in currently marginal habitats but stand to make large amounts of money.

Many companies around the world are working towards the goal using different approaches. Aquaz (http://.aquz.dk) of Denmark (mentioned above) is one of a number looking to exploit the properties of naturally-occurring structures, aquaporins, which, if perfected, would permit membranes to operate at far lower pressures than current technologies and with far greater efficacy (producing purer water). Surrey Aqua Technology and Modern Water (http://www.modernwater.co.uk/technology/platform-mo-technology) of the UK have developed and trialled a system based on their manipulated osmosis technology and German conglomerate Siemens has partnered Australian company Windesal to exploit renewable energies to power a desalination plant (based on Danish technology).

In the past few years significant improvements have been announced in the field of desalination by means of Reverse Electrodialysis. This is a very promising development of an old technology, as no membranes are involved and the by-product of the process is electric power based on the difference between the chemical potential of concentrated and dilute solutions of salt.

Using rainwater - decentralized rainwater technologies

There is a move in many new developments towards the collection of rainwater locally and its re-use with little or no treatment for those purposes where high quality water is not required (such as vehicle washing and irrigation of landscaping). This is achieved via a variety of techniques and can contribute to cost savings but also helps in the reduction of runoff to drains and watercourses, thereby contributing to the control of flood-waters during heavy rainfall events. The advent of 'green roofs' is another mechanism for the use of rainwater at the point at which it is encountered. Green roofs offer both insulation in winter and cooling in summer. Although extremely efficient at preventing runoff and retaining water, green roofs serve other functions. In summer, they prevent solar radiation from being absorbed by roof surfaces. Instead, green roofs convert solar energy into photosynthesis activity and evapotranspiration. In winter, they not only insulate through added mass and materials, but also induce heat through biological activity

Enrichment of groundwater bodies with storm water

The increasing urbanization of Europe has contributed to flooding and loss of storage in aquifers resulting from greater runoff from hard surfaces. One way to overcome these effects is to recharge aquifers by directing rainfall to detention basins or other, similar, structures designed to slow the transmission of flood waters through catchments. Much of this can be achieved through town planning and landscaping which incorporates engineered features. Other mechanisms that have been demonstrated include infiltration 'galleries' in the banks of rivers, which fill only when a river is in flood, pumping excess water to boreholes in winter and replacement of impermeable hard surfaces (e.g. car parking) with porous pavement or semi-permeable surfaces.

In this case it appears that innovation is required in the way that drainage and water resources issues are considered within the planning context.

3.2 | Treatment

Membranes – nano-technology and materials science.

Membrane technologies include any process for water or wastewater treatment achieving filtration through a porous or permeable media made of polymeric, mineral or composite material. Depending on the pore size and the rejected pollutants membrane processes as referred to as microfiltration (MF, for turbidity and bacteria removal), ultrafiltration (UF, for removal of viruses and colloidal substances), nanofiltration (NF, for removal or organic substances and divalent ions) and reverse osmosis (RO, for removal of monovalent salts). Hybrid membrane systems may combine membrane filtration with another technology, such as membrane activated sludge, or membrane bioreactor (MBR), for advanced treatment of wastewater.

The main economic hindrance to all membrane technologies for water application today is membrane life span (durability of membrane systems) and the specific energy requirement. Commercial competiveness will be secured by developing durable and low cost membrane systems with much lower energy demands or by meeting those demands through the application of renewable energy technologies such as Thames Water's desalination plant which uses a combination of biodiesel and recycled cooking oil from London restaurants in the generation of its electricity. Another area of emerging technology is that of functionalized surfaces utilizing nanotechnology and chemical catalysis.

One European company at the global forefront of innovation in membrane science is AquaZ of Denmark. Experts have sized up the market for Aquaporin at around $300 billion (The Biometric Watermembrane Research Project, 2010) and AquaZ, working with Danish Industrial giant Danfoss, with backing from Vaekstfonden (a state investment fund which aims to create new growth companies by providing venture capital and competence) is developing a filter system incorporating synthetic aquaporin proteins, which it claims will increase the efficiency of sea water desalination plants by 5-10 times.

Another area of technology development is that of Forward Osmosis (FO). Much previous work on FO as an alternative desalination process has exposed the two major limitations of FO: lack of high-performance membranes and the necessity for an easily separable draw solution that can induce a high osmotic pressure (T.Y Cath et al, 2006). Research into membranes for FO use is likely to be a significant area for funding in the near future.

The use of carbon nano-tubes in membranes is also likely to be important in the future. It has been shown (M.Majumder et all, 2005) that the rate of flow of water across such membranes is much faster than might be expected according to standard hydraulics and as such they offer a more rapid and low energy alternative to conventional membrane structures.

Real-time monitoring and management

Water treatment and distribution systems are large and complex. Many were constructed a long time ago and are operated on principles that have been established through trial and error or 'best-practice' protocols. Through the use of pervasive measurement and process-control algorithms it is possible to generate real-time feedback and intervention to ensure that existing systems are managed as efficiently as possible even where they are not built to modern design standards.

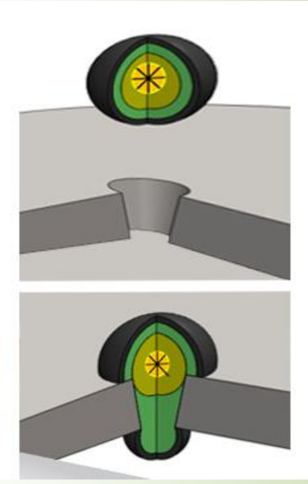
Companies at the forefront of this technology sector include Perceptive Engineering (UK) and TaKaDu (http://www.takadu.com) (Israel) as well as the slightly longer-established Derceto (http://www.derceto.com) (New Zealand). Perceptive Engineering's (http://www.perceptiveapc.com/waste-water-treatment-process-optimisation.html) trials of its WaterMV system at a water treatment works in North West England demonstrated a 25-35% energy saving. WaterMV is a multi-variate model predictive control solution which enables the operation of a water treatment plant at its optimum efficiency by 'learning' what is efficient and continually monitoring the parameters used to define that situation, using the feedback to adjust inputs as required. TaKaDu provides a Software-as-a-Service solution for monitoring water distribution networks and gives the utility real-time control over network events to readily identify leakage. Derceto's Aquadapt software takes advantage of the ability to choose when to use energy to minimize energy costs by optimizing valve and pump schedules.

Non-UV disinfection

CM Ventures, based in Ireland, has developed a novel electrolysis based disinfection system utilizing sodium chloride (salt). The efficacy of their Elimbac solution means that a lower oxidant demand is required to achieve disinfection of wastewater and potable water, resulting in low volume dosing. Compared with conventional UV, Elimbac has demonstrated superior kill rate, reduced energy consumption, lower CAPEX, and leaves no chemical residues. CM Ventures initially targeted their technology at the food processing sector but were introduced to the water sector through involvement with the Tritech ETV scheme and Water TAG (Isle Utilities) who were able to make introductions at a senior level in an unfamiliar industry sector. Since the generation UV light is very energy and resource intensive such a system has the potential to offset large amounts of CO_2.

3.3 | Distribution

Self-healing pipe materials
With losses due to leakage from aging infrastructure as high as 50%, the cost-effective repair of leaks is a goal for all water utilities providers. The use of no-dig solutions for the remediation of pipes to reduce leakage has developed rapidly over recent years.



Box 1 | Platelets™ by Brinker

Examples include the Brinker Platelets™ technology, spun out from the University of Aberdeen as an oilfield technology then developed with Yorkshire Water in the UK, whereby small fragments of neutrally-buoyant silicon rubber are introduced to the water distribution system, which then become drawn into cracks and form a plug to stem losses from the pipe until such time as effective repair or replacement can be undertaken. Curapipe of Israel has devised a method of no-dig pipe repair originally developed for the oil and gas industry.

Potentially the next step in pipe material development is pipes that respond to damage by repairing automatically. Examples of self-healing concrete have been demonstrated at the Delft University of Technology in the Netherlands (http://www.newscientist.com,) and the University of Michigan (Yingzi Yang, Michael D.Lepech, En-Hua Yang and Victor C.Li, 2009) in the US and self-healing polymers are already being used in pipe coatings (e.g. Autonomic Materials Inc., US).

Energy recovery from high pressure distribution mains
Zeropex of Norway has developed the Difgen technology: a pressure-reducing system generating electric power from the pressure drop in fluids. Used in the place of a traditional pressure reducing valve (PRV) it combines the pressure control from chokes and electricity generation from hydroturbines. The unit can be used in high-pressure water distribution mains to effect step-down in pressure whilst capturing the embedded energy to form a micro-hydro power supply.

3.4 | Use

Innovative subsurface irrigation techniques
Progress has been made (by UK start-up DTI-r (http://www.dti-r.com) in conjunction with US chemicals giant DuPont) towards the use of sea water for irrigation through the use of semi-permeable DutyionTM membrane pipes buried below ground which permit the escape of water vapour but not salt, thus hydrating the root system and allowing crops to be grown in arid coastal zones.

The Hydrip system (http://hydrip.at/principle.htm) from Austria combines soil conditioning agents and a novel pipe configuration to allow low-pressure sub-surface irrigation. This results in reduced water and nutrient leaching and evaporative losses and uses significantly less energy than conventional sub-surface irrigation.

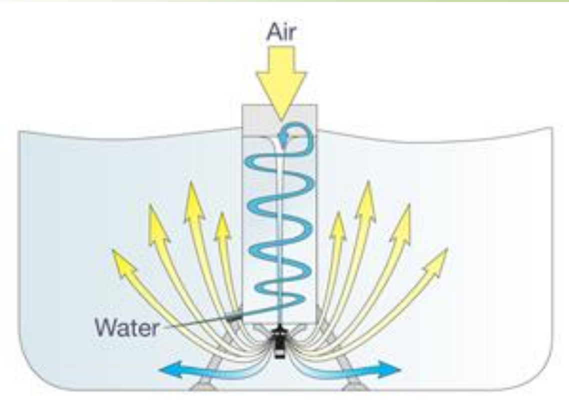
3.5 | Waste Water

Low energy aeration

The aeration of wastewater consumes more than 50% of the energy at a sewage treatment plant. Advances in aeration technologies using micro-bubbles or no bubbles for greater Oxygen saturation, aeration through siphon or vortex technology to reduce energy input have the potential to greatly reduce cost and the carbon footprint of the wastewater industry.

UK based Hydro International (http://www.hydro-international.biz/wastewater/hiox.php) has developed the HiOx® sytem; an ultra-fine, high efficiency, bubble aeration system that claims to increases aeration efficiency by 20% or more compared to commonly used fine bubble devices. To an extent this is a refinement of existing technology whereas Swedish SME, Sorubin (http://www.sorubin.se/index.php?lang=en&tab=1) has developed a passive aerator (Microluft®) that has a high yielding oxygen transfer rate and offers the prospect of a 90% reduction in energy requirement.

Box 2 | Stormrotor^{TM} by Sorubin



Sorubin's Stormrotor technology is a bottom mounted aerator. By generating a vortex in a tube that has contact with the atmospheric air, a pillar of air reaches all the way down to the bottom of the tube – at a low energy cost. At the bottom of the tube is a special impeller that sucks in a mix of air and water and puts it under very high pressure. The result being that very small bubbles are dispersed radially from the aerator.

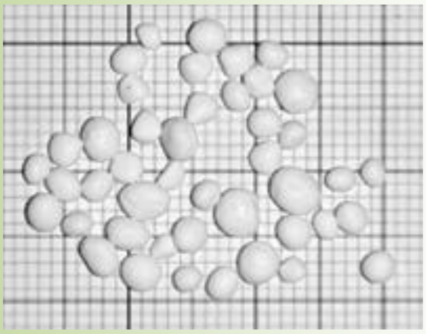
Anaerobic Digestion

The generation of gas, which can be converted to energy for powering a wastewater treatment works or else sold onto the energy market. Anaerobic digestion (AD) is a relatively simple process however to make it commercially viable there are a number of elements (component technologies) e.g. gas scrubbers, gas storage membranes, gas-engines that must be optimized. The rate-limiting step in conventional AD is cell lysis or hydrolysis – the breaking-down of the cell walls within the organic components of sludge. This results in long residence times needed, hence larger vessels and more capital cost. Most recent innovations have been to enhance AD by pre-treatment of the sludge by thermal, chemical, ultrasonic and thermochemical means. Others are working to develop enzymatic lysis techniques and there are early-stage attempts to apply synthetic biology (genetic modification and bacteria selection) to enhance biogas production.

AD is increasingly popular as a means of reducing CO_2 generation by wastewater treatment undertakers and AD facilities have been recognized by the United Nations Development Programme as one of the most useful decentralized sources of energy supply, as they are less capital intensive than large power plants (i-sis.org.uk, 2007). However, despite being extremely common in a number of industrial sectors such as food, beverage, pulp and paper, where thousands of plants have been installed all over the world, the use of wastewater treatment facilities to generate biogas is still a long way from being universal. As such it seems likely that AD will constitute a larger market for innovators in the future. Some commentators predict the use of micro-biogas generation plants operating at the household or community scale.

Box 3 | Phosphate (nutrient) recovery

Nuresys (http://www.nuresys.org/start_eng.html) of Belgium has developed a mechanism for the generation of Struvite - a crystalline form of magnesium ammonium phosphate - from waters rich in phosphorus. This material can then be used as a slow-release fertilizer, minimizing nutrient losses. The recovery of nutrients in this manner means that wastewater processing can become much more cost efficient or even profitable while protecting receiving watercourses from eutrophication and minimizing CO_2 generation from the manufacture of conventional fertilizer.



Ostara Nutrient Recovery Technologies Inc. of Canada achieves the same outcome through a different process and with significant financial backing appears to be better positioned to capitalize on this innovation than its European competitor. Ostara 'Pearl' technology is being further developed and applied in Europe through Grontmij of the Netherlands.

In addition to the recovery of phosphate there have been promising developments in the removal of nitrogen from ammonium-rich wastewaters. The Sharon/Anammox process, developed by Paques (http://www.paques.nl/) on the basis of research at TU Delft and Grontmij consulting engineers, achieves nitrogen removal by combining two separate treatment steps: a partial nitrification process (Sharon) followed by an anaerobic ammonium oxidation process (Anammox). This will result in significantly lower plant energy consumption since not all ammonia needs to be fully oxidised to nitrate in these processes.

Separated drainage systems to reduce loading on wastewater treatment works

It is common for water treatment works to receive combine sewer flows – both runoff and sewage effluent. This has numerous disadvantages: by directing rainfall from hard surfaces to sewer natural recharge is reduced which can impact on groundwater resources, wetland ecosystems and river flows; large runoff events can overwhelm sewer systems and lead to flooding or overflows of sewage to watercourses and the volume of effluent to be treated is higher with greater variability in quality.

Most new developments are now built with separate sewer systems however the use of SuDS or Sustainable Drainage Systems is becoming more prevalent. In many instances the incorporation of landscape features such as roadside infiltration ditches or ponds to retain excess runoff is sufficient to solve the problem. Other innovative technologies such as permeable hard paving, hydraulic brakes and sub-surface detention basins comprising modular high-strength plastic cells have been developed in response to the growing issue of urban drainage.

Box 4 | Reuse/recycling of waste water

This line of research and development is one of the most prevalent in the innovation literature relating to water.

Organica (http://www.organicawater.com/#8.node/About/Mission) of Hungary builds wastewater treatment plants that utilize and enhance the forces nature to purify water by harnessing the metabolic processes of living organisms that digest organic pollutants. Organica treatment plants are populated by thousands of species of plants, animals, and microbes. The organisms' ability to self-organize and capture solar energy maximizes biological degradation of contaminants.

Other systems are targeted at the individual property scale and look to reuse 'grey water' such as that from a shower, bath or washing machine to flush toilets. At present this is not economically achievable to the level of purity required to avoid potential health risks associated with trace faecal matter. Such reuse does occur in Japan however it is understood that this is confined to large apartment blocks and achieved using expensive and sophisticated treatment processes. Since a large percentage of potable water usage in the home is for flushing toilets there are significant water savings to be made if this issue can be addressed. If, as seems likely, the cost of water increases with the introduction of full-pricing, re-use of water in the home may be a significant means of saving money.

4 | Water eco-innovation support initiatives

Throughout Europe there exist many different models of innovation support and stimuli with respect to the water sector. This section provides a selective overview of a number of EU level and national initiatives in Europe as well as examples of relevant initiatives outside EU.

4.1 | European initiatives

There are at least seven European Water Sector initiatives, with different areas of focus. Some are complementary, some appear to compete.

Joint Programming Initiative (Water Challenges for a Changing World)

Initially submitted in 2009 this proposal (http://www.era.gv.at/attach/JPIWaterChallenges2010-05-04.pdf) is currently being re-defined with a view to receiving approval in 2011, for commencement in 2012/13. It is one of a number of initiatives that aim to provide an impetus for research cooperation between nations in areas of major societal challenge. The water JPI is coordinated by Spain and the Netherlands, supported by 14 other national economic, environmental and research agencies and the anticipated budget is €100-200 million per annum depending on how many nations will contribute. The water JPI proposes to address the themes of water quantity and quality and extreme events, for which four main challenges have been identified: "the bio-based economy", "sustainable ecosystems", "healthier water systems for a healthier society" and "closing the water cycle".

The emphasis of the JPI appears to be on research rather than technology development and it is not an industry-led initiative although there is an intention that industry will play a role. One significant outcome of the JPI will be cooperation between countries on issue-specific projects. This has the potential of avoiding duplication of (applied) research; a concept that has already been demonstrated in the water sector by a cooperation between Belgium, The Netherlands and Spain through a collaborative initiative that these countries had/have in place. As such, while likely to accelerate understanding of the water environment it appears unlikely to be a significant stimulus for eco-innovation. Further information on the water JPI can be found at http://ec.europa.eu/research/era/areas/programming/joint_programming_en.htm

Water Supply and Sanitation Technology Platform

The WssTP (http://www.wsstp.eu/site/online/home) has existed since 2004 and was developed by water industry representatives, having been initiated by the European Commission to promote a research agenda based on the needs of industry. It has developed a research vision (a common vision for European Water Innovation to 2030) and from this came a Strategic Research Agenda (SRA) - first published in 2006 and updated in 2010. The SRA is built around four global drivers (Demographic growth and urbanisation, Globalisation and wealth growth, Spatial and temporal pressure and climate change) and has five major challenges:

- Coping with increasing water stress (quantity & quality)
- Reducing impact of extreme events (droughts and floods)
- Managing aging or lack of infrastructure

- Facilitating technology transfer
- Establishing an “Enabling Framework”

The secretariat of the WssTP initiated and has been involved in the development of the Acqueau cluster, described below.

Eureka and Eureka Umbrella

Eureka is the pan-European network devoted to improving the competitiveness and productivity of businesses through technology. As such, innovation and by extension eco-innovation are central to Eureka's purpose. The Eureka organization manages the EUREKA programme and the "Eurostars" programme specifically aimed at assisting SMEs with technology development. Umbrellas are thematic networks within the EUREKA framework which focus on a specific technology area or business sector. The main goal of an umbrella is to facilitate the generation of EUREKA projects in its own target area, usually involving government, industry and academia. The Eureka umbrella (cluster) for water was launched in 2010 and is known as Acqueau.

Eureka Acqueau Cluster

Through the Water Supply and Sanitation Technology Platform (WssTP) a ‘water research vision’ for Europe has been identified by using knowledge from stakeholders, innovators, researchers, etc, involved in the water industry. This research vision, supported by a Strategic Research Agenda (SRA) outlines future scenarios for the water industry. By employing the SRA the water cycle has been further examined and a ‘technology roadmap’ has been produced which ‘leads the way’ so that all players ‘flow’ in the right direction.

In order to facilitate the innovation of products, processes and systems needed on this roadmap the Acqueau Cluster (http://www.acqueau.eu/) will initiate R&TD calls on a regular basis, identifying key ‘technology needs’. It is anticipated that successful projects resulting from these Acqueau R&TD Project calls will strengthen the technological base of the European Water industry. The strategy of the cluster is published in the "Blue Book" (downloadable from the Acqueau website). The initial priority areas for research and technology development are:

- Membrane technologies
- Real-time system management
- Low impact disinfection and oxidation processes
- Low energy wastewater treatment
- Materials for pipes and coatings

The Acqueau cluster is very much concerned with promoting and funding research into innovation within the water industry, which it does through funding competitions. As such it can be seen as an enabler of eco-innovation in respect of water however the focus is very much on the 'water industry', i.e. the water and wastewater utilities, and as such does not encompass all areas of the economy in which water plays a significant part, such as industrial water use and irrigation.

European Water Partnership

The European Water Partnership (EWP) is an independent non-profit organization structured as an open, inclusive member association. The EWP (http://www.ewp.eu/) harnesses European capacity, helps to coordinate initiatives and activities in international water issues and undertakes worldwide promotion of European expertise related to water. The ultimate goal of the EWP is to elaborate strategies and implement concrete actions to achieve the objectives of the Water Vision for Europe. Since the formation of the EWP in 2006, over 20 national Water Partnership initiatives have developed, (e.g. France, Spain, Portugal, UK, Czech Republic, Germany) which together form a coherent network.

The EWP operates at the policy level but also has engagement with innovation at the technology level; notably the Innowater, Stream, Desiras and European Water House projects. The European Water House is not only a conceptual house wherein resides a Water Think Tank and education and awareness programs, but also a technical demonstration facility which permits the showcasing of new technologies, especially in the domestic setting.

The EWP has initiated the development of a set of voluntary standards for sustainable water use, by a series of stakeholders, amongst which are Coca-Cola, BASF, the paper industry, agricultural organisations, WWF, etc. This European Water Stewardship (EWS) is now a lead partner of the International Alliance for Water Stewardship (http://www.allianceforwaterstewardship.org/) and aims to introduce sector-specific schemes in 2011.

Innowater, Europe INNOVA

Innowater (http://www.ewp.eu/projects/innowater) is a project under Europe INNOVA programme of the European Commission. The role of the project is to establish and implement innovation partnerships that develop and test new and better innovation support tools. The project is aimed at the supply chain and focuses largely on SME organizations; helping suppliers to find markets and end users to make better use of innovation in the sector. Unlike the other initiatives described here, Innowater places significant emphasis on the need for innovation in the water-intensive industries, in particular food and drink, pharmaceuticals, paper manufacture and agriculture. Because Innowater was launched in 2010 it has not yet reported on outcomes from the project.

European Innovation Partnership (EIP) for "Water Efficient Europe"

Not yet established, this is one of the key ideas contained in the European Commission's "Innovation Europe" communication, published in October 2010. European Innovation Partnerships are proposed to find practical solutions to societal challenges and build competitive advantage in key markets. These partnerships will be challenge-driven, will cover the whole innovation chain from basic research to demonstration and access to market, and will help streamline existing instruments and initiatives around key Grand Challenges. A pilot project on healthy ageing will be launched at the beginning of 2011, with new partnerships in the following years on subjects that include 'Water-efficient Europe' and 'Agricultural productivity and Sustainability'. The precise construction and focus of the Innovation Partnership for water has yet to be finalized however it is understood that co -funding of large scale demonstration sites by the Commission would potentially enable new innovative technologies to be built (and so lessons learned), to be evaluated (and so improved), and to be demonstrated (and so introduced to a wider market).

ERA-NETs

The European Research Area Networks scheme is a tool of the FP7 programme and is aimed at stepping up the co-ordination and networking of national and regional research and innovation programmes. In relation to the water sector there is the SPLASH ERA-NET, the aim of which is to improve water research for poverty reduction, and IWRM-net which aims to improve co-ordination of research in the field of Integrated Water Resources Management. Both of these initiatives focus more on fundamental research rather than technology development and innovation.

TRITECH ETV

Environmental Technologies Verification (ETV) was a pilot project, initiated by ETAP (the Environmental Technology Action Plan), which ran from 2006 to 2009 to develop an EU-wide scheme for validating the performance of environmental technologies. It was funded by the European Union's Life Environment Programme.

For technology providers and vendors, persuading the market of the environmental benefits of a particular technology can be a difficult and daunting one. This is especially true for Small and Medium sized Enterprises (SMEs). The links between the provider and the purchaser need strengthening to instil both confidence and acceptability for all parties.

The overall aim of the TRITECH project was to establish a mechanism to objectively validate the performance of innovative environmental technology products; this will ultimately lead to new environmental technologies being introduced into the market place at a much quicker rate.

The TRITECH project concentrated on three technology areas; soil remediation, waste water and energy related technologies. The project partners were brought together to provide the necessary expertise in each of these specialist areas, ensuring a successful outcome. It is not certain whether the ETV model will be implemented on an EU-wide basis.

4.2 | Initiatives in the EU member states

A number of European countries have national programmes of support for innovation in the water sector. These have different organisational structures and funding mechanisms, some of which are examined below. This is not intended as a comprehensive list of European initiatives but rather as a selection of some of the major country-level models.

France

The French Water Partnership (Partenariat Français pour l'eau) brings together the French water stakeholders active on the international stage: Ministries, NGOs, local authorities, companies, river authorities and scientific and technical organisations. It currently has about sixty members and is a forum for debate concerning the governance and management of water resources, which helps ensure that water is on the international agenda and maintains a political decision-making focus on water-related challenges.

Two of the world's largest water companies, Suez Environnement and Veolia Environnement, are headquartered in France. Both of these organizations have global reach and comprehensive offerings, from the development and supply of equipment and consultancy to water supply and wastewater treatment. Both companies spend very large sums on Research and Technology Development and have in-house RTD teams. In addition the French Agence National de Recherche provides much of the funding for Cemagref (http://www.cemagref.fr/actualites); a research group that focuses on water resources, land and aquatic systems, water technologies, agrosystems and food safety.

Germany

Germany is the second largest supplier (after the USA) of water equipment. The sector, with few exceptions such as Siemens, is predominantly SME based. Much research is done at Universities and there are many instances of linkages between municipal water operators and local university researchers. There are, however, also some research centres funded in large part by water companies, notably:

- Kompetenz Zentrum Wasser Berlin; a joint venture between BerlinWaser, Veolia and Technologiestiftung Berlin
- Technologiezentrum Wasser; an R&D facility financed by the national gas and water works association (DVGW)
- IWW Zentrum Wasser Duisburg; also part-financed by DVGW along with water company Gelsenwasser, this facility concentrates on research into issues of drinking water quality and standards.

The German Water Partnership, formed in 2008 includes in its membership five federal ministries, NGOs, water associations, consultants and scientific research institutions. This joint initiative was formed for the purpose of promoting the German water industry.

Italy

In Italy a traditionally very localised water sector has, in recent years, undergone some rationalisation. However with the exception of a few large private and semi-private utilities the market is still quite fragmented. Research into water issues is largely carried out by the Water Research Institute, IRSA, which has 3 sites and around 100 staff. Its research activities are largely driven by legislation and seem focused on environmental issues. Research in matters closer to the 'water industry' is carried out by Fondazione AMGA (http://www.fondazioneamga.org/), funded by the Gruppo Iride based in Genova.

Netherlands

In the Netherlands there is a long tradition of water science and innovation. There is a great deal of research done in Dutch universities, notably Delft and Wageningen, but also several well-established research organisations with different areas of focus. Principal among these are KWR, WETSUS, DELTARES and STOWA.

KWR, the Watercycle Research Institute, is funded by a levy on the water companies and employs circa 150 staff to work on water systems, water quality and health, and water technology. One of the major outputs of KWR is the Joint Research Programme of the Water Sector (BTO).

STOWA, the Foundation for Applied Water Management Research (http://www.stowa.nl/Header/English/index.aspx) employs a much smaller staff (around 10) and is a procurement organization that sets research agendas and issues contracts to 3rd parties for research in the areas of wastewater and drainage on behalf of the 26 boards responsible for these matters.

WETSUS centre of excellence for sustainable water technology (http://www.wetsus.nl/) is a facilitating intermediary for trend-setting know-how development. Wetsus creates a unique environment and strategic cooperation for development of profitable and sustainable state of the art water treatment technology. Wetsus' scientific research program is defined by the private and public water sector and conducted by leading universities.

DELTARES is an independent, Dutch-based research institute and specialist consultancy for matters relating to water, soil and the subsurface. Deltares (http://www.deltares.nl/en) conducts research and provides specialist advisory services for government authorities and the corporate sector in The Netherlands and globally. The essence of the company's work is the development, application and sharing of knowledge, developed in partnerships with universities, other knowledge institutions and the business sector.

In their paper 'Innovations in the water chain – experiences in The Netherlands', Krozer et al. describe regional arrangements for innovation, with specific reference to the Frisian[2] Water Alliance (now known as the Water Alliance). This program is funded by subscription from more than 35 companies who get to contribute to the definition of R&D programmes and to jointly access the results. Technology is concentrated in the laboratories of the regional water company, Vitens, and Wetsus, the national water technology centre comprising an alliance between the Universities of Delft, Twente and Wageningen. The initiative has been running for more than 10 years and yet Krozer et al. report that 'the resulting innovations are modest as only a few R&D-based technologies have gone beyond the stage of successful demonstrations'.

Other initiatives developed by the Dutch government include the Netherlands Water Partnership (http://www.nwp.nl/en/) (a network of stakeholders which has existed for more than 12 years), the Stuurgroep Watertechnologie (support for business consortia offering turnkey services, export products and demonstration products) and support for cooperation between research and business. These, too are reported by Krozer et al. (2010) but are judged not to have substantially improved Dutch competitiveness in the water supply-chain. This assertion is strongly contested by the Netherlands Water Partnership which points to a doubling of water technology exports in 5 years and a continuation of the programme.

Denmark

Denmark's R&D effort in respect of water is largely coordinated by the Danish Water Forum, (http://www.danishwaterforum.dk/) of which there are approximately 40 members including leading universities, contractors and manufacturers, water companies, consultants, government authorities and NGOs. The DWF fulfils many roles. It is part advocacy organization for Danish water sector companies and researchers, part knowledge transfer function, part shop-window. It hosts a number of high-profile programmes, such as EU Waternet to promote the participation of Danish organizations in European collaborative R&D, and the Danish Water Research Platform to identify the needs, the possibilities and the challenges for Danish research, innovation and technological development within the water sector.

[2] Interestingly, the Dutch Regions have all focussed on key areas in the water-field: the Northern area on Water technology; the West part on Delta-technologies, while the North-East is more dedicated to sensoring, and in the Southern area Water and Health (Personal comment, Tom Vereijken, Chairman, Netherlands Water Partnership)

Danish consulting and research organisation, DHI, is internationally recognized as a leader in the development of hydrological and water quality software, research into the effects of water on health, and water and the environment. The company is the result of mergers between the Danish Hydraulic Institute, the Institute for the Water Environment and the Danish Toxicology Centre. DHI tends not to be involved with the development of new technologies per se, but rather of software solutions and consultancy interventions.

Spain

As a country with significant areas of water stress, Spain has a great deal of interest in water technologies and Cetaqua, the Centre for Water Technology,(http://www.cetaqua.com/) was constituted by water company Agbar, the Polytechnic University of Catalonia and the national research council (CSIC). It is a not-for-profit organization, managing research, technological development and innovation in the field of integrated water management, especially in the urban cycle.

Located in North East of Spain, the Catalan Water Partnership (CWP) (http://www.cwp.cat/en) is the Catalan Cluster for water treatment. It is the space where engineering and environmental consultancies, centres of knowledge, equipment manufacturers and other entities work to develop innovative and sustainable solutions to global water needs.

The Spain Netherlands Water Partnership (http://www.snwp.info) is a venture between the Spanish Water Technology Platform (Plataforma Tecnológica Espanola del Agua) (http://www.plataformaagua.org/index.php?id=20&L=1) and The Dutch Water Technology Innovation Office, represented by the Netherlands Water Partnership. These two organizations decided to cooperate in order to share experience and foster research and investigations. The rationale behind this venture lies in perceived sector similarities such as the innovative nature, the domination of Small and Medium Enterprises in the sector, a strong willingness to collaborate and the need to collaborate, nationally and transnationally.

United Kingdom

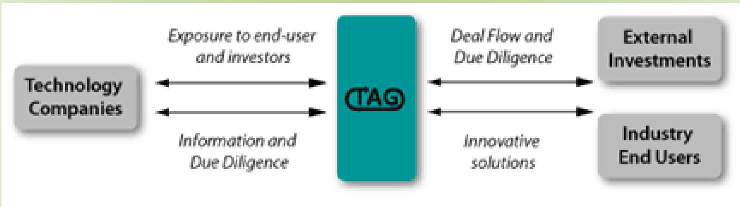
Similar in concept to the Dutch STOWA, United Kingdom Water Industry Research (UKWIR) (http://www.ukwir.org/site/web/content/home) is a membership organisation funded by contributions from all of the UK's water and wastewater undertakers. It commissions and awards research contracts for collaborative research and technology development in areas of interest to all or many of its members. The UK water industry was privatised in 1989 and at, or around the same time formerly public research and development facilities were privatised, for example WRc (previously the Water Research Centre) and HR Wallingford (previously the Hydraulics Research Station). Both of these organizations continue to operate as consultancy-based companies with some R&D functions.

There are numerous UK universities with strong research interests in water, and some research funding is provided by the government's Research Councils; notably the Engineering and Physical Sciences Research Council (EPSRC) and the Natural Environment Research Council (NERC). The Environmental Sustainability Knowledge Transfer Network (ESKTN) (www.innovateuk.org/sustainabilityktn) is a UK government funded project set up for the purpose of facilitating the commercialization of research from UK universities and establishing connections between academia and industry.

Two private initiatives to promote innovation in the water sector are Isle Utilities' 'Water Technology Approval Group (Water TAG) (http://www.isleutilities.com/tag.php) and Anglian Water and UKCEED's Water Innovation Network (WIN) (http://waterinnovation.net/). These two models approach the issue of technology development from opposite ends, with the Water TAG basing its offer around a 'pull model' and responding to demands from water utilities for innovative products and solutions and the WIN helping the supply chain to develop and innovate, with particular emphasis on the SME sector. Water TAG has operated since 2005 whereas WIN was established in mid 2010.

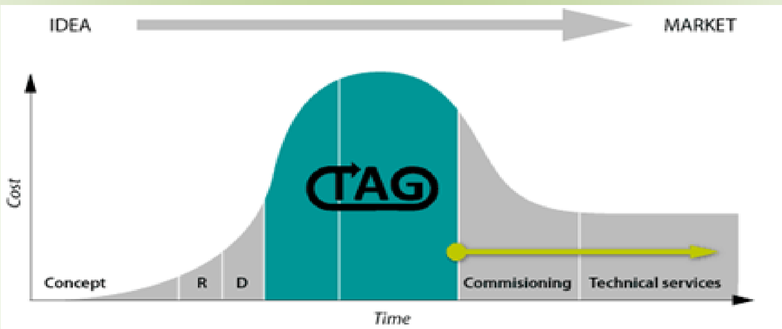
Box 5 | UK - Isle Utilities Water Technology Approval Group (TAG)

An interesting model for the promotion of innovation in the UK water sector is provided by Isle Utilities' "Water TAG". The Technology Approval Group (TAG) was established in 2005 as a novel innovation forum with the objective of accelerating the commercialisation and market uptake of new technologies. TAG brings together industry know-how with the financial backing of institutional investors to facilitate technology development in line with the market's needs. The initiative is funded through annual subscription from end users (members). Although Isle is now expanding the TAG model overseas, the TAG concept was originally developed and proven within the UK Water and Wastewater sector.



TAG identifies over 500 novel technologies a year. Each technology is carefully screened and evaluated by the appropriate specialists within Isle, ensuring that each "approved" technology is novel, robust, has a strong unique selling point, addresses key business and market needs and presents significant cost benefits over and above the competition.

TAG typically works with technologies that are pre-commercial but post-R&D, and its reach extends beyond the water industry's supply chain. This allows for the most novel technologies from other industry sectors to enter the water market.



Five "approved" companies are invited to present to the TAG members (i.e. industry end-users) on a quarterly basis. These TAG meetings guarantee direct exposure to the industry. The outcomes from the TAG meetings include:

1. **Gathering feedback and market intelligence directly from the industry end-users;**
2. **Collaborative trials or sales opportunities; and**
3. **Introductions to the right contacts within each water utility.**

Where appropriate, technology companies looking for funding are introduced to suitable venture capital and private equity investors. This not only attracts external investment to the industry, but it also enables the technology company to better deliver their product in line with the industry's requirements.

TAG has delivered a focused, collaborative framework for innovation in the UK water industry - not only by introducing new step-change technologies to the market, but also by leveraging venture capital investment. Its success is exemplified by the track record to date:

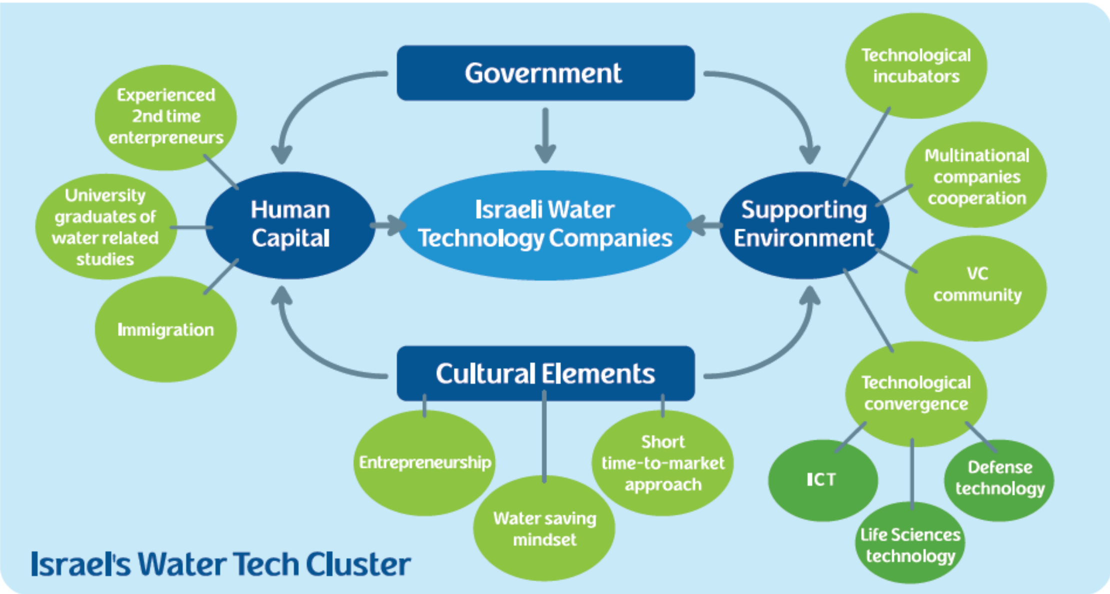
- **Over 100 "approved" technologies have been formally presented to TAG members since November 2005**
- **75% of these technologies have been taken forward by the TAG members**
- **50% are now commercial**
- **TAG has helped to secure more than £50m (c. €65m) of external investment for these companies since 2005.**

4.3 | Initiatives beyond EU

Outside Europe there are many examples of investment in initiatives to promote innovation in the water sector. A few high profile examples, chosen to illustrate the variety of approaches, are given in the following section. These should not be taken as the entire contribution to innovation in the water sector in the countries to which reference is made.

Israel: Government funding
According to a survey by Cleantech Group, Israeli exports of water technology are approximately $2.5 billion per annum (US dollars) (Cleantech,). The Israeli government-backed Novel Efficient Water Technology cluster NEWTech (http://www.israelnewtech.gov.il) is a national program for the promotion of the water technology sector. Israel NEWTech is led by the Ministry of Industry, Trade and Labor's Foreign Trade Administration (Investment Promotion Center) but supported by many other government ministries, water and sewerage authorities, the office of the Chief Scientist and other agencies. Initiatives include heavily subsidized (85% government funding) incubator facilities and links to research facilities such as the Grand Water Research Institute at Technion University and the Zuckerberg Institute for Water Research at Ben-Gurion University of the Negev.

Figure 9 | The structure of the Water Technology Cluster in Israel



Source: 'Water The Israeli Experience', State of Israel, Ministry of Industry, Trade and Labor Foreign Trade Administration Investment Promotion Centre

Australia: Privately-funded centre of excellence

Port Pirie on the Spencer Gulf in South Australia (SA) has been earmarked as a location for a water technology hub, which aims to position the city and other regional areas as global leaders in water innovation. Under a Memorandum of Understanding signed between Windesal and Siemens, a water technology hub could be set up in regional SA and serve as a world-class industry showcase for new water technologies. It is unclear how the hub would be funded but it is apparent that at least a significant portion of the investment would be private.

A report by Patent Attorneys, Griffith Hack (www.griffithhack.com.au, 2010), analyzed the situation in respect of innovation in the Australian water sector and found that whereas there were a large number of patents filed in respect of water technology, many of these were domestic patents only and there is not a significant level of water technology exports from a country suffering severe water stress, in contrast to Israel and Singapore. The authors of that report conjecture that this may be partly because "…Australia has not followed other industrial nations in developing a strong, local water technology business grouping, with that space being occupied mainly by multi-nationals."

Singapore: Private-public model

Singapore is heavily reliant on its neighbour, Malaysia, for water and as 50-year agreements between the two nations draw near to an end the importance of water is acutely felt. The Singaporean government has taken steps to address the issues of resource constraint by promoting the development of water technologies, largely through university-based institutes and in conjunction with leading overseas organizations. Singapore's efforts to promote reuse of water have lead to the realisation of giant water treatment plants, producing an effluent that is of such high quality it is reintroduced to the drinking water system and known as 'New Water', serving as an example for the rest of the world. Apart from widely achieved public acceptance, most of the produced water is now used by local industries for its high quality. Last year, on the occasion of the Singapore International Water Week, the Singaporean government announced its goal to significantly increase the water treatment capacity. The Singapore Membrane Technology Centre was established Nanyang Environment & Water Research Institute (NEWRI) (http://www.ntu.edu.sg/ohr/Career/CurrentOpenings/ResearchOpenings/Pages/NEWRI.aspx) at Nanyang Technological University (NTU) and is closely associated with Japanese membrane specialists, Toray. Also based at NEWRI is the DHI-NTU Water & Environment Research Centre (http://www.dhi-ntu.com.sg/) in conjunction with DHI of Denmark. Meanwhile, the Singapore-Delft Water Alliance (http://www.sdwa.nus.edu.sg/index.php?option=com_content&view=article&id=44&Itemid=59) has been established at the National University of Singapore in order to take advantage of the expertise of Netherlands-based Delft Hydraulics. According to the Singapore Economic Development Board (Singapore International Water Week, 2010), by 2015 the environment and water sector will be worth $1.7 billion (US). Of the 27 cleantech companies on the Singaporean stock exchange, 13 operate in the water sector (ibid.).

USA - legislative driver and competitions

H.R. 1145, the National Water Research and Development Act of 2009 is a bill intended to coordinate national research and development efforts on water and provide a clear path forward to ensure adequate water supplies for generations to come. The bill requires the president to establish or designate an interagency committee with representation from all federal agencies dealing with water to implement a National Water Research and Development Initiative to improve federal activities on water, including research, development, demonstration, data collection and dissemination, education, and technology transfer including the development of new water technologies and techniques and information technology systems to enhance water quality and supply. There are a number of competitions in the USA which are aimed at innovators in the water sector. These serve as a source of deal-flow for the investment community which is able easily to identify those companies adjudged to have the greatest commercial potential. Examples are given below.

Imagine H2O is a not-for-profit company with a mission to inspire and empower people to solve water problems. Its vision is to turn water problems into opportunities. Each year the organization runs a themed competition for water innovators with a $100,000 prize fund. A quotation from the website indicates the thinking behind this approach:

- Prizes have inspired some of humanity's greatest achievements, from Charles Lindbergh's flight to advancements in genomics.

- We believe in the power of prizes to inspire innovation, and we welcome more prizes targeting water problems.

The Artemis Project Top 50 Awards is a business competition for advanced water technology companies. This award distinguishes advanced water and water-related technology companies as leaders in their trade. It is specifically designed to evaluate the investment potential of emerging providers of Water Technology solutions. Companies are judged by a panel of judges on four criteria: intellectual property, technology, market potential and team. The Cleantech Open is a competition aimed at all sustainable technologies including those in the water sector. Its first prize of $250,000 was won in 2010 by Puralytics, a water quality monitoring company. It is worth noting that water-technology prizes do exist in Europe. A good example is the Neptun Wasserpreis in Austria.

5 | Drivers and barriers of water eco-innovation

5.1 | Understanding drivers and barriers of eco-innovation

Innovation process is influenced by numerous drivers and barriers. The chapter follows a comprehensive typology of determinants of eco-innovation (Eco-Innovation Observatory 2010). The determinants are grouped into five groups:

- Economic and financial factors (e.g. market position, access to capital, cost factors)
- Technical and technological factors (e.g. access to and ability to develop technical and technological solutions, infrastructure, technological lock-ins)
- Environmental factors (e.g. access to and need of material and natural resources)
- Social factors
- Human resources and knowledge base
- Organisational and management capacity
- Social capital (ability to collaborate and to take collective action)
- Cultural capital (including attitudes towards change, risk)
- Regulatory and policy framework (including legal system, standards and norms, IPR etc).

The above classification is analysed taking into account both demand and supply side origin of the barriers and drivers (see Horbach 2005, 2008) as well as the level at which they occur (e.g. firm, sector or socio-economic system).

5.2 | Mapping drivers and barriers of water eco-innovation

In general, the rationale to introduce eco-innovations is based on, on the one hand, the need to preserve the quality of natural environment and public health typically supported by public interventions and, on the other hand, by the economic stimuli to make profit (Lanjouw and Mody 1995, Ekins 2009). Thus, eco-innovation process is driven by the interplay of both market drivers, as innovative companies seek return on investment, as well as the “public good” type of determinants, as public sector responds to the “market failure” and intervenes to improve outcomes of innovations in terms of their social and environmental impacts. The economic incentives remain the key drivers from the point of view of a company (Krozer et al 2010).

The water eco-innovation is approached here as any other innovation process that starts from the need or an idea, continues or not to the development and demonstration stages and then to the successful or failed implementation on the market. The section highlights the most relevant determinants of water innovation in Europe, giving main emphasis to the barriers and drivers that are specific to water innovation. The focus on eco-innovation enlarges the usual scope of enquiry on innovation process to include also environmental aspects, notably the availability and quality of water due to the geographical and geological factors.

Table 1 presents an overview of key barriers and drivers to the water innovation at the level of a company (micro), sector (meso) and entire economy (or socio-economic system).

Table 1 | Classification of drivers and barriers to water eco-innovation

		Barriers	Drivers
Micro (firms)	Economic and financial	• Cost of water relatively low access to finance for risky eco-innovations (notably SMEs) • Too high cost of infrastructural upgrades • Problem of appropriation of profit from innovation	• Growing cost of water and the prospect of the full-cost pricing of water • The possibility of recovery of energy and resources from waste water • Global demand for water efficient solutions and technologies (market potential) • Tax-breaks for water-efficient technologies
	Technical and technological	• Predominance of existing technological solutions (choosing existing tested technologies rather than getting involved in R&D) • Lack of consistent standards means that it can be difficult to design one product or technology to sell into many markets	• Availability of new tested technologies (possibility of technology transfer and upgrades)
	Environmental	• Stringent environmental legislation means that new technologies must meet very high performance criteria	• Geological and geographical context: existing and current water scarcity and variability (both in Europe and in the global dimension) • Water pollution
	Social (human capital, networking and knowledge base)	• Many water utilities have established supply chains and these are dominated by large corporations meaning that entry to market is difficult • Perception of the importance of water in terms of public health - risk-aversion of buyers • Water not a visible market for those companies unfamiliar with the sector	• Perception of the importance of water (link to health and safety) • Increased public awareness of water stress, water footprinting etc.
	Regulatory and policy framework	• High barriers to entry in terms of registration and compliance costs	• Need to comply with regulations, notably EU directives (incremental changes)
Sub-system (sector, value chain, product system)	Economic and financial	• Water price too low to support significant investment in water innovation in water-intensive sectors, e.g. agriculture, energy	• The future prospect of full-cost pricing of water

		Barriers	Drivers
	Technical and technological	• Technological lock-ins: old water supply and waste water treatment infrastructures • Energy generation infrastructure and processes (e.g. use of cooling water)	• ICT and logistics (e.g. real time monitoring) • Industrial symbiosis and other closed-loop processes
	Environmental		• Water scarcity and variability, relevant notably for water intensive sectors (such as agriculture, energy etc) and in specific regions (e.g. south Europe)
	Social (human capital, networking and knowledge base)	• Lack of collaboration in the water value chain (problem differs among countries) • Conservative, risk-averse ownership. Familiarity with established technologies and suppliers.	• Supply chain pressures resulting from water footprinting and eco-labelling
	Regulatory and policy framework	• Regulations not recognising sectoral specificities of water use	• Need to comply with regulations (regulatory push)
Socio-economic system	Economic and financial	• Water pricing • Water as a public good (problem of privatising profits)	• Increased awareness of water scarcity and quality • Greater level of metering
	Technical and technological	• Old water infrastructures (i.e. combined sewer systems) • Expectation of clean water on tap and wastewater removed at the push of a button	• Renewal of aged infrastructure offers opportunity to employ radical alternatives instead of employing 'the same old ways of working'
	Environmental	• Water environment is a 'common good' and not perceived by individuals as 'their issue'	• Increasing or imminent water scarcity and variability • Extreme weather conditions (growing rainfalls and floods)
	Social (human capital, networking and knowledge base)	• Fragmented research and development efforts in the water sector • Aversion to re-use of 'grey water' and 'black water'	• Perception of water as a vital resource linked to the quality of life and health
	Regulatory and policy framework	• Ownership and governance regimes of water infrastructure and utilities • Risk-averseness in investing in water innovation	• The prospect of full-cost pricing of water • EU regulations (notably for the end of pipe solutions such as water treatment facilities)

5.3 | Key drivers and barriers

5.3.1 | Regulatory and policy framework

General considerations

Policy measures can influence development and diffusion of water eco-innovation in diverse ways by devising both demand pull and supply push measures. The policy can support equally technological and non-technological innovations (including organisational and social innovations) responding to the identified challenges related to water.

The following table succinctly summarises various types of policy measures and their potential relevance for water eco-innovation. The measures are divided between those aimed primarily at influencing supply or demand side. The innovation policy taxonomy has been adapted from Edler and Georghiou (2007).

Regulatory framework: Water Framework Directive and other EU regulations

Environmental regulation is one of the strongest determinants of innovation activity as repeatedly confirmed by the results of innovation surveys, notably Community Innovation Surveys (see Horbach 2008, Rennings and Rexhauser 2010). EU legislation on water is the most ambitious regulatory framework in the world and as such it forces technological and organisational upgrades in the water sector as well as in other water intensive sectors. There are seven EU directives related to water, with the Water Framework Directive (WFD) setting a comprehensive framework for water policy. The Water Framework Directive commits EU Member States to achieve good qualitative and quantitative status of all water bodies (including transitional and coastal waters) by 2015.

The European Commission is currently working towards a new policy for water in Europe. This Water Blueprint is likely to arrive in November 2012, the European Year of Water, and has three pillars, amongst which is a review of the implementation of the Water Framework Directive.

Key EU water directives

- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000, p. 1–73),
- Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (OJ L 372, 27.12.2006, p. 19–31);
- Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council (OJ L 348, 24.12.2008, p. 84–97);
- Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (OJ L 135, 30.5.1991);
- Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ L 375, 31.12.1991, p. 1–8) and
- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (OJ L 288, 6.11.2007, p. 27–34).

Table 2 | Policy measures and their potential impact on water eco-innovation

	Type of policy measure		Effects on water eco-innovation
Supply side focus	Equity support	Public venture capital funds	• potential indirect effect • companies investing in water eco-innovation may benefit from the equity support measures as any other companies
		Tax inceptives for companies investing in R&D	
		Public guarantee funds	
	Grants for industrial R&D	Grants for R&D	• potential direct effect • companies involved in water eco-innovation may benefit from generic R&D grants • water issues may be one of the priority areas of R&D industrial grant funding
		Collaborative grants (more than one company and/or business and science partners)	
	Support for public sector research	R&D funding	• potential direct effect • water issues may be one of the priority areas of R&D grant funding • research organisations involved in water eco-innovation may benefit from generic R&D grants
		Collaborative grants	
		R&D infrastructure	• potential direct effect • R&D infrastructure may be used for performing water innovation R&D • companies and research organisations involved in water eco-innovation may benefit using shared infrastructures
		Research infrastructure sharing	
	Fiscal measures	Corporate tax reduction or exemption on R&D	• potential indirect effect • companies involved in water eco-innovation may benefit from fiscal measures
		Personal tax incentives for R&D personnel	
	Education, training and mobility	Tailored training courses for companies	• potential indirect and/or direct effect • companies investing in water eco-innovation may benefit from both generic trainings in innovation managements and entrepreneurship as well as from the tailored measures supporting recruitments of innovation personnel
		Entrepreneurship training	
		Placement schemes for students	
		Support for R&D workers recruitments	
	Networks and partnerships	Competence centres, clusters, science-technology parks	• potential indirect effect • companies involved in networks and partnerships relevant for water eco-innovation may benefit from the collaboration by sharing information and creating shared visions that may also lead to concrete collaborations
		Technology platforms and innovation networks	
		Foresight and common vision building	
		Market intelligence and other forms of information sharing	

<table>
<tr><th></th><th colspan="2">Type of policy measure</th><th>Effects on water eco-innovation</th></tr>
<tr><td rowspan="10">Demand side focus</td><td>Regulations and standards</td><td>Regulations and standards (including targets)</td><td>• potential indirect effect
• performance standards and targets related to water quality and use drive (both technological and organisational) innovation efforts within companies and utilities as well as support wide diffusion of eco-innovative solutions</td></tr>
<tr><td rowspan="2">Public procurement</td><td>Public procurement of goods and services</td><td>• potential direct effect
• public sector can procure goods and services giving an explicit preference to innovative water efficient solutions</td></tr>
<tr><td>R&D procurement</td><td>• potential direct effect
• public sector can procure R&D on innovative solutions explicitly preferring water efficiency</td></tr>
<tr><td rowspan="2">Technology Transfer</td><td>Support for technology adopters (advisory services)</td><td>• potential indirect or direct effect (diffusion)
• companies may benefit from the generic technology transfer advise and/or specific advice on preferable water eco-innovation</td></tr>
<tr><td>Support for technology adopters (grants for purchasing new technology)</td><td>• potential direct effect (diffusion)
• companies may benefit from the grant purchasing water eco-innovative solutions</td></tr>
<tr><td rowspan="5">Support of private demand</td><td>Regulations (e.g. water charging)</td><td>• potential indirect effect
• faced with higher prices for water use, households seek water efficient (technological and non-technological) solutions</td></tr>
<tr><td>Tax incentives for consumers (e.g. for purchasing environmentally efficient products)</td><td rowspan="3">• potential indirect effect
• policy measures reducing the cost of environmentally efficient goods and services to consumer may influence the consumer's decision to purchase these goods or services, which in turn supports the producer and may indirectly support their eco-innovation activity</td></tr>
<tr><td>Tax reductions for products and services (e.g. VAT reductions)</td></tr>
<tr><td>Demand subsidies (including eco-vouchers)</td></tr>
<tr><td>Awareness raising and information provision (including labelling schemes)</td><td>• potential indirect effect
• measures aiming at providing the information on environmental performance of products allow consumer to make informed choices; assuming that consumer makes a choice to purchase eco-innovative good or service this supports the eco-innovative producer and may indirectly support their innovation activity</td></tr>
</table>

The implementation of EU directives was expected to require innovation and technological advancement. The requirement to reduce losses of substances into the environment included in the Environmental Quality Standards Directive (EQS), for example, was to kick-start the development and commercialization of cleaning - and cleaner - technologies. In particular, the obligation to halt discharges, emissions and losses of priority hazardous substances was expected to require a leap in innovation (EC 2006). Given the long-term perspective of 20 years, there was thought to be "enormous opportunity to develop new niche markets". (EC, 2006)

There is evidence on the positive influence of European legislation on innovation and technological advancement in some countries (see Krozer et al 2009). Caution is needed, however, in terms of expecting positive impacts of regulations on more radical innovations. Krozer et al (2009) list the possible perverse effects of public intervention that may hinder more significant innovations:

- Standards laid down in permits tend to discourage innovations, because policy-makers prescribe standards less stringent than the state-of-the-art possibilities to avoid the risks of non-compliance (Kemp 1994; Klink et al. 1991, ibid)
- Effluent charges are usually introduced to generate income for the water treatment utility in the public domain, which competes with the firms' impulse to innovate (Schuurman 1988, ibid.).
- Subsidies in water management discourage innovations when available technologies from the past share in this support (Nentjes and Scholten 1989; Kanazawa 1994, ibid).

Thus, public intervention can both drive and hinder innovation activity in the water sector. The regulations have an influence on innovation activity of a significant share of innovative companies. On the other hand, they do not support radical innovation and may unintentionally support the existing technological regime.

Efforts have been made to direct subsidies more precisely to encourage innovation, such as the UK's Enhanced Capital Allowance scheme for water efficient equipment and a Dutch government initiative to subsidise 'unexpected costs' during full-scale demonstration of novel technologies. These efforts target specific blockages in the development/adoption process and appear to be at least partly beneficial..

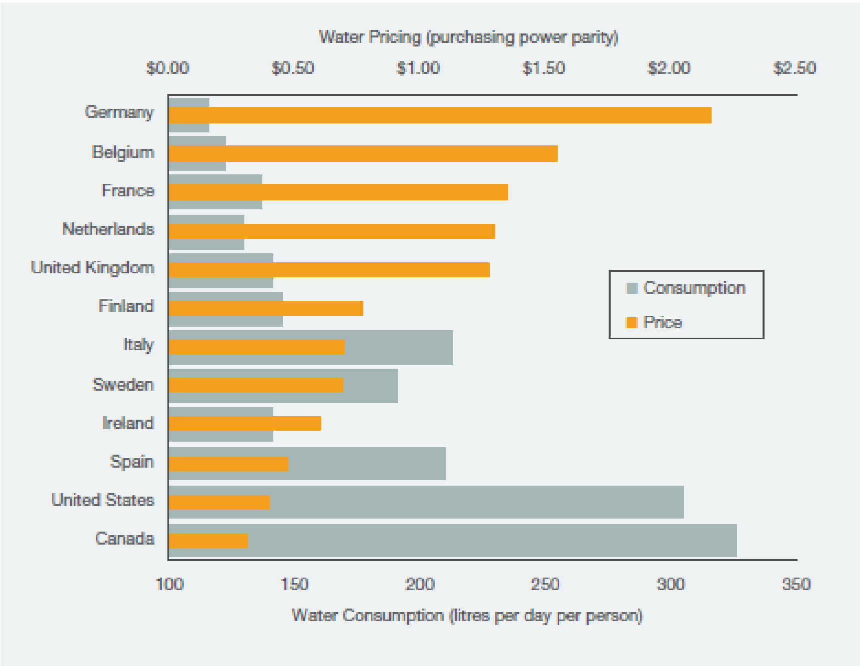
Water pricing

The prospect of rising costs, also due to rising prices of material, is one of the key factors that drive behaviour of companies. The EU Water Framework Directive, however, introduced a requirement of introducing adequate water pricing by 2015. Full pricing is to become an incentive for the sustainable and efficient use of water. Member States will be required to ensure that the price charged to water consumers (e.g. the abstraction and distribution of fresh water and the collection and treatment of waste water) reflects the true costs. These costs include in most cases a high percentage of fixed costs due to investment in infrastructure (WssTP, 2010).

It is also the case that water has a particular set of attributes associated with it that are not applicable to other resources or services. So it is that clean water is largely available throughout Europe at a very low price compared to many other 'essentials'. Until such time as water ceases to be freely available or is much more expensive there is little incentive for water utilities to invest heavily in innovation – they do not need to make their product cheaper and cannot materially alter its character. Yet in spite of the very low cost of domestic water, consumers are quick to complain when there is any interruption to supply, whereas the loss of mobile telephone signal, for which consumers often pay more than for water, is shrugged off as a minor inconvenience. This contradiction is known to economists as the paradox of value (or the diamond-water paradox), in which the usefulness of a commodity has no bearing on its exchange value. The issue is explored in the 2009 document 'Water: A Global Innovation Outlook Report' published by IBM. (IBM, 2009)

In this respect water is different and is perceived as a right. Consumers take for granted something, which was for their ancestors an unimagined luxury: fresh, drinkable water at the turn of a tap and toilet waste removed at the touch of a button. Although in many territories water and wastewater services have been privatized they are always regulated to ensure that all citizens have access to an essential service. This regulation includes price control and as such there is not scope for outright competition or excessive profits. Even so, it can be seen from Figure 10 below that there is scope for price adjustment in some territories.

Figure 10 | Water Pricing power (purchasing parity)



Source: 2030 Water Resources Group, 2010

Much has been written about the price-elasticity of water and it has been shown (e.g. EEA 2009) that where charging for water is based on volume rather than a flat-rate, less water is used and there is greater adoption of best-practice advice in relation to irrigation. This is particularly so when a threshold-based tariff is imposed such that the cost per cubic metre is more above a certain volume. According to the European Environment Agency, effective water pricing needs to be based, at least in part, on the volume of water used, rather than adopting a flat-rate approach. To this end, water metering plays a key role and must be implemented widely across all sectors as a spur to innovation and the adoption of innovative technologies and management practices.

Similarly, where water is used for industrial or commercial purposes but is a minimal element of the entire process there is no economic need to innovate in order to reduce or eliminate it. One mechanism to encourage change in these circumstances is through tax breaks for the purchase of water-efficient equipment such as the UK government's Enhanced Capital Allowance scheme. This permits 100% tax relief on purchase and installation of products from the Water Technology List; a selection of water-related technologies that have passed strict efficiency criteria. Because companies are incentivized to buy these technologies over alternative systems supplier companies are encouraged to innovate.

Expected regulatory changes are also among innovation drivers (Horbach 2009). Given the prospect of the rising cost of water, investments in improved water efficiency notably in water intensive sectors (e.g. agriculture, energy) may follow.

Governance and ownership of water infrastructure

The degree of fragmentation of water infrastructure and water utilities also has an influence on the propensity and capacity to innovate. In some countries (notably the Netherlands and the UK) capital-intensive operations have driven mergers in the water chain, which are assumed to be cost-effective due to economies of scale. In reality, however, they may incur higher costs and lead to a reduction in innovative efforts (Krozer et al 2009).

Particularly in the UK it is often said of the water sector that it is risk-averse (Council for Science and Technology, 2009). This situation arises from a number of factors, including governance and ownership. Many UK water companies are owned by consortia comprising superannuation (pension) funds and infrastructure investment funds looking for moderate but predictable returns on investment – a situation that is enhanced by the regulated non-competitive nature of the industry. UK water companies have long-established operating models, a transparent regulatory regime and a requirement from the regulator for 'strategic direction statements' to provide a 25 year context for the companies' five-year business plans. Innovation; the deployment of new business models or technologies, carries with it a certain degree of risk and in trying to get new technologies accepted by UK water company technical staff it is commonly held that there is a 'rush to be second', i.e. the water utilities will only accept innovation that has been demonstrated elsewhere.

A consequence of a small number of water utilities is that the procurement, or purchasing, is concentrated in the hands of a few individuals (or purchasing departments). Large organizations tend to operate on the basis of a 'preferred supplier' list and these are often dominated by larger firms, able to supply in bulk and offer discounts on multiple product lines. This is discouraging to smaller firms and, because they are established with a large customer there is less incentive for the preferred supplier to innovate.

Where the water sector has not been so consolidated or ownership remains in the hands of the municipality, innovation by the water utility itself may be restricted because of the relatively high cost; however a greater multiplicity of potential buyers can be a spur to the supply chain to devise a wider variety of technological solutions.

5.3.2 | Economic and financial factors[3]

Access to finance

Investment in new water technologies is relatively low and as such it does not drive the innovation in the sector. In a review of water start-ups and the VCs that backed them in 2009 Cleantech Group, LLC (www.cleantech.com) stated that. "*The price of water does not reflect its scarce nature and ultimately betrays its value. Holistic water policies and regulatory structures are emerging, but slowly. And buyers of water-related goods and services across public and private sectors have very different needs.* "

What did emerge from the analysis, however was that the more successful companies at attracting investment were those that emphasized solutions that help reduce customers' water and energy use. Whereas the total amount invested in water technology companies fell in 2009 the number of deals in early-stage resource management technologies, focused on improving water treatment and distribution efficiency increased.

The publication of the Water Disclosure 2010 Global Report by the Carbon Disclosure Project, along with initiatives such as the CEO Water Mandate and the popularization of the concept of the water footprint are likely to draw increasing amounts of attention to the dependencies of large corporations on access to supplies of fresh water (what might be termed 'Corporate Water Risk'). In time, investors will demand to see reporting of this exposure and to know what measures are being taken to minimize liabilities, in the same way as we have seen the rise in environmental reporting. Indeed, a few companies, such as brewers SAB Miller, are at the forefront of this trend. The increased visibility of water as a material consideration in the valuation of companies seems likely to drive innovation in methods to reduce reliance on water through efficiencies and substitution by non-water based methods.

Investment in innovation from private water companies may also be less forthcoming than perhaps it should be. The cost of capital for private water utilities is linked to their market valuation which, in turn, is dependent on the value of infrastructure. By spending money on capital works programmes (Capex) rather than the refinement of or innovation in operational aspects of a system (Opex) a company may be perceived to have strengthened their asset base; thereby rendering themselves more 'investable'.
There is a widely held perception that water companies are psychologically (or culturally) wedded to Capex solutions because 'that is what they do'. In an interview with BlueTech Blog in 2010 Peter Williams' CTO of IBM's Big Green Innovations Unit gave a slightly pessimistic view about the likelihood that water utilities are looking at smart network approaches:

"I could show you an example — I'm not going to name them — where we demonstrated that applying a more analytic approach to the management of their combined sewer overflow could probably save them about $15 million bucks worth of new sewer. We proved it, and they still went ahead and built the new sewer. That's what they do — "Hey, we're concrete and steel guys"

[3] *In 2006 a report published by Sir Nicholas Stern discussed the effect of global warming on the world economy. A "Stern Report" for water does not yet exist however it is understood that such an endeavour is being undertaken as the result of cooperation between WssTP and EWP, so as to reveal the enormous impact that water has on the economy.*

Global market for water technology

Water and wastewater technologies and integrated water management systems are of high demand in many regions of the world, notably in the fast developing countries such as China and India. European companies are entering the international arena to secure new markets however those that can afford to undertake the business development and marketing are primarily the larger and more established suppliers, unless supported by government trade initiatives. It is therefore questionable whether they are the providers of truly innovative solutions.

Based on the research for this report it appears that those countries making significant investment in support for innovation in the area of water technologies are those faced by immediate resource constraints (Israel and Singapore in particular). Whereas there are myriad documents relating to world water shortages and quality problems, it seems that the development of an export market comes on the back of domestic demand rather than on the basis of knowledge that demand exists elsewhere.

5.3.3 | Technical and technological factors

Technological lock-ins: water infrastructure

Water infrastructures are vast interconnected physical multi-modular facilities that require major investments if they are to be revamped. This dependence on the existing infrastructures is a barrier to introducing major innovations in a sense that in order to improve their efficiency on the system level the change would have to a coordinated effort encompassing the entire network.

Krozer et al (2009) confirm that lock-in in water management occurs because of the large sunk costs of past investments. In the Netherlands, nearly three-quarters of the total annual water management costs are depreciation costs of past infrastructure investment at the interest rates far below the commercial interest and this infrastructure remains in place for decades (ibid). This barrier can be generalised to other European counties with management costs differing depending on the quality, size and age of infrastructures. Another hindrance to innovation is that a large part of the investment in the water industry is for fixed constructions, and this limits their export potential (ibid).

Technological lock-ins: energy generation and irrigation systems

Taking into account that water efficiency improvements can be achieved in most water intensive sectors, the innovations depend also on the quality of infrastructures in these sectors, notably the systems used in cooling processes (energy sector) and irrigation (agriculture). These dependencies can be both drivers and barriers to water innovation. The prospect of increasing price of water may lead to reconsideration of investment decisions in these sectors.

Technological advancement: waste water as a resource

As indicated in the previous sections waste water is increasingly seen as a resource and can become an important source of energy or specific minerals and substances, such as phosphates. This perception is due to new processes that allow the isolation of useful elements from waste water. Technological and scientific advancement if economically viable is a key driver of eco-innovation in this sense.

5.3.4 | Environmental factors

Water scarcity and variability
Difficult access to, or variability in access to, water inspires the search for novel technological and behavioural solutions. The former include development or transfer of water efficient technologies (e.g. irrigation). Behavioural innovation includes measures such as the provision of incentives for homeowners in arid or semi-arid areas to plant native species and remove lawns from their gardens. Such an approach has been demonstrated in pilot programmes in America such as Reno and Sparks in Nevada.

Water scarcity appears also to be a driver for innovation support mechanisms, notably in the two examples quoted previously: Israel and Singapore. Both of those states are constrained in their ability to import water owing to historic diplomatic issues with neighbouring countries relating to water rights. With growing populations and a degree of uncertainty about the continued security of supply it is in those countries' governments' interests to promote and support technological innovation to reduce dependence on external sources. What begin as responses to internal demands develop into exportable solutions.

Although many nations recognize the looming problems associated with water shortage it is perhaps the more imminent and easily-recognized resource constraints that focus the attention of governments.

Water pollution
The low quality of drinking water can have serious health impacts. As such it is a strong driver of applying innovative solutions to improve water quality. An interesting illustration of this point was the introduction in 2001 of a limit of 10 micrograms per litre for bromate in drinking water in Europe. This immediately rendered groundwater in a large chalk aquifer in south east England contaminated and unusable, requiring Thames Water and Veolia Water to think hard about how to supply customers in that densely populated part of Europe and adopt innovative solutions to overcome the sudden shortage in resource.

More commonly, water quality is degraded over a long period, for instance as a result of nitrates from fertilizers leaching into groundwater or the accumulation of phosphates. These changes in quality force water utilities and other users to seek out innovative treatment or management solutions.

Much work is currently being undertaken across Europe (e.g. The Drastrup Project, Aalborg, Denmark; Sustainable Catchment Management Programme, United Utilities, North West England; Groundwater Protection Programme of the Water Board of Oldenburg and East Friesland (OOWV), North West Germany) to establish best-practice for catchment management. Whilst not usually involving technological innovation these solutions nevertheless rely on innovative approaches to agriculture and land management. In some cases land is taken out of agricultural production altogether, in others those with responsibility for water quality work with farmers to develop best practice in order to minimize pollution.

5.3.5 | Social capital and knowledge factors

Understanding water innovation: from efficient pipes to GMO crops
One of the important drivers of innovation in water use may be "framing" of what water innovation is in the research and innovation support programmes and for the purpose of attracting funds. In the Report Water: A Global Innovation Outlook, the authors state that "*the economics of water can be complex and confounding to most business people. Whether you're building a business around it or attempting to invest directly in it, water often defies common business sense... That is not to say there is no commercial opportunity in water, however difficult it is to identify.*"

The introduction of realistic pricing models and other financial innovation will probably make it easier to invest in water infrastructure and water utilities; however for the innovators and entrepreneurs looking to raise finance for new technologies the ubiquity of water is a problem. It appears that investors are becoming more aware of water management issues[4] but perhaps greater emphasis needs to be placed on the consequential benefits such as resource husbandry, energy saving, cheaper crop production and reduced maintenance. Since these are often more familiar concepts they may be more palatable to the financial sector than 'water' which is largely a mystery to those not involved in its management. Thomas Schulze, Chief Executive Officer of Cleantech Europe, a Munich-based venture capital firm says, "We need a Google of water. We are still looking for that outstanding innovator, that brand that defines the sector and excites the market."

The unique character of water: water and public health

The interest in water innovation may be supported by the unique character of water seen as a "vital" resource closely linked to the public health issues. As such, water innovation, notably linked to the provision of drinking water and food production, 'should' easily attract investment, notably from the public sources. In reality, because of the often hidden nature of water and the perception of water as a public good it is sometimes difficult for governments to justify large-scale expenditure on infrastructure projects that are not visible.

[4] *e.g. The publication of documents such as the CDP Water Disclosure Report*

6 | Visions of sustainable water innovation

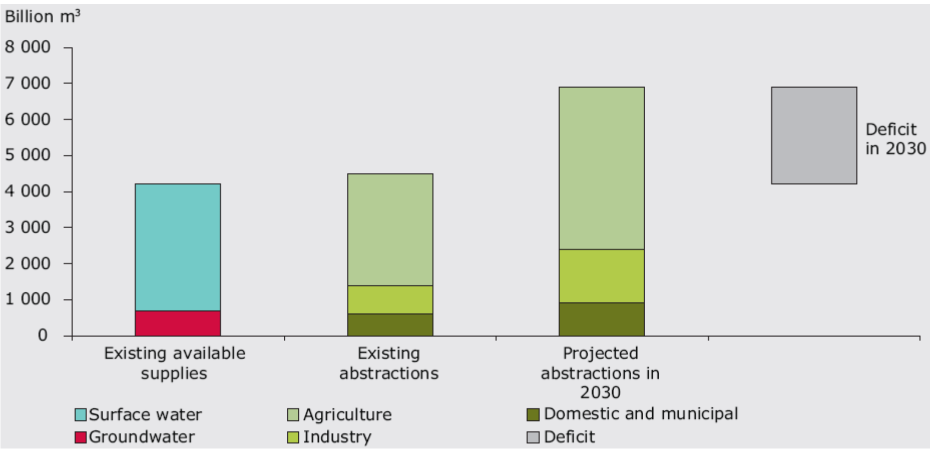
Future trends in water use and water scarcity

The 2030 Water Resource Group estimates that by 2030 more than a third of the world's population will be living in river basins that will have to cope with significant water shortages, including many in countries and regions that drive global economic growth. The authors foresee that in just 20 years global demand for water will be 40 % higher than it is today, and more than 50 % higher in the most rapidly developing countries (see Figure 10). Extrapolating historic rates of supply expansion and efficiency improvement only a fraction of this gap will be able to be closed using current knowledge and technology. This circumstance will result in an increase in population suffering hunger and also in environmental degradation - unless local, national and global communities come together and dramatically improve the way they consider and manage water. Further, economic development itself will be at risk in many countries (2030 Water Resource Group, 2009).

European and national outlooks

In its new report The European Environment – State and Outlook 2010 the EEA compares different analyses regarding the future situation in terms of water availability and use in Europe and concludes that compared with the global situation water stress in Europe may be easier to manage. Scenario calculations show that demand for water in most of Europe is expected to be stable or to decrease. More efficient use of water by all sectors together with a generally stable population, as well as the projected limited change in the area of irrigated land are assumed to lead to decreasing water demand. Still, in specific river basins high demand combined with low availability will result in continued water stress (EEA, 2010).

Figure 11 | Forecast of global water demand



Source: 2030 Water Resource Group, 2009

2050: How Europe uses water

Although it is specific to the UK Market, the report (A Vision for a Low Carbon Water Sector in 2050', published by the Environmental Sustainability Knowledge Transfer Network (ESKTN)) is a useful reference for those wishing to see how water might be managed differently in the coming decades (ESKTN, 2010). The following scenario is of course one of many possible outcomes but references innovation mentioned earlier in this report and information in the ESKTN document. It also draws heavily upon the document "Water for a sustainable Europe – our vision for 2030" by the European Water Partnership, which looks at the attitudinal shift and legislative drivers that will be needed to achieve sustainable water resource management and universal access to modern and safe water supply and sanitation.

In the European Union of 2050 the population is similar to that of 2010, i.e. 510 million (PRB, 2010) and climate change has resulted in weather patterns which bring slightly increased average precipitation but with more intense precipitation events (especially in winter) and droughts in summer (IPCC,). This leads to losses from aquifer storage as runoff from saturated or frozen ground increases in winter and there is less rain to replenish soil moisture deficits and fill reservoirs in summer. As such there is somewhat less freshwater available in large-scale storage (although this is made worse by the constantly increased demand for a meat-based diet, requiring ever-greater drinking and process water for animal growth and meat preparation, coupled with an increase in the growth of high water-demand crops as other nations, formerly exporters of 'virtual water' seek to address internal food demands).

There is still marked spatial variability and in Southern Europe there is significantly less precipitation. Even so, because of advances in desalination and greater efficiencies from wind and solar power, large volumes of sea water are used in the irrigation of crops in the vicinity of coastal regions, alleviating much of the stress from aquifers, rivers and reservoirs.

Source: Low Pressure Manipulated Osmosis Desalination plant by Modern Water, Oman

Distributed monitoring networks continually record levels, temperature, chemical and biological quality in water bodies and feed these into dynamic models, updated in real or near-real time, permitting automated decision-making regarding abstraction and recharge. Much salad crop production is done in indoor 'vertical farms' and glasshouses with advanced water management and reuse.

Source: Vertical farm as envisaged by Dr Dickson Despommier, Columbia University

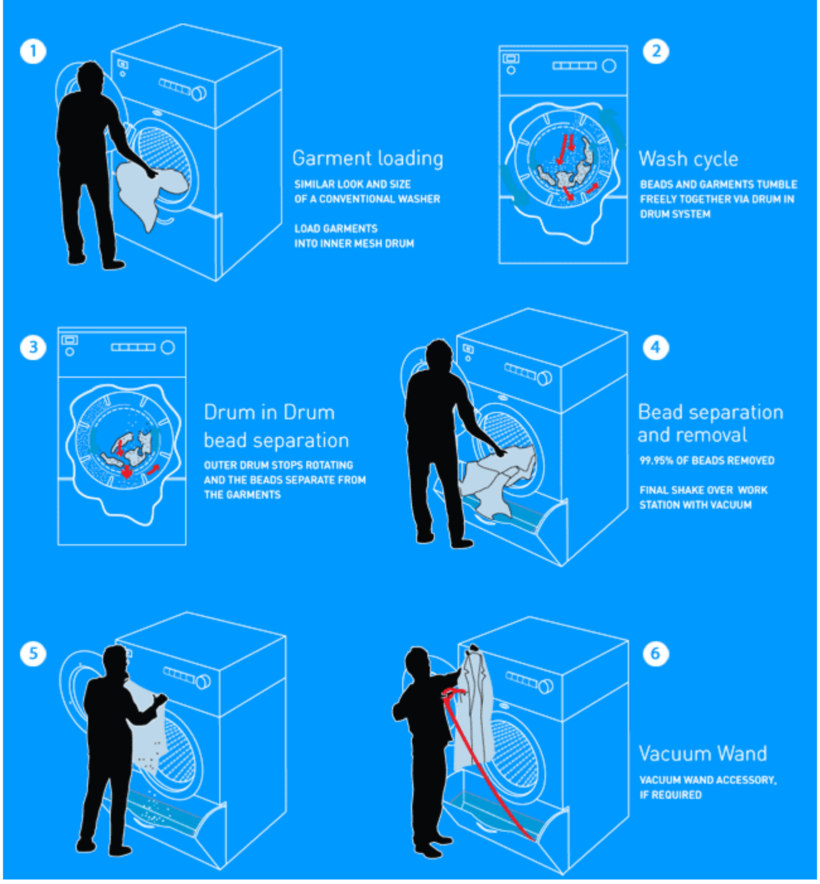
Intake monitoring, integrated with the catchment-scale monitoring, predicts quality changes and enables water companies to avoid abstracting low-quality water which is, in any case, rarer thanks to improved wastewater and industrial effluent treatment. As such, the degree of treatment required is considerably less and comprises mostly biological methods in combination with functionalised, self cleaning membranes based on nano-technology, passive aeration and daylight-activated UV catalysis.

In spite of the additional stresses on the urban water infrastructure as a result of increased urbanization of society, water is pumped into distribution systems in which leakage has been universally reduced to less than 5%. This is thanks to a combination of pervasive system-monitoring and pressure optimization, in conjunction with fault detection and pipe re-lining or spot repairs in legacy pipework and self-healing pipe materials in newly-laid systems. Distributed energy recovery devices that harness excess pressure enable the utility company to recover some of its power costs by selling the electricity for recharging electric vehicles at roadside boxes.

Source: Zeropex difgen micro-hydro generator as replacement for PRV

Because of the effective communication campaigns and 'nudge' policies (social innovation), Europe has learnt to embrace the waterless washing machine and realised that it is not necessary to shower every day. Nano-technology paint coatings mean that cars no longer need to be washed and the cost of water makes domestic irrigation less acceptable. The widespread acceptance of the re-use of grey water and 'fit-and-forget' compact treatment technologies mean that when showers are taken the water is recycled for toilet flushing or watering of private lawns. Since public perception of the quality of water is now much more favourable and water is valued much more highly (partly as a result of increased prices, largely due to universal metering and the consequent 'visibility' of water) there is greater direct consumption of water from the tap - offsetting the dramatic reduction in purchase of bottled water as the wise citizens of Europe realize they have been duped for many years. Still, the average per-capita water use has reduced from circa 130 l/day to 80 l/day.

The Xeros polymer cleaning process can be applied to numerous cleaning sectors - both commercial and domestic. However, the team's first objective is to build a system for the Commercial laundry sector, designed to wash garment loads up to 20 kg per cycle.



Source: The Xeros waterless washing machine

Unintended consequences of the reduction in leakage and water use and segregation of surface drainage from sewerage systems are that insufficient flushing of pipe networks, designed on the basis of much higher flow rates, results in the build-up of sediment which, in turn, requires greater levels of pipe-cleaning. Some groundwater abstraction boreholes have to be reactivated in cities purely to maintain stable groundwater levels as the reduced demand from heavy industry and a more efficient distribution system lead to rising water tables and this, in turn, results in flooded deep basements and destabilization of buildings.

Due to the full implementation of the Urban Waste Water Treatment Directive, nearly all Europeans are connected to efficient and effective treatment systems. The sewage that is collected is considered a resource and the recovery of phosphates and nitrates for use in fertilizer is commonplace. Anaerobic digestion, often co-digestion with food and other organic wastes, is widespread and the gas generated is used to fuel turbines which supply electricity for use on site, with the surplus being exported to the grid or used by local industry. In many areas of water stress the final effluent (or 'new water' as it is termed due to the very high quality) is re-used for industrial, agricultural and even potable supply.

The water that is discharged back to the environment is of such good quality that Europe is well along the road to full compliance with the terms of the Water Framework Directive, with the vast majority of water bodies achieving 'good ecological status'. This has been achieved with the application of a whole range of novel technologies and driven by successive acts of legislation targeting different contaminants.

The importance of water has long been recognized by European governments and the problems associated with population growth, water quality and water shortage elsewhere in the world have been identified as economic opportunities by governments and businesses. Innovation in technology has been stimulated by a portfolio of measures drawing upon the experiences of different countries and as a consequence European countries are at the forefront of water treatment, measurement, monitoring and management.

7 | Main findings and key messages

Water innovation is diverse and pervasive

1. Innovation in respect of water is widespread and diverse because water is so central to human existence and activity. It encompasses both technological and non-technological solutions. Technological solutions range from highly complex technologies for modelling, monitoring and controlling distributed multivariate systems to technologies developed in other industrial sectors which are adapted to the water industry. Non-technological solutions include awareness-raising activities, organisational changes or novel pricing structures based on the full costing of water.

2. Eco-innovation can influence both demand and supply of water. Both technological and non-technological solutions can be applied to influence either supply or demand. In order to better use and conserve fresh water in Europe and the world it is necessary to foster a broad range of innovation activity addressing both demand and supply of both technological and non-technological innovations.

Addressing the structural issues

3. The water sector has so far benefited mainly from incremental eco-innovations. Particularly in the water supply and sanitation industry, improvements have tended to be incremental and largely in response to legislative drivers. Success in that sector might be viewed as the avoidance of litigation by meeting performance standards whilst operating within the parameters set out in the business plan. In the absence of direct competition between suppliers it is difficult to invoke the profit motive as a spur to thinking about how things might be done differently. As such the supply chain has improved and evolved technology but with relatively few step-changes in approach, guided by the conservative end-user market.

4. The water sector faces significant barriers to advancing innovative solutions. The structural barriers include notably:

- Firstly, those that benefit from innovation in the water sector are often not in a position to demand those changes. Public policy and regulation should act in the interests of the beneficiaries, however these systems are often imperfect.
- Secondly, innovators face the high sink costs of previous infrastructural investments and concerted actions for innovations are needed to overcome the costs.
- Thirdly, capital-intensive operations have driven mergers in the water chain, which are assumed to be cost-effective due to economies of scale but in reality can incur higher costs and lead to a reduction in innovative efforts.

Public intervention to stimulate the market for water innovation

5. It is apparent that the ownership and governance of a water supply and wastewater treatment sector and the degree of fragmentation or consolidation plays a role in determining how much risk is considered acceptable and therefore how much innovation will take place in a given territory. Where an industry is

particularly risk-averse, or where there are other market or systemic failures, such as failures in networks of actors in the innovation system or of frameworks and institutions, it is perhaps necessary for government to intervene to promote innovation It is reported that, because of the intervention, and the focus on a dedicated water innovation program, set up by the government in close cooperation with the whole water sector (organised under the umbrella of the Netherlands Water Partnership), the Netherlands was able to double the export of Water Technology in the course of 5 years, as expressed by the Water Export Index (WEX) (Gibcus & Verhoeven, 2008).

6. Assistance to innovators that create high-value niche products could challenge the vested interests through more new, cost-effective options but providing this assistance would involve risk-taking policies. There seems to be no simple way to address the issue of innovation in the water sector. Rather, a combination of policy measures,such as the introduction of full cost pricing, and measures to facilitate entry to market by innovators is required.

7. This report references a significant number of initiatives intended to promote innovation in the water sector, from the state-sponsored, through public-private arrangements of varying configurations to the purely private-sector. Two promising alternatives to government intervention are seen in the form of collaborative programmes (Acqueau and Innowater) and private-sector supply chain initiatives such as Water Innovation Network and WaterTAG. The success or otherwise of the different models is difficult to determine although anecdotal evidence suggests that the Water TAG in UK has achieved a high percentage of uptake and there appears to be a large number of new companies from Israel challenging the established water technology suppliers.

Focussing on sectors and supply chains

8. In promoting policies to effect the greatest impact on the use of fresh water resources it is perhaps worth targeting those sectors in which water consumption (or usage) is greatest. Incentives that attract technology developers to those sectors will achieve the maximum environmental impact in respect of the water environment. For this reason it is considered appropriate that attention is given to the ongoing work which seeks to determine the water footprints of sectors and products.

9. In the light of the concept of "virtual water" it is of crucial importance to aim for innovation activities along the whole production and supply chain. This is also relevant for the parts of the supply chain, which are located outside of the European Union. Where the EU is heavily reliant on imported goods and produce that have high water input in their growth and production it is, by implication, vulnerable to changes in water resource availability and regulation in the exporting countries. By mapping the major components of the European water footprint it will be possible to establish where it would be in the EU's interests to promote innovation to reduce reliance on those products or to permit them to be produced with less water.

A market opportunity

10. Due to the decline of heavy industry and the stabilisation of population growth, it is foreseen that in many parts of northern Europe water usage will remain stable or actually decline. There is a danger that this will be taken as a signal that support for innovation in water technologies by EU countries is not necessary, As such, in the absence of concerted eco-innovation-enabling tools, the solutions to the problems which seem likely to arise in southern Europe might well come from non-European countries. In

reality there is a significant and growing market for eco-innovative water technologies within those parts of Europe where climate change will be felt most strongly, in addition to the huge global market Whereas those countries that currently lead the world in terms of water innovation do so through response to water scarcity in their own territory, European governments may need to look beyond their borders for compelling reasons to stimulate the development of radical new technologies for managing water and to do so through non-technological measures

Box 6 | Critical Actions

To aid and enable greater levels of eco-innovation in Europe in the area of water, the following actions are recommended:

- Introduce full-cost pricing for water such that its true value as an economic resource is recognized widely throughout industry and society, for which it will also be necessary to;
- Engage public opinion. Make the visibility of water consumption greater, through the widespread use of information campaigns and metering of domestic properties.
- Focus measures to foster innovation activity on those industry sectors where the largest impacts can be achieved.
- Examine the water footprints of major European imports to determine where there are supply-chain vulnerabilities, which might usefully be addressed through innovation in respect of water. Engage with the agenda on the life cycle water footprint labelling of products.
- Review the European policy landscape in respect of measures encouraging water innovation, with a view to publishing a guide for legislators.
- Study carefully those initiatives (both in Europe and beyond) that have demonstrated success in stimulating innovation in the area of water technology and use so as to develop best-practice solutions for implementation in the EU.

References

Allan, J. A. (1993)
"Fortunately there are substitutes for water otherwise our hydropolitical futures would be impossible" In: ODA, Priorities for water resources allocation and management, ODA, London, pp. 13-26.

Bocanegra, E., et al. (2005)
Groundwater and Human Development, Balkema, Leiden Chapagain, A.K. and Hoekstra, A.Y. (2004) ‘Water footprints of nations’ Volume 1: Main Report’, Value of Water Research Series No. 16, UNESCO-IHE

Biomimetic Watermembrane Research Project (2010)
http://www.watermembrane.dk/About_the_Water membrane_Project.aspx

Cath, T.Y et al (2006)
“Forward osmosis: Principles, applications and recent developments”. Journal of Membrane Science 281 70-87

Chapagain, A. K. and S. Orr (2008)
UK Water Footprint: The impact of the UK's food and fibre consumption on global water resources, Volume 1, WWF-UK, Godalming, UK.

Cleantech (2010)
http://www.cleantechinvestor.com/portal/water/6445-israel-the-qsilicon-valley-of-waterq.html

Council for Science and Technology (2009)
Improving innovation in the water industry: 21st century challenges and opportunities. http://www.bis.gov.uk/cst-reports#Water

Dietzenbacher, E. and Velázquez, E. (2006),
"Virtual water and water trade in Andalusia. A study by means of an input-output model," Working Papers 06.06, Universidad Pablo de Olavide, Department of Economics

EEA (2009)
Water resources across Europe — confronting water scarcity and drought ISSN 1725-9177

EEA (2010)
Use of freshwater resources (CSI 018) http://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources/use-of-freshwater-resources-assessment-2

EEA (2010)
The European Environment. State and Outlook 2010. Water Resources: Quantity and Flows. EEA Report, European Environment Agency, Copenhagen.

Edler, J. and Georghiou, L . (2007)
Public procurement and innovation – resurrecting the demand side. Research Policy 36, 949–963.

Ekins, P. (2009)
Resource Productivity, Environmental Tax Reform and Sustainable Growth in Europe. Anglo-German Federation ISBN: 978-1-900834-53-7

EPRI (2006)
Water & Sustainability (Volume 3):U.S. Water Consumption for Power Production – The Next Half Century, Topical Report March 2002, EPRI, Concird. Viewed 1 November 2006. http://www.epriweb.com/public/000000000001006786.pdf

Ercin, A.E., Aldaya, M.M. and Hoekstra, A.Y. (2009)
A pilot in corporate water footprint accounting and impact assessment: The water footprint of a sugar-containing carbonated beverage

ERM (2010)
CDP Water Disclosure 2010 Global Report. Carbon Disclosure Project. http://webadmin.cdproject.net/CDPResults/CDP-2010-Water-Disclosure-Global-Report.pdf

ESKTN (2010)
A Vision for a Low Carbon Water Sector in 2050 A Priority for the UK Strategic Report produced by the Environmental Sustainability Knowledge Transfer Network.

European Commission (2006)
Proposal for a Directive of the European Parliament and of the Council on environmental quality standards in the field of water policy and amending Directive 2000/60/EC {COM(2006) 397 final}{COM(2006) 398 final} .

European Commission (2007)
Communication from the Commission to the European Parliament and the Council: Addressing the challenge of water scarcity and droughts in the European Union COM(2007) 414 final

European Commission (2010)
COM (2010) 546 final Communication from the Commission to the European Parliament, the Council, the Europan Economic and Social Committee and the Committee of the Regions Europe 2020 Flagship Initiative Innovation Union SEC(2010) 1161

European Commission (2011)
Flash Eurobarometer FL315, Attitiudes of European entrepreneurs towards eco-innovation

Eurostat (2004)
The European Strategy for Environmental Accounting. European Commission

FAO (2010)
Main Country Database. United Nations Food and Agriculture Organization http://www.fao.org/nr/water/aquastat/dbase/index.stm

Gibcus and Verhoeven (2008)
De Watersector Exportindex (WEX) Zoetermeer, February 2008. EIM

Greentech Media (2010)
Greentech Media Research & Analysis | Air & Water, Eric Wesoff: September 1, 2010 eRealities of VC. Investment in Water Tech http://www.greentechmedia.com/articles/read/Realities-of-VC-Investment-in-Water-Tech/

Griffithhack.com.au (2010)
Water innovation in Australia: pipeline to profit? www.griffithhack.com.au

Hoekstra, A.Y. (2006)
'The global dimension of water governance: Nine reasons for global arrangements in order to cope with local water problems' UNESCO-IHE Research Report Series No. 20

Hoekstra, A.Y. and Chapagain, A.K. (2007)
Water footprints of nations: water use by people as a function of their consumption pattern, Water Resources Management. 21(1): 35-48.

Hoekstra, A.Y. and Chapagain, A.K. (2008)
Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M. (2009)
Water Footprint Manual - State of the Art 2009. Water Footprint Network, Enschede, Netherlands.

Horbach. J. (2005)
Determinants of Environmental Innovation – Theoretical Concepts and Empirical Evidence from Different Data Sources. DIME Workshop, Karlsruhe.

Horbach, J. (2008)
"Determinants of Environmental Innovation: New Evidence from German Panel Data Sources", Research Policy, Vol. 37, pp. 163-173.

IBM (2009)
Water: A Global Innovation Outlook Report http://gio.typepad.com/blog/2009/03/gio-report-on-water.html

IPCC (2007)
Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, (2007) Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

i-sis.org.uk (2007)
Biogas Bonanza for Third World Development, i-sis.org.uk, retrieved 4.11.07, cites United Nations Development Programme (UNDP) 1997 Report, Energy After Rio: Prospects and Challenges

Kanazawa, M. T. (1994)
Water Subsidies, Water Transfers, and Economic Efficiency. Contemporary Economic Policy, 12: 112–122

Kemp, René (1994)
'Technology and the Transition to Environmental Sustainability. The Problem of Technological Regime Shifts', Futures 26(10): 1023-46.

Klink, J., et al. (1991)
Technologische ontwikkeling en economische instrumenten in het milieubeleid, Nederlandse Organisatie voor Technologisch Aspectenonderzoek, Den Haag, p. 42–45.

Krozer, Y., et al. (2009)
Innovations in the water chain – experiences in the Netherlands.
Journal of Cleaner Production, 23 September.

Krozer, Y. et al. (2010)
Innovations and the Environment. Springer

Lanjouw, J. & Mody A. (1995)
Stimulating Innovation and International Diffusion of Environmentally Responsive Technology, World Bank, Washington, DC.

Majumder, M. Et al (2005)
"Nanoscale hydrodynamics: Enhanced flow in carbon nanotubes". Nature 438:44

Molden, D. Et al. (2007)
"Trends in Water and Agricultural Development" in Water for Food Water for Life: A Comprehensive Assessment of Water Management in Agriculture Ed. Molden, Earthscan

Nentjes, A. and Scholten, H. (1989)
Een financiële impuls voor het milieu? Tijdschrift voor Politieke Economie, jrg. 12, nr.1: 17-27

OECD (2004)
Organisation for Economic Co-operation and Development (OECD) (2004) *Agriculture and the Environment: Lessons Learned from a Decade of OECD Work.* OECD, Paris.

OECD (2011)
Greening Household Behaviour: The Role of Public Policy, OECD Publishing.

Olsen, Thomas (2003)
The Danish NAMEA Water Accounts with Examples of Its Use. Statistics Denmark 2003.

PRB (2010)
2010 World Population Data Sheet Population Reference Bureau
http://www.prb.org/pdf10/10wpds_eng.pdf

Rennings, K. and Rexhäuser, S. (2010)
Long-Term Impacts of Environmental Policy and Eco-Innovative Activities of Firms, International Journal of Technology Policy and Management (IJTPM) Special Issue "Laws, regulation and New Product Development - The Role of the Regulatory Framework for the Management of Technology and Innovation".

NewScientist.com
http://www.newscientist.com/article/dn19386-for-selfhealing-concrete-just-add-bacteria-and-food.htm

Rosengrant, M.K., Cai, X. and Cline, S.A. (2002)
World Water and Food to 2025. Washington, DC: International Food Policy Research Institute.

SABMiller and WWF-UK (2009)
Water footprinting: Identifying & addressing water risks in the value chain, SABMiller, Woking, UK / WWF-UK, Goldalming, UK

Schuurman, Jacob, (1988)
De Prijs van Water, Arnhem: Gouda Quint BV

Seckler, D. et al, (1999)
Water Scarcity in the Twenty-First Century, Water Resources Development, 15, 29-42

Singapore International Water Week (2010)
"Daily Solutions". Singapore International Water Week, Issue #3, July 1, 2010

Sonnenberg, A.. et al. (2009)
Der Wasser-Fußabdruck Deutschlands: Woher stammt das Wasser, das in unseren Lebensmitteln steckt? WWF Deutschland, Frankfurt.

Statistisches Bundesamt Deutschland (2010)
Economy and Use of Environmental Resources Tables on Environmental-Economic Accounting Part 7: Use of water.
Statistisches Bundesamt, Wiesbaden

Stern, Sir Nicholas (2006)
Stern Review on the Economics of Climate Change
http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm
ISBN number: 0-521-70080-9

UNESCO (2009)
Water in a Changing World: The 3rd United Nations World Water Development Report

United Nations – Water (2007)
Coping with water scarcity – Challenge of the 21st century United Nations Statistics Division (2007) System of Environmental-Economic Accounting for Water.

Van Oel, P.R., Mekonnen M.M. and Hoekstra, A.Y. (2009)
The external water footprint of the Netherlands: Geographically-explicit quantification and impact assessment, Ecological Economics 69(1): 82-92.

Velazquez, E. (2006)
An input-output model of water consumption: Analysing intersectoral water relationships in Andalusia. Ecological Economics, 56, 226-240

World Resources institute and Rabobank (2002)
Watering Scarcity: Private Investment Opportunities in Agricultural Water Use Efficiency. Rabobank International.

World Water Council (2009)
Charting our water future.
http://www.worldwatercouncil.org/index.php?id=25

WssTP (2010)
Strategic Research Agenda: WssTP, A common vision for water innovation
http://www.wsstp.eu/files/WSSTPX0001/library/SRA%202010/WssTP%20SRA%20Internet%20version.pdf and
http://www.wsstp.eu/content/default.asp?PageId=911&LanguageId=0

WWF (Le Quesne, T. et al.) (2010)
The Implementation Challenge: Taking stock of government policies to protect and restore environmental flows. WWF

Yang, B et al., (2003)
Late Holocene temperature fluctuations on the Tibetan Plateau. Quaternary Science Reviews 22, 2335–2344.

Yang, Y et al., (2009)
Autogenous helaing of engineered cementitios composites nder wet-dry cycles. Cement and Concrete research, 2009; DOI: 10.1016/j.cemconres.2009.01.013.

About the Eco-Innovation Observatory (EIO)

The Eco-Innovation Observatory (EIO) is a 3-year initiative financed by the European Commission's Directorate-General for the Environment from the Competitiveness and Innovation framework Programme (CIP). The Observatory is developing an integrated information source and a series of analyses on eco-innovation trends and markets, targeting business, innovation service providers, policy makers as well as researchers and analysts. The EIO directly informs two major EU initiatives: the Environmental Technologies Action Plan (ETAP) and Europe INNOVA.

This thematic report explores how eco-innovation can contribute to the conservation of one our most precious resources; fresh water. It considers the uses of water and how to account for water consumption throughout the economy. It emphasises the importance of considering both technological and policy-based innovation and addressing both demand-side initiatives and supply-side responses. It also examines current examples of schemes to stimulate innovation and individual innovative technologies. The report argues that for innovation to be truly stimulated it is necessary to recover the full cost of water through pricing and that, for this to be enacted, there will need to be social learning through water metering and education of consumers.

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