Planning for resilient water supply and sanitation systems

State-of-the-art

SEVENTH FRAMEWORK PROGRAMME

Planning for resilient water supply and sanitation systems

State-of-the-art

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Summary

In FP5, the cluster project CityNet included projects with relevance for Work area 5 (WA5). Several projects were aimed to development of tools for decision support based on a description of the actual situation and statistical frequency for various types of situations. CityNet included rehabilitation of the networks, wastewater treatment plant, urban water management, river water quality, storm water hydraulics and urban water balance, but without a focus on the influence of global change on urban water systems.

The ongoing TECHNEAU project has a major focus on operation of the water supply systems, but the outcome will certainly be relevant for future planning of these systems as well.

NeWater is focusing on the river basin water management, with a management based on adaptation rather than experience is a goal. Included in NeWater is the possibility of adaptation of the river basin water management within a climate change scenario.

SWITCH has a focus on future storm water management, including technology for storm water control, decision-making and environmental change.

Work area 5 is designed to provide guidance and frameworks to help the utilities planning for more resilient water supply and sanitation systems in the context of climate change. It addresses the entire urban water cycle.

WP 5.1 addresses the water shortage that will increase in several cities as a consequence of the climate change. Future management must include IWRM (as in NeWater), alternative sources (like reuse as in SWITCH), leak reduction (through rehabilitation as in CARE, or by optimisation of network operations), or other possibilities to reduce water consumption. We may expect more severe variations in quantity and quality, and all these aspects have to be implemented in decision-making and planning.

WP 5.2 focuses on adaptation of water supply systems to new raw water qualities, both with regard to microbiological and physical/chemical parameters.

WP 5.3 will focus on storm water management, both with regard to issues addressed in the Flood directive, which is more towards possible damages in the urban areas, and the opportunities local intense precipitation means for water management. The latter will partly build on the outcome from SWITCH.

WP 5.4 focuses on the impact of both storm water runoff and sudden sea level rise on the sewer system, both the ability to transport the water and the influence on water treatment and the recipients.

WP 5.5 focuses on how the operation and maintenance of the water and wastewater infrastructure have to be adapted to a climate change scenario. The operation of the water supply systems will build on the outcome of TECHNEAU, while the maintenance of the transportation systems will partly build on CARE.

Previous project have produced several tools and considerable knowledge on how to operate and maintain drinking water, wastewater and storm water systems. In Prepared we intend to use and further develop these tools and knowledge on the aggravated and new challenges likely to be results from climate change, both with regard to robustness and resilience.
Important contributions from PREPARED will be guidelines for how to plan operation and maintenance for this new long-term situation, including modifications of elements like CSOs to minimize impact on recipients or human health.

In short: While most previous projects have addressed the present challenges, Prepared will address the upcoming challenges.

Contents

1 WP 5.1 Water scarcity

1.1 Legislation

Climate change impacts were identified in EU Water Framework Directive (WFD). It is stated that the RBMP (River Basin management Program) and the Programmes of Measures should take into account uncertainties over long-term factors such as climate change. WFD additionally provides tools and plans for public participation, pricing policies improving water resources sustainability by 2010 for control of water demand, River Basin Management Plans (RBMPs) by 2009 and implementation of the Programmes of Measures and achieve the environmental objectives by 2015. It is also emphasized that climate impacts caused by precipitation changes would not be expected to be a major threat to the achievement of good ecological status by 2015.

Currently, the legislative applications of countries for the safe use of treated wastewater have different approaches. Some countries have regulations, which are enforceable and some of countries use guidelines, which are only advisory. WHO and EPA guidelines are among this class. The guidelines provide information on methods of treatment, application of reuse alternatives and required standards for treated wastewater. Reuse applications are in the form of agricultural and/or landscape irrigation, in-house uses, industrial uses, aquifer recharge for non-potable and potable purposes, and aquaculture.

National guidelines for water reuse were published in August 2004 in the USA. However, regulations and guidelines are different from each state. State of Arizona, California, Florida, Hawaii, Nevada, Texas and Washington have own regulations which are quite different in terms of required treatment. In the State of California Title 22 regulations were revised in 2000, which is among the tightest. In the UK the Government's Market Transformation Programme (MTP 2007) examined the potential for developing water quality standards for rainwater and greywater and they suggested limits for 3 categories of reuse as external cleansing, drip irrigation and WC flushing (Environment Agency, 2008a,b). In the Mediterranean basin, Israel, Cyprus and Tunisia, are pioneer countries in the development of treated wastewater reuse practices. In addition to the increased water demand and water scarcity, it is thought that legislations are likely to increase the drive towards the reuse of treated wastewater.

1.2 Practices in the different European countries

Water resources management traditionally focused on supply-side approach focusing, water supplies ensured by using reservoirs, inter-basin transfers and increasing abstraction of surface and groundwater. Europe's reservoirs have a total capacity of about 1400 km^3 corresponding 20% of the total freshwater resource. Romania, Spain and Turkey, with relatively limited water resources, are able to store more than 40 % of renewable resources. Whereas, Bulgaria, Cyprus, Czech Republic, Sweden and Ukraine, have storage capacities in the range of 20–40 %. The number and volume of reservoirs in Europe grew rapidly in 20^{th} century. However, the rate has slowed considerably recently since, suitable river sites available for dams were used or due to the growing concerns for environmental impacts of reservoirs (EEA, 2007).

Demand management (DM) concept has been encouraged since 1990. As a result, legislative issues emerge and conservation programs, water saving measures have been implemented. DM is recognized as an adaptation measure for climate change (Water Working Notes, 2010). As a related improvement, development of river basin scale water balances are made (EEA, 2009). In addition, artificial recharge of groundwater by river water during high flow periods, is considered as a method to improve supply. It is used to produce drinking water in Belgium, Cyprus, the Czech Republic, Denmark, Finland, Greece, the Netherlands, Poland, and Spain. Furthermore, desalination plants are also playing an increasing role (EEA, 2009). Moreover, within the sustainable water management (SWM) concept, the use of waterless urinals, various types of composting toilets and water saving taps are also promoted to reduce water consumption.

The use of greywater for watering gardens and flushing toilets have been implemented in Cyprus, reducing water use by up to 40% on per capita basis (EEA, 2009). Greywater recycling started in Berlin in 1989 and 300-400 systems were reported to be operated in Germany successfully (Nolde, 2005). However, microbial quality of grey water always raises public health concerns. Coombes et al. (2000) reported that in Newcastle rainwater usage would promote potable water saving of 60%. The Millennium Green housing development project in UK uses rainwater for gardens, washing machines and toilet flushing (Environment Agency, 2008a,b). A study performed by Ghisi et al. (2006) in Brazil for 62 cities showed the potential water saving by using water harvesting ranges from 34% to 92% with an average value of 69%. Rainwater and grey water uses in water efficient buildings emphasizing legislative and regulatory issues are focused closely. Activities, especially in the UK, showed that it is possible to set up such buildings, provide further experience in this field and up to 20-30% potential savings may be expected in 20 years based on different scenario options (DG-Env., 2009).

The total volume of reused wastewater was reported to be 964 Mm^3/ year corresponding to only 2.4% of total treated effluent in Europe. Spain accounts for 347 Mm3/year and Italy is reusing 233 Mm^3/year treated effluent. 75 % of reused wastewater is used primarily in agriculture (Mediterranean EUWI Wastewater Reuse Working Group, 2007). Additional uses include irrigation of golf courses and municipal land and reuse by industry, which shows an increasing trend. The figures predict that Europe has not invested sufficiently in wastewater reuse (EEA, 2009).

1.3 Identified threats from climate change

Low rainfall, high population density, intensive irrigation and/or industrial activities, intensive energy production, water quality deterioration are the main reasons of water scarcity in Europe. Total freshwater resource in Europe is about 2270 km^3/year. Although, 13% of this resource is abstracted, overexploitation by sectors cause a threat to the water resources. Due to the imbalance abstraction and availability river flow reductions, low levels for lakes and groundwater and drying up of wetlands are encountered (EEA, 2009). Precipitation ranges 400-1000 mm/year for the Mediterranean region and central parts of Europe which, indicates a large variation. Moreover, considerable amount of precipitation is lost by evapotranspiration, the effective rainfall is envisaged to be less than 250 mm/year across much of Europe and for some parts 50 mm/year (JRC, 2006). As Water Exploitation Index (WEI), based on river basins, taken into account, most of the river basins are initially identified as water scarce by the Member States having a WEI above 10% (DG Env., 2007; EEA, 2009). Although, for some river basins, WEI is calculated to be below 10% they are still suffering from water scarcity. In this manner, the overall water scarcity area is estimated to be 418600 km² with the corresponding overall population of 76375000 inhabitants. Hence, 11% of the EU territory and 17% of the EU population have been affected so far by water scarcity. 62% of the total estimated affected area is in Southern Europe (DG Env., 2007). Up to 80 % of tourist stays in the regions in the period of May to September when water availability is at a minimum which also cause additional stress (EEA, 2009). According to the WSSTP (2010) water stress results from structural supply and demand imbalance and affects 130 million inhabitants (30% of European population) in Southern Europe but also in Northern countries such as Belgium, Denmark, Germany, Hungary and the UK.

Over the past 30 years, Europe has been affected by major droughts, in 1976, 1989, 1991, and 2003 summer, which covered large parts of the continent. The most serious drought in the Iberian Peninsula in 60 years occurred in 2005(UNEP, 2006). Climate models predict precipitation increase in northern Europe and a decrease in southern Europe, whereas, many parts of Europe may experience drier summers (EEA, 2008, IPCC 2008). Annual river flow is anticipated to decrease in southern and south-eastern Europe and increase in northern and north-eastern Europe (Arnell, 2004; Milly et al., 2005; Alcamo et al., 2007) In the Mediterranean region, some river basins, having low levels of water, may encounter 10% or more decreases as compared to today's levels by 2030. Furthermore, water availability varies more distinctly in longer term (DG-Env. 2007). Scenarios giving a 3°C global warming, as compared to 2°C, shows increasing risks of freshwater scarcity with increasing degrees for many Mediterranean and other subtropical regions (ENSEMBLES, 2009). Along these lines, the decrease in precipitation for Turkey is estimated to be up to 5-15% for 2021-2050.

For the A2 and B2 scenarios (IPCC, 2000), annual average runoff is predicted to increase in northern Europe (north of 47°N) by 5–15% and by 9–22% up to the 2020s and 2070s respectively (Alcamo et al., 2007). In the meantime, runoff is estimated to decrease by 0–23% and 6–36% up to the 2020s and 2070s respectively in southern Europe for the same set of assumptions. Moreover, climate change is projected to reduce water resources in many small islands by the mid-century (IPCC 2008). Projections indicate lower groundwater recharge, partly because of climate variations and higher abstractions (Eckhardt and Ulbrich, 2003). More decreases in groundwater levels are predictable because of the short recharge seasons and the drop in water

retention as snow. Since, increase in winter rainfall increases groundwater recharge, saturated soil conditions could mean occurrence of more surface run-off instead of infiltration (EEA, 2007).
As the pressure on water demand is quite high in coastal areas in Southern Europe, the reduced surface water during dry periods and reduced groundwater recharge will increase the pressure on groundwater significantly. Some groundwater bodies will not be suitable any more as drinking water because of saline water intrusion due to the rising sea levels. Climate change could also affect the variables of water quality. For instance, in the last century the water temperature of European rivers and lakes increased by 1-3°C. Water temperature increase causes reduced dissolved oxygen levels. In addition to that climate change has impacts on bacteriological parameters and nutrient cycles in aquatic systems (EEA, 2007).

1.4 Awareness of these threats and identified needs for changes in W&S works

Awareness of climate change impacts is generally high. Particularly Southern European Countries are aware of the negative impact of decreased precipitation from climate change on water supplies (EEA 2007). Significant changes potential in water resources and hydrology is expected. Policy-makers are generally well-informed. Initiatives including management of water scarcity are being planned. However, many adaptation activities seem to be focused on flood management. For water scarcity and drought, although the issue is recognized, activities not seem to be widespread yet. The major obstacle to the development of adaptation actions is considered to be uncertainties with respect to future climate change impacts.
In accordance with the study conducted for 20 cities and their utilities all over the world including Seville and Istanbul indicated that many cities have begun to face extreme climatic variability and its effects on water resources. Among these, 80% of utilities have faced extreme droughts (Wat. Working Notes, 2010). Extreme events may result in short term water supply reductions and lead utilities to implement water conservation measures. These measures can be in the form of DM such as water rationing and intermittent supply, which may be considered as unfavorable. This type of approach can be costly due to hydraulic shocks and long-term damages. A study conducted by EEA/German Ministry for Environment related to drought and scarcity measures actions were grouped as: technical measures to increase supply, increasing water efficiency economic instruments, restricting water use, spatial planning, forecasting and monitoring, insurance schemes (EEA, 2007).
Furthermore, the concept of Integrated Urban Water Management (IUWM), managing freshwater, wastewater and storm water for entire river basin is getting importance. IUWM requires the management of the urban water cycle in consideration with the hydrological water cycle and involves water facilities and their interactions. IUWM includes evaluation of alternative water sources, rainwater and reclaimed water (UNEP, UNESCO, 2010).

1.5 Gaps between present practice and identified or expected needs

In longer term, expansion of reservoirs and water-transfer schemes to overcome the climate change impacts and to tackle with water scarcity is thought to be non-sustainable. So, alternative and sustainable means of ensuring water supply have become gradually more crucial. Although, promoting demand-side measures, efficiency represent the most favorable approach to water resource management in Europe, for some regions demand may exceed availability (EEA, 2009). In this case more sustainable supply-side measures should be considered. Potentially, these methods include rainwater harvesting, reuse of grey water and treated wastewater. Rainwater, grey water, reclaimed water may constitute alternative water resources which are important for the point of potential enhancement of water supply along with the other benefits for pollution and hydraulic considerations. Reclaimed or harvested water can be employed for non-potable needs, in the form of toilet flushing, washing, irrigation, washing etc. or to increase groundwater when it is used for recharging the aquifers.

This approach, in turn, leads to resilient green cities adapted to climate change impacts to a substantial extend associated to infrastructure, water, wastewater, solid wastes, energy and transport management deliberations. Along these lines, referring to the figures described under the topic "EU practices" the relevant incentives as well as comprehensive implementation examples at various scales, so far seems to be insufficient to achieve the goal of "green cities". It should be pointed out that comprehensive pilot or real scale implementation examples are needed to cover the issues regarding legislation, most appropriate technology for design and operational ease, public acceptance, economy, risk management and mitigation and durability. Hence, although considerable amount of research are being conducted towards various directions, it is hard to conclude there are representative examples at sufficient number and scale to demonstrate or make use of the results for further innovative modifications. Regulations and rules should be determined based on the research and experience gained from practical implementations. Furthermore, monitoring and control strategies must be developed on local basis to follow-up the compliance with the developed legislative issues.

1.6 Overview - international projects

Some, examples of the projects on water stress in Europe are listed below.

Aquastress (http://www.aquastress.net)

Aquastress aims to develop stakeholder driven, European scale, comprehensive multi-sectoral, integrated (institutional, socio-economic, technical) approaches for the diagnosis and mitigation of water stress.

TECHNEAU (http://www.techneau.org)

Technology Enabled Universal Access to Safe Water. Traditional system and technology solutions for drinking water supply to cope with present and future global threats and opportunities.

WATCH (http://www.eu-watch.org/)

Water and Global Change, aimed bringing together the hydrological, water resources and climate communities to analyse, quantify an predict the

components of the current and future global water cycles and related water resources states.
CLIMATEWATER (http://www.climatewater.org/)
Adaptation strategies of climate change impacts and European water policies.
SWITCH (http://www.switchurbanwater.eu/)
Managing water for the city of future. The vision of SWITCH is for sustainable urban water management in the City of the Future.
ENSEMBLES (http://ensembles-eu.metoffice.com/)
Climate change and its impacts at seasonal, decadal and centennial timescales.

1.7 National projects – References

Projects of TUBITAK MRC on water reuse

Sustainable water management and reuse is one of the major research fields of MRC Environment Institute where several relevant international and national level projects have been conducted to obtain reusable water from domestic or industrial sources. Some of the projects conducted by MRC or taken part as a consortium are listed below.

EU MEDA Program project: Sustainable Concepts Towards A Zero Outflow Municipality (Zer0-M)

Zer0-M aimed at concepts and technologies to achieve optimized closed-loop usage of all water flows in small municipalities or settlements (e.g. tourism facilities) not connected to a central wastewater treatment. Several technologies were practiced for wastewater treatment and reuse. These included sanitation systems with low water consumption, separation of grey and black water, biological treatment of grey and black water for reuse for non-drinking purposes and rainwater harvesting. Within the scope of the project, grey and black water were segregated from two lodging houses of TUBITAK MRC. A water reuse center was constructed in MRC premises including various types of pilot scale reactors for treatment of segregated household wastewater (www.zer0-m.org).

EUREKA project: Textile industry wastewater management and CP application

A series of wastewater segregation, application of biodegradability oriented wastewater treatability studies, water reuse/recycle CP options were investigated and evaluated in the selected integrated enterprise. The project was funded by EUREKA, registered as E! 2054-Surveyor and lasted through 2001-2003. The project was conducted jointly by 2 EU partners.

Integrated textile plant wastewater management and reuse

Detailed characterization of the wastewaters generated from an integrated textile plant involved in cotton and related products for knitting, dyeing, finishing and apparel operations, combination of membrane technologies, in the form of microfiltration, ultrafiltration and reverse osmosis practiced to develop the optimal sustainable approach for reuse.

Tannery industry wastewater treatment plant effluent tertiary treatment and reuse

For leather production industrial organized park area effluent of the wastewater treatment plant was investigated to obtain reusable water for the leather operations. A series of membrane filtration were employed for optimum result. A feasibility study was also accomplished.

Effluent treatment for Pasakoy-Istanbul central wastewater treatment plant for reuse

Pilot scale constructed wetland natural systems were used to obtain reusable effluent from the existing central wastewater treatment plant. The study was conducted by using several options of constructed wetland combinations. The further treated wastewater was intended to reuse for irrigation purposes.

Other relevant projects in Turkey

The other projects examples which, the institutions taking part are: MEDAWARE, Development of Tools and Guidelines for the Promotion of Sustainable Urban Wastewater Treatment and Re-use in Agricultural Production in Mediterranean countries; ADIRA, Autonomous Desalination System Concepts for Sea Water and Brackish Water in Rural Areas with Renewable Energies.

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2 WP 5.2 Water supply systems

2.1 Water supply systems and climate change

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection (WHO, 2004). In most countries in Europe >85% of the population has access to piped water, and the safety of drinking water at the tap is regulated through the EU Drinking Water Directive (98/83/EC). Drinking water supply involves the whole chain from water source, abstraction, treatment and distribution, and climate change is likely to affect each of these. Raw water qualities, both surface and groundwater, will change and treatment schemes may have to be adjusted. Changing weather regimes may increase the risks of flooding of water wells, introducing the risk of microbial contamination of the pumped water. Higher temperatures may promote bacterial re-growth in distribution networks.

These effects call for adaptation of water supply systems. Technologies and practises have to be developed, making the water supply chain more robust, flexible and resilient against effects of climate change. Measures are to be directed both to source, treatment and distribution of drinking water.

2.2 Legislation

The Drinking Water Directive (98/83/EC) protects the health of the consumers in the European Union and makes sure the water supplied is wholesome and clean. It sets quality standards for drinking water quality at the tap (microbiological, chemical and organoleptic parameters) and obliges EU states to regular monitor drinking water quality and to provide this information to the public. While the Drinking Water Directive protects consumers at the tap, drinking water sources, both surface and groundwater, are protected by the Water Framework Directive (2000/60/EC). The directive sets ecological and chemical quality standards for surface waters. For groundwater, the presumption is that it should not be polluted at all, thereby banning activities that could. Quality standards are set only for particular issues, namely nitrate, pesticides and biocides. Other important policies are the EU Floods Directive (2007/60/EC) and the EU Action on Water Scarcity and Droughts. The Flood Directive requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. The Action on Water Scarcity and Droughts addresses issues like water efficiency, water savings (COM/2007/0414 final) and overexploitation of Europe's water resources. Water scarcity and drought policy will be developed further by 2012.

2.3 Practise in the different European countries

Member States have implemented the EU Drinking Water Directive in their national policies and acts. These national acts are more detailed and often cover other aspects of the water supply chain as well, and not just quality standards at the tap. The Dutch Drinking Water Act, for example, sets rules for the both the production and distribution of drinking water, including issues like protection of water abstraction zones, effects of production on the environment and monitoring of raw water qualities. In addition, water companies have their own internal practical guidelines, for instance on construction and operation of water abstraction wells. In Germany, the branch organization DVGW provides many practical guidelines (source to tap), which are followed (implemented) by most of the water supply companies.

The WHO (World Health Organisation) considers water safety plans (WSP) as the most effective means of maintaining a safe supply of drinking water to the public. WSPs ensure the safety of drinking water through the use of a comprehensive risk assessment and management approach that encompasses all steps in water supply from catchment to consumer. The key components of WSPs are (1) a system assessment, which determines if the drinking water supply chain as a whole is capable of supplying water of sufficient quality, (2) operational monitoring, and (3) management plans, which document the system assessment, describe actions taken during various operational conditions and define monitoring and communication plans. Implementation of WSPs by water suppliers is encouraged in the UK, the Netherlands and elsewhere in Europe.

2.4 Identified threats from climate change

Climate change affects many of the steps in drinking water supply, from source to tap. Reductions in available groundwater resources are projected in regions in southern Europe, as a result of dryer weather conditions. This will result in increased competition for available resources and the need for alternative resources, like rain and storm water.

Strong changes in the seasonality of river flows are expected, including summer droughts and winter floods. In areas vulnerable to flooding or, like in the Netherlands, areas designated for flood storage, floods pose a risk for contamination of water wells. Low river flows in summer will concentrate contaminants. Other effects on surface water quality include temperature increases and changes in oxygen, nutrient and NOM contents (EEA, 2008). In addition, there are concerns that climate change can cause enhanced phytoplankton blooms, favouring and stabilising the dominance of harmful cyanobacteria in phytoplankton communities.

Raw water qualities will thus change and current treatment schemes may have to be adapted. The NOM content has increased during the last 20 years in Scandinavia and Scotland, some places slowly and some places with major steps during a few years. The further development of NOM content is sometimes hard to quantify, and the NOM removal must be easily adaptable to quite rapid changes. Increased turbidity in some surface waters may also be foreseen. Effects of climate change on water distribution are just beginning to be studied. Climate change introduces some hygienically risks in networks due to enhanced microbial re-growth. Increased NOM contents, as observed in northern countries, will enhance the decay of chlorine disinfectant.

Furthermore, microbial activity may be promoted by higher temperatures in networks.

2.5 Awareness of these threats and identified needs for changes in water and sanitation works

Climate change and its possible impacts on water supply is well recognized by organisations like EUREAU (European federation of national associations of water and waste water services), IWA (International Water Association) and the WHO. EUREAU, for example, pleads for continued research into adaptations of water supply systems (EUREAU, 2008). The WHO is preparing a guidance document for adaptation of water utilities to climate change. Water suppliers are more and more aware of climate change impacts, either because impacts are already noticed (e.g., NOM in northern countries) or as a result of projections of future changes in raw water quality.

2.6 Gaps between present practise and identified or expected needs

Climate change is one of the many threats faced by the water supply sector. Other threats, or 'challenges', include emerging contaminants and pathogens, aging infrastructures, and shortage of good quality and readily treatable resources. To deal with the many challenges, adaptive supply system options and new and improved treatment and monitoring technologies were developed within the TECHNEAU project. PREPARED work package 5.2 builds upon the TECHNEAU results, providing options to adapt the water supply systems in relation to climate change. The need is for systems that are more robust, flexible and resilient than before.

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3 WP 5.3 Stormwater

3.1 Introduction to the urban water sector and identified threats from climate change

The urban water sector is worldwide facing a considerable evolution because of three major drivers: (1) Climate change will likely cause changes in precipitation, temperature patterns and increase in sea levels, thus affecting the temporal and spatial distribution of urban runoff and leading to increasing problems of flooding and combined sewer overflows (CSO). (2) Existing infrastructure is ageing and deteriorating; therefore, there exists a technological and financial challenge to maintain the existing systems, and (3) urbanisation leads to an increase of peak runoff and runoff volume because of increasing of impervious surface and decreasing of soil infiltration, overloading the existing public drainage systems.

Talking specifically about the climate change driver, research reveals that its effects can already be seen in terms of a frequency increase of extreme precipitation events, which will in turn lead to large runoffs in urban-scaled catchments. The consequences are urban floods followed by damage in buildings, traffic obstructions and increasing CSO to receiving waters. In addition, the increase of sea levels will have an important effect on the operation of the actual drainage systems of coastal areas that can lead to expensive infrastructural changes, such as the increase of pumping stations and non return valves.

Climate effects in urban runoff have not yet been quantified accurately, as Regional Climate Models (RCMs) are still inadequate in terms of both spatial resolution of convective systems and knowledge of the parameter values.

3.2 Awareness of climate change threats and identified needs for changes in water and sanitation works

The need for continued research into climate change impacts is well understood within water professionals, and its position is reflected in documents such as the EUREAU (European federation of national associations of water and waste water services) position paper on Climate Change and Water and Waste Water Services.

One of the major identified challenges related to climate change in the urban water sector is the need for reduction of peak runoff and runoff volume, which could be achieved by implementing Sustainable Urban Drainage Systems (SUDS) and Rainwater Harvesting (RWH). On this topic, the previously mentioned position paper talks about the planning of SUDS to better manage rainwater, in the context of cost-effective adaptation. Another EUREAU position paper (EUREAU position on Combined Sewer Overflows) supports the promotion of SUDS, stating that introduction of such schemes should be considered as part of any urban development planning process. It also mentions that the cost of these systems (construction and maintenance) should be properly allocated and welcomes all policies and proposals for the application of SUDS.

3.3 Legislation and guidelines regarding stormwater management

Current European legislation is related with stormwater management and specifically with urban runoff. The main identified legislations are: (1) Water Framework Directive (WFD) (Directive 2000/60/CE); (2) Directive 1991/271/EC, regarding urban wastewater treatment; (3) Directive 2008/105/EC on environmental quality standards in the field of water policy; (4) Directive 2006/11/CE on contamination on aquatic environments; (5) Directive 96/61/CE on Integrated pollution prevention and control, and (6) Directive 98/83/CE on Water quality for human consumption. However, it does not still exist an European Directive regarding to the topic of RWH.

On a national scale, an increasing number of European countries are starting to develop legislation aimed at the promotion of implementing SUDS. In addition, some countries have created their own guidelines. However, there is not a nationwide approach of legislation regulating the use of RWH. Nevertheless, there exist several examples where legislation has been developed, and in some cases the use of rainwater is even promoted for potable applications, such as in India, China and Brazil.

3.4 Practise in the different European countries

According to an EUREAU survey (2008), the implementation of SUDS is well extended in countries such as UK, Belgium or Sweden. However, there are countries in which their use is on an embrionary stage, and are only applied to new urbanized areas (i.e.Spain) or small villages (i.e.Hungary). Moreover, the existence of combined instead of separate sewer systems is identified as a motivation for the implementation of SUDS. Therefore, countries with mainly separate drainage systems (i.e. Finland) are not as concerned about the implementation of SUDS as other countries such as Spain with 90 % of combined networks.

A disparity between European countries also exists relating to the inclusion of climate change in the design of drainage systems, mainly due to changing rainfall patterns. A lot of work is being conducted in some countries like UK, Norway and Denmark. However, only a small fraction of European countries are currently adapting sewer design according to climate variability. Further work should be done in order to model runoff at urban scale in changing climate.

3.5 Previous and ongoing research that is relevant for the WP5.3

Some European research projects that are somehow related to the effects of climate change in stormwater are currently underway. Within the EU 7th Framework Programme (7FP), it is worth mentioning the CLIMATEWATER project, which aims at bridging the gap between adaptation strategies of climate change impacts and European water policies, and the ACQUA project, which assesses climate change and its impacts on the quantity and quality of water, specifically in vulnerable mountain regions. A 6th Framework Programme (FP6) project that can be mentioned is SWITCH, whose goal is to catalyse change towards more sustainable urban water management, including options for stormwater reuse. Within LIFE+ projects, two projects related to RWH are *Preventing pollution and saving water resources by reuse of industrial rainwater* and *Treatment and re-use of urban stormwater* *runoff by innovative technologies for removal of pollutants*. Another LIFE+ project in which SUDS and RWH are also included is *Integrated sustainable urban drainage Infiltration & transport system Dordrecht, filtering of rainwater at the source*.

Results from these research projects need to be transferred to water utilities in order to support their application.

3.6 Gaps between present practise and identified or expected needs

The effects of climate change on urban runoff and their induced consequences have not yet been quantified accurately, because RCMs could increase in spatial and time resolution to provide a major improvement in representing mesoscale and convective systems.

This review has also allowed noticing gaps related to RWH and SUDS, which need to be solved for a broader implementation of these techniques. It can be mentioned: (1) excessively local implementation of SUDS and lack of a nationwide and European approach, (2) lack on legislation at European level and incomplete legislation with a nationwide approach, (3) lack of homogenisation in research work across Europe in terms of adaptation to changing rainfall patterns and adapting sewer design, (4) disparity in both the interest and the implementation of RWH and SUDS across European countries, and (5) lack of transfer between the research projects and its application in water utilities, which are not as aware of the climate change induced threats. It is therefore necessary to reduce this last gap by implicating water utilities in the application of adaptation measures to climate change using the results of research projects, which is one of the aims of PREPARED.

4 WP 5.4 Adaptation of sanitation system

4.1 Legislation

Legal requirements for CSO follow the precautionary principle and usually set emission standards. Within the Urban Waste Water Treatment Directive 91/271/EEC of May 1991 it is written that "member states shall decide on measures to limit pollution from storm water overflows". The directive does not give standards but solely proposes that "such measures could be based on dilution rates or capacity in relation to dry weather flow, or could specify a certain acceptable number of overflows per year."
The European Water Framework Directive 2000/60/EC of October 2000 goes beyond and asks for a combined approach to river basin management. On the source side, it requires that all existing technology-driven source-based controls must be implemented as a first step. On the effects side, it provides a new overall objective of good status for all waters, and requires that where the measures taken on the source side are not sufficient to achieve these objectives, additional ones are required.

In France, one of the applications of European Water Framework Directive (WFD) is now managed with the "Arrêté du 22 juin 2007". Its first objective is to impose a monitoring system to control the efficiency of the sewer system concerning rejected flows. For a collector with a dry capacity > 600 kg BOD5/day the operator has to monitor the CSOs. The CSO flows have to be continuously measured; the pollution charge has to be evaluated (TSS, COD). The prefect can determine that only those overflows have to be monitored, which represent min. 70% of total CSO load. This can be adapted to the demand of the receiving water. The prefet can also determine that for a collector with a dry capacity between 120 kg BOD5/day and 600 kg BOD5/day, the pollutant charge from the CSOs must be evaluated.
In Germany

In Germany, concerning water law the Federal Government has framework legislation competence only. The competence authority for water law is the Federal State, there is no national standard. The worksheet ATV-DVWK-A 128 (1992) suggests that the pollution due to CSO and to WWTP effluents has to be equivalent to the pollution of a comparable separate sewage system, not more. The worksheet is considered as technical state of the art and in most Federal States it is the reference, the indicator value is COD. The pollutants mass can be assessed by simulation; it doesn't have to be measured.
With a wastewater tax for discharges from the combined sewage system stimulation for CSO reduction is created. In most of the Federal States exoneration from wastewater tax is linked to the application of state of the art measures (worksheet ATV-DVWK-A 128, 1992). A national German standard for combined sewage treatment conform to the European legislation is currently developed.

In the USA, in 1994 the U.S. Environmental Protection Agency (EPA) published a CSO policy (EPA (1994)). It is a national framework for control of CSOs through the National Pollutant Discharge Elimination System (NPDES) permitting program. It provides guidance to municipalities and State and Federal permitting authorities on how to meet the Clean Water Act's pollution control goals as flexibly and cost-effectively as possible. In order to become an authorisation for combined waste water discharge the communities first have to apply a nine points program. Communities with combined sewer systems are expected to develop long-term CSO control plans, including i.e. monitoring the impacts of CSOs on waterways. CSOs are only aloud 4 times a year; the CSO rate must be lower than 15%. Cities with more than 100000 inhabitants need a NPDES-authorisation. The Combined Sewer Overflows-guidance for monitoring and modelling (EPA 832-B-95-005) was published in 1995 from EPA to help contractors and administrations. In a report for the congress in the year 2004 the EPA wrote that improved monitoring and reporting programs would provide better data for decision makers to assess the frequency and magnitude of CSO events, the impact these discharges have on the environment and human health, and the importance of CSO discharges with respect to other pollution sources. Too often, the monitoring data do not meet the needs of specific programs or are not readily available (http://www.epa.gov/npdes/pubs/csossoRTC2004_chapter10.pdf).

For odour control there is also no international legislation. Within the European Directive on Landfill of Waste (1999/31/EC) no limits are specified, it is mentioned that "measures are taken to reduce the nuisance and dangers produced by emissions of odours and dust".
In Germany, for example, different laws can be considered for odour regulation, though there is no specific law for odours from the sewer system, the "Bürgerliches Gesetzbuch (BGB)" mentions odour are not important if an average human being doesn't smell it.

4.2 Practise in the different European countries

In Germany, the German water organisation wrote a report in May 2010 "climate change, challenge and solution approach for German water management", which clear mentions that climate change will influence the water management sector, but that at this time, there is no clear dimensional or verification concept

In Denmark, a climate factor has been defined for the design of sewer system considering a 1.2 factor on rainfall series, the government's strategy for adaptation to climate change focuses on the necessity
of adaptation at national level. Cities are developing individually action plans adapted to their needs as Copenhagen.

A different approach, introduced in Oslo, has been to increase robustness and resilience with increased buffer volumes and adapted wastewater treatment.

4.3 Identified threats from climate change

For the sanitation system, three phenomena due to climate change have to be considered:

- Increase in temperature
- Change in precipitation characteristic: decrease in summer precipitation, increase in winter precipitation, more frequent and intense extreme events
- Sea level rise

There will be a regional specific evolution of those phenomena. One scenario that can be considered is the one from the IPCC (intergovernmental panel on climate change).

The consequences of these evolutions for the sanitation system are:

- Increased odour and corrosion risk
- Operational reality impacts
- Uncontrolled surcharges and more frequent CSOs
- Stress on sanitation system
- Evolution of infiltration
- High flow variation
- Sea entrance into the sewer system

4.4 Awareness of these and identified needs for changes in W&S works

These threats are by now well known but are very different depending of the geographical situation. The city of Oslo or Lisbon will have problems with the sea level rise, whereas Paris and Berlin with CSO and Odour and corrosion. Cities organise plans to cope with the problems they identified. In Hamburg (Germany), for example, a first study showed that a 50%increase of yearly CSO volume is predicted in 100 years; the next step is to do a monetary quantification of adaptation strategies before a strategy will be framed.

4.5 Overview of projects at national and international scale that deal with the specific subject

SWITCH (6th framework programme)
One objective of SWITCH is to develop and demonstrate pollution prevention-based approaches to wastewater handling in urban areas in which concentrated waste flows are separately collected and treated.

CD4WC (5th framework programme)
CD4WC deals with optimising the efficiency of the urban wastewater system with regard to ecological consequences in natural water bodies and with regard to investment and operation costs. A variety of possible systems approaches, operation strategies and management options are considered. A synthesis on the interactions and synergy potential between different options and a cost-benefit analysis follow the analysis of the single options.

DAYWATER (5th framework programme)
In DAYWATER an Adaptive Decision Support System (ADSS) for the Integration of Stormwater Source Control into Sustainable Urban Water Management Strategies has been developed. Two reports can be considered

for PREPARED, “Criteria Relevant to the Assessment of BMP Performance” and “
Review of the Use of stormwater BMPs in Europe”.

Fuzzy-sewage system for cities Rheine (D) and Oldenzaal (NL) (program Interreg IV)
For both cities the adaptation of the sewer system to more intense rain events will be defined considering cost pressure.

Global Change Research Program (US EPA)
Aging Combined Sewer Systems in the United States are being redesigned to comply with EPA's Combined Sewer Overflow Control Policy but without considering climate change. Global Change Research Program has demonstrated that redesigned systems might not satisfy EPA's control policies, climate change is already leading to an increase in the number of intense rainfall events. The research program has shown that the risks are manageable, meaning it is possible to anticipate the effects of climate change on the new designed systems and to adapt them.

Dynaklim: „Dynamic adaptation of regional planning and development processes to impact from climate change for Emscher-Lippe-Region (Germany), 2009-2014 (Program KLIMZUG BMBF federal ministry of education and research)
Within this project innovative concepts for rain water management and the potential of an adaptable sanitation system for the region will be studied.

4.6 Ongoing research or previous research in our company that is relevant for the WP we are responsible for

Several projects have been conducted with the objective to reduce the impact of combined sewer system onto the receiving water by reduction of CSOs:

- Project ISM “Integrated sewage management” (2003-2005): Development of strategies for the integrated management, as well as the initialization of decision support tools for the planning and the operation of the Berlin sewage system. By integrating the subcatchment model into the operational decision-making process an optimized utilization of storage- and treatment-capacities of the overall system has been achieved.

- EVA “Global control of sewage pump stations” (2006-2007): Implementation of a decision support system for global control of sewage pump stations and analysis of advanced control concepts

- Spree 2011 (WP 1.2, 2007): Water quality simulation and estimation of hydraulic and pollutant load on a stormwater tank

- MONITOR (2007-2008) : Simultaneous Monitoring of Combined Sewer Overflows and Receiving Water: Analysis of pathways of stormwater-bound pollutants from urban zones to the natural water body, analysis of the impact of CSO on receiving water quality, better process understanding and process description in modelling

- MIA-CSO (2009-2012): Monitoring and impact assessment of combined sewer overflows: The overall objective of MIA-CSO is to develop a model-based planning instrument for impact based CSO control.

One project focuses on the odour problems from the sewer system, which may also play an important role in the context of climate change.

- ODOCO-ARTNOSE (2010-2012): Evaluation of electronic noses for online control of odour emissions from sewer systems: The overall objectives of ODOCO-ARTNOSE are the identification of the current technological status and the evaluation of the abilities of electronic noses to fulfil the needs in current sewer odour management (such as optimising dosing strategies).

5 WP 5.5 Adaptation of operation and maintenance

5.1 Introduction

Operation and maintenance of water, wastewater and storm water systems are important and necessary to get these systems function. Utilities carry out such activities every day, both as planned, preventive maintenance and to deal with unexpected problems.

Some maintenance activities need to be routinely done quite often, for example every 14 days, while others are repeated less frequently. Some methods are purely operation, while others may be considered as rehabilitation. It may in practice be difficult to draw a very stringent line between the terms shown in figure 1 below.

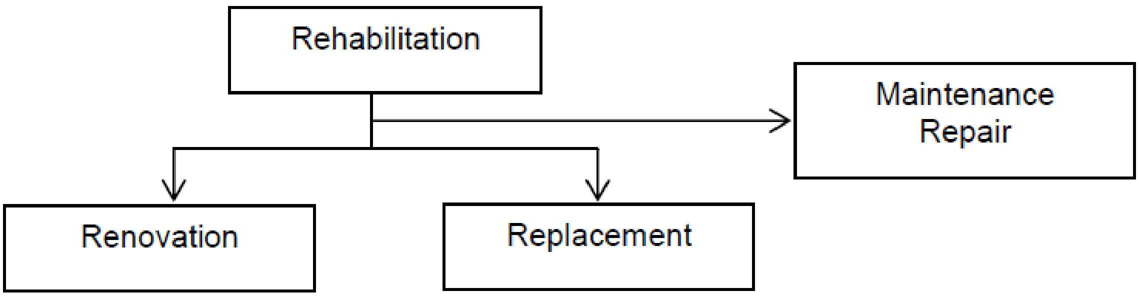

Figure 1 : Rehabilitation, Maintenance, renovation, replacement.

The maintenance plays a very important role in the rehabilitation process in order to prolong of the pipe life, i.e. to postpone the rehabilitation and keep the system in a good operational state.

Table 1 shows how O&M methods are effective to solve different problems.

Table 1: Effectiveness of a variety of sewer O&M methods (EPA; Office of Water, Washington DC)

Solution to Problem	Type of Problem: Emergency Stoppages	Grease	Roots	Sand, Grit, Debris	Odors
Balling		●		●	●
High Velocity Cleaning	•	●		●	●
Flushing					●
Sewer Scooters		●		●	
Bucket Machines, Scrapers				●	
Power Rodders	●	•	●		
Hand Rods	●	•	●		
Chemicals		●	●		●

● = Most effective solution for a particular problem

• = Least effective solution for a particular problem

5.2 Legislation

What do we mean by legislation?

The term 'Legislation' covers terms such as

- Laws and regulations are juridically binding. Examples are laws concerning water quality and the Water Framework Directive.
- Standards, for example EU Norms (EN) and national norms (e.g Norwegian Standard – NS). Standards may be used a reference in a court of law, if it is a generally accepted and widely used norm. In a juridical sense, a standard may or may not be binding.
- Norms, which are less stringent than standards, and describe normal practise. Each municipality may have its' own norm, or common norms may be agreed. Branch organisations may suggest norms. Norms are similar to standards, from a legal point of view a court of law will regard it depending on the extent it is applied in the market.

As such, a proper operation is integrated the necessary actions to comply with the water frame directive (Directive 2000/60/EC of The European Parliament and of The Council and the drinking water directive (Council Directive 98/83/EC), as well as in national and regional regulations. However, these regulations and directives are mainly on the outcome of the water and sewerage works' actions and not on how the outcome is achieved.

5.3 A few words on various practice in different countries, and when applicable on the reasons for differences

Operation and maintenance practice as well as design of water, wastewater and storm water systems will vary for several reasons:

- Nature, like topography, available sources for water supply and climate
- Culture, or tradition, like the extreme variations in chlorination practice throughout Europe
- Economy, which enables some to reconstruct where other may have to operate old and deteriorated systems
- Operation and maintenance may of course be adapted to the historic development in urban infrastructure, with old combined sewer systems in the older parts of the European cities

One example is from Central Europe, where taxation of water and wastewater has changed dramatically during the last decades, due to the transition from communism (where water was "free") to new, democratic regimes (where water is considered more as a commercial product). As a result, water consumption has decreased, leading to operative challenges in networks with surplus capacity.

Another example is flushing of networks. Many utilities are experiencing water scarcity problems, and have decided to stop flushing water pipes, both to save water and to avoid a public opinion that water is being wasted by the utility. Methods to clean pipes using a minimum amount of water are therefore required.

5.4 Threats from and awareness of climate change effects

In several countries projects are established to identify the expected effects of climate change on water supply and sewerage, and the present outcome of this will be summarized in WA 2 as a list of future challenges. Based on these challenges existing operation & maintenance technologies will be evaluated to identify missing knowledge and technology to handle these effects.

5.5 What is missing/gaps to be filled in order to be prepared for climate change

a. overview of projects at national and international (EU but also outside EU) scale that deal with this specific subject

Operation & Maintenance Best Management Practice have been addressed in TECHNEAU for water supply, CARE-S for the sewer systems and DAYWATER for storm water. The SWITCH project "aims to bring about a paradigm shift in urban water management away from existing ad hoc solutions to urban water management and towards a more coherent and integrated approach" (www.switchurbanwater.eu) . This includes water sensitive urban design, a method where the urban storm water is considered in an early planning phase.

b. in short the major outcomes of these studies and possible knowledge gaps, where we can start to work from + implementation of research, where are results implemented, what do we aim for?

This infrastructure is in general built, and improvements in capacity, adaption to deteriorated raw water quality or stricter operational goals should preferable be based on optimization of he existing systems. In

TECHNEAU, several tools for evaluating and optimizing operation of water treatment and distribution systems for water supply. These tools are implemented in a number of waterworks, based on their present status.

In Prepared, the tools developed in previous projects will, when necessary, be further developed, in order to be able to adapt to faster and more severe changes in water quality than known from the waterwork's historical records. Changes in water quality and quantity that has not been addressed earlier, like how to handle the possibility for a change in the microbial community over time due to increased temperature, will also be addressed in Prepared.

CARE-W and CARE-S (Computer Aided REhabilitation of Water / Sewer networks) are 2 projects that were supported by the EC 5FP. The project developed a philosophy, methodology and a set of tools that can be used for planning of rehabilitation of pipes. Pipes can be analysed as a whole (zonal or network level) or individually. In brief, it covers aspects of

- Strategic planning on "network level"
- Tactical planning on pipe level, deals with the selection and ranking of projects to improve service.
- Technological level for selection of adequate technologies for the projects

CARE-W ended in 2003, and CARE-S in 2005. The software is still available as a prototype. Although the projects had rehabilitation as a focus, a few aspects of operation and maintenance were addressed.