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SmartH2O

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Executive Summary

This document is the Deliverable D5.1, **Review of pricing instruments**, which, according to the DoW, has the following goals:

D5.1 Review of pricing instruments: The deliverable contains a review of water pricing instruments and EU regulatory frameworks: review of past and current pricing policies that have been adopted or considered for adoption in Europe. Review of the regulatory framework in the main EU countries. It provides an assessment of pricing tools: the effectiveness of traditional pricing tools on water consumption is evaluated using an econometric model for the SmartH2O case studies. It reports on pricing for smart water management: detailed analysis of pros and cons of existing pricing models that could only be envisaged given smart metered data and/or social media data. Finally it provides the water demand baseline: using available data in the two case study the current water demand will be estimated as baseline for subsequent analyses.

The present document reports the preliminary achievements of the **Saving water by dynamic water pricing** work package (WP5). At the end of the first year, WP5 aims at identifying and evaluating water pricing instruments being applied or considered in EU states, with a particular attention to water pricing in UK. In addition, an in-depth analysis of empirical studies focusing on water demand was required in order to provide the SmartH2O with a water demand baseline.

According to these aims, after a brief introduction, section 2 of the document provides an overview of the European Union policies focusing on the field of water conservation and having as a goal a more efficient use of the water resources throughout the Member States. A particular emphasis is placed on economic policy instruments (EPI), aimed at incentivizing a more efficient use of water through market-driven mechanisms. After, regulatory frameworks of the water sector in UK and other selected European countries are summarized, in order to offer a descriptive snapshot of traditional pricing schemes currently adopted throughout the EU.

Section 3 reviews the state of the art with respect to water demand and price elasticity estimations. The section discusses the most relevant characteristics of the studies published so far, by focusing on the drivers taken into account and their impact on household water consumption. It also offers an overview of estimation methods and summarizes the findings shared by the extant literature.

Section 4 focuses on the role of innovation in water conservation. Firstly, the role of smart water metering systems is discussed, with particular regard to benefits and costs, current stage of development and deployment and customers' feedback. Secondly, an overview of innovative pricing schemes is provided, along with relative pros and cons and current evidence on customers' response (referring mainly to energy sector applications). Thirdly, a preliminary picture of the increasingly pivotal role online communities and web and gamified applications are playing in the resource conservation efforts (and particularly in the water sector) is offered.

Finally, Section 5 concludes and outlines the forthcoming activities that will be done in WP5.

1. Introduction

To the aim of promoting water conservation, various policies can be employed, some more costly than others. Choosing the least costly method of achieving some water conservation goal is characterized in economic terms as cost-effective water management [Olmstead2009].

In the context of the SmartH2O project, this document focuses on the issue of economic policy instruments for water conservation. Economic instruments can be various. They are not limited to pricing instruments, but broadly speaking, they include every mechanism able to incentivize people to perform water saving actions for something in return. This document focuses on:

- **Pricing mechanisms**, which can range from traditional ones (fixed rate or fixed plus volumetric rate) to more innovative ones (dynamic pricing) and be designed to fulfill a large array of objectives, from the mere financial sustainability of water service delivery to the water efficiency.
- **Rewards**, monetary or not, adopted so far in the energy sector as a means to incentivize customers to commit on smarter behaviors in the energy use. A typical reward mechanism provides customers successfully engaged in resource conservation actions with rewards based on the amount of saved water (or energy) within a given time period.

The adoption of economic instruments requires, as a prerequisite, the possibility to measure water consumption. In this fashion, they are intimately linked with the deployment of **water metering system** technologies.

Water metering is supposed to promote, on the one hand, the implementation of water saving strategies aimed at exploiting **information and feedbacks** targeted to customers, on the other hand, the access to useful information to analyze in more detail the **water demand** (response to price changes) and the customers behaviors with respect to water usage (users' profiling).

The document highlights the above mentioned issues and the relationships among them by reviewing:

- EU and country-level water policy instruments and regulatory frameworks, with an emphasis placed on economic mechanisms (Section 2);
- The state of the art of water demand estimations (Section 3);
- The role played by water innovation in the implementation of water saving strategies (Section 4).

Given the strong expected cost advantages of market-based approaches to water efficiency goals over possible alternatives, and the emerging empirical evidence for the potential water savings from switching to economic instruments to conservation, the document represents a promising toolbox for the following SH2O activities.

2. Evaluation of regulatory schemes and price systems for water efficiency

2.1 EU water policy

Natural resources such as rivers, lakes, coastal waters and forests are vital for life; they provide drinking water, give life to plants, animals and people and they are a significant resource for agriculture, energy, industry and recreation. Although we could think that most of the natural resources such as wind and water are renewable, their limitless exploitation can have harmful effects for species and people and threaten sustainability. Protecting therefore the health of rivers and lakes (e.g. bathing quality), the availability of water resources (e.g. surface and groundwater), and the ecosystem services they provide (e.g. wildlife, recreation) is among the challenges we face. In line with the above challenges, in 2000 the European parliament and European Council published the 'Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework directive for Community action in the field of water policy', in short the EU Water Framework Directive (WFD). The main objectives of the WFD (Article 1) could be summarized as follows [Morris2004]:

- to prevent deterioration of, and where necessary enhance, the status of aquatic and related ecosystems;
- to promote sustainable water use;
- to progressively reduce, and for priority substances eliminate, pollution from hazardous substances;
- to ensure reduction/prevention of groundwater pollution;
- to contribute to the mitigation of floods and droughts.

The WFD (2000/60/EC) therefore sets out the general guidelines for water management in its Member States (MS). It also recognizes the role of economics in the water resources management process (Articles 5, 9, 11 for instance) and more particularly, promotes the adoption of pricing systems by MS to reflect the real cost of water use.

Article 9 of the WFD includes specific provisions on the concept of *full cost recovery* and *incentive pricing*. On the one hand, cost recovery of water services requires that water prices to reflect the financial, environmental and resource costs of supplying water [EC2007a]. On the other hand, incentive pricing involves implementing water pricing policies that "provide adequate incentives for users to use water resources efficiently, and thereby contribute to the environmental objectives of this Directive" [EC2007a ; EEA2012].

Operation & maintenance costs: The daily costs occurred when running the business.

Capital cost: The cost of funds (equity and/or debt) to run the business.

Opportunity cost: The value of water in alternatives foregone when allocating water to any use and not others [Delacamara2013].

Resource costs: The cost linked the economic or relative scarcity of water once it is used [Delacamara2013].

Social costs: The costs linked to the different societal groups when planned or unplanned intervention occurs such as infrastructure project, drought, pollution.

Environmental damage costs: Welfare losses linked to the actual or potential deterioration of natural assets due to economic activities [Delacamara2013].

Long Run Marginal Cost: The change in total cost in the long run when the product changes by one unit.

Box 1. Definition of costs.

A complete definition of Full Cost Recovery (FCR) could possibly include: a) Operation and maintenance costs; b) Capital Costs; c) Opportunity Costs; d) Resource Costs; e) Social Costs; f) Environmental damage costs; e) Long Run Marginal Costs (LRMC) (see Box 1) [Roth2001]. Although the definition of the FCR principle is clear, its implementation is difficult, because of data availability, methodology and implementability issues.

Along with the FCR principle, there are the Precautionary Principle and the Polluter Pays Principle (PPP). The former promotes the prevention of pollution, which also includes the use of substitutes or bans, rather than the use of end of pipe solutions [Roth2001], whereas the latter refers to the internalization of environmental costs, i.e. charging the polluter with all costs associated with the negative impacts produced by given activities [Caliman2012]. The above principles define the sustainable management of water resources and environmental policy in EU.

Over the years, there were several policy documents and reports by the European Commission (EC) and the European Environmental Agency (EEA) to assess and promote the efficiency use of water resources in Europe [EC2007a; EC2007b; EC2007c; EC2007d; EC2010; EEA2009; EEA2010a; EEA2010b; EEA2010c; EEA2012]. For instance, the 2007 Commission Communication on Water Scarcity and Droughts included options related to ‘putting the right price tag on water’, ‘allocating water more efficiently’ and ‘fostering water efficient technologies and practices [EC2007a]. It was concluded that little progress has been made so far in implementing transparent pricing policies across Member States due to the lack of metering. Moreover, the assessment of River Basin Management Plans (RBMPs) suggested that only 49% of RBMPs plan to change the water pricing system to foster a more efficient use of water and only 40% include measures to improve water metering [EC2012]. These documents fit into with the overall objective of the 'resource efficient Europe' flagship initiative of the Europe 2020 strategy which sets out a long term framework to guarantee that several areas such as water, energy, climate change, research and innovation, industry and environmental policy will lead to a resource efficient Europe [EC2011; Harou2014].

In strengthening and facilitating resource efficiency, the Europe 2020 strategy underlines the important role of water economics (e.g. metering and pricing) and of strengthening policy integration and water governance across all economic sectors [EEA2012]. The outcome of the above reviews and initiatives led to the recent publication of “A Blueprint to Safeguard Europe’s Water Resources” by the European Commission. Among others, this document proposes as a continuing enforcement action the implementation by Member States of water pricing/cost-recovery obligations under the Water Framework Directive, including metering when relevant.

Furthermore, the presence of a water pricing policy is envisaged as an ex ante condition to obtain financing for certain projects under the Commission’s proposals for Rural Development and Cohesion funds [EC2012]. Moreover, a recent initiative by the EC is the European Innovation Partnership (EIP) on water where voluntary multi-stakeholders Action Groups (AG) develop and implement new approaches (e.g. smart metering, water pricing across sectors) disseminate and promote the uptake of innovations by the market and society for major water-related challenges (see for instance WaterReg – AG(102) for pricing policies in domestic water use and SPADIS – AG (014) for pricing policies in agriculture) [Harou2014].

2.2 Economic policy instruments for water resources management

Economic Policy Instruments (EPIs) are incentives for individual water users to decide why and how much water to use and are purposely designed in such a way that decisions taken by anyone are compatible with the overall objectives of water policy [Strosser2013]. If properly designed, an EPI must result in changes in the use of water (as broadly defined by the WFD), e.g. reducing water abstraction and water demand by adapting practices and production processes; reducing the use and discharge of polluting substances into the aquatic environment; reducing or halting hydro-morphological alterations originating from specific economic and land development activities [Strosser2013]. The table below describes the different types of EPIs such as pricing, taxes, trading, that could be employed in water management to achieve collective water goals such as water quality, water efficiency and protection of ecosystem services.

Table 1. Broad categories of EPIs [Lago2012].

Type of instrument		Function / main purpose
Pricing	*Water tariff*	Price to be paid for a given quantity of water (or sanitation service), either by households, irrigators, retailers, industries, or other end users. Although prices obviously contribute to collect financial resources for the operation of a given water service (that is, they are also a financial instrument), in strict sense they can only be said to be economic instruments should they create incentives to promote water use efficiency, via deliberate changes in consumer behaviour.
	Environmental tax	Compulsory payment to the fiscal authority (whichever it is), where the benefits provided to the taxpayer are not directly linked to the payment (that is, when there is no immediate real consideration). Thus, it is an unrequited payment (i.e. there is no link between the payment and the water service rendered). They are levied on the measured or estimated effluents of noxious or other harmful substances to water bodies, the effluent collection and treatment, water abstraction, etc. They are considered economic instruments (besides their revenue-raising financial function), as long as they intend to modify behaviour.
	Environmental charge (or fee)	Compulsory payment for a service to the competent body. As opposed to taxes, charges or fees are requited payments; their function, though, as economic instruments, is alike.
	Subsidies on products	Unrequited payments from government bodies to producers, with the objective of influencing their levels of production, their prices or the remuneration of inputs. They can also be paid to households to subsidy consumption. They are said to be environmental subsidies (and therefore EPIs for water management), if reducing the use of some proven, specific negative impact on the water environment.
	Subsidies on practices	Unrequited payments from government bodies to producers to increase the attractiveness of more sustainable production processes that limit negative impacts on water sources or produce positive environmental externalities.
Trading	*Tradable permit for abstraction*	Right or entitlement of an individual (either natural or legal person) to use water from a given source (i.e. river, pond, stream, aquifer, etc.), under the conditions and with the attributions resulting from law. “Water use” must indeed be read in a broad sense: consumption, abstraction, discharge, etc. Water rights, within trading systems, can be exchanged thus creating incentives to improve allocation (efficiency) of water quantity amongst different sectors (including the natural environment).
	Tradable permit for pollution	Right or entitlement of an individual (either natural or legal person) to pollute the water environment under certain limitations and conditions, through the discharge of a toxic substance or wastewater effluent. Tradable pollution permits, once exchanged on a voluntary basis, may create incentives to abate pollution at an aggregate level.
Cooperation		Negotiated arrangement between parties to promote good practices for the reduction of pressures on water resources often linked to subsidies or compensation schemes. Settlements to preserve water resources and to share benefits thus obtained (i.e. voluntary agreements, including PES

		schemes).
Risk schemes	*Insurance*	Insurance (risk management instrument primarily used to hedge against the risk of a contingent, uncertain loss, for example in the event of flood or drought)
	Liability	Offsetting schemes where liability for environmental degradation leads to financial payment that is allocated to compensation for environmental damage.

More particularly, water pricing is defined as “applying a monetary rate or value at which water can be bought or sold” [EEA2013]. Pricing schemes (e.g. tariffs, taxes, charges and subsidies) can pursue multiple policy goals, seemingly at odds but reconcilable in principle: water use efficiency, that is avoiding wasteful use of water; allocation efficiency, thus maximizing overall society’s benefits from water uses; financial viability, meaning ability to compensate capital, skills and technology needed to ensure water services and sanitation; and social equity, standing for affordability of water as a public interest good [Amadio2013]. However, according to Weitzman [Weitzman1974], an important drawback of pricing schemes is the uncertainty associated to the environmental outcomes they deliver [Lago2012]. A recent report by [EEA2013] on reviewing water pricing schemes across Europe showed that the need to design and implement innovative pricing schemes is of outmost importance so that full cost recovery principle is satisfied and efficient use of water resources is incentivized. 'Innovation', however, does not necessarily imply the creation of new economic instruments — often, it is about improving or coming up with innovative combinations of existing instruments [EEA2013; Strosser2013].

2.3 Traditional pricing schemes for water conservation

When designing tariff schemes one should balance between five main principles (objectives): full cost recovery, economic efficiency, equity, affordability and simplicity. These principles are discussed in more detail in Whittington et al. [Whittington2002], Barberan and Arbués [Barberan2009], Hoque and Wichelns [Hoque2013], Molinos-Senante [Senante2014]. A brief presentation is provided below:

- *Full cost recovery*: the revenues collected from water rates should cover the full cost of supply (financial, environmental and resource costs), thereby ensuring long term service provision and not financial difficulties for any utility [Senante2014].
- *Economic efficiency*: water services should be provided in a way that maximizes the community’s net benefits [OECD1987]. This approach implies that the price should reflect the marginal cost of providing the service. Ideally, the marginal cost should reflect not only the financial cost of supplying water but also the social cost of diverting water resources into supply rather than using them for other purposes [Whittington2002].
- *Equity*: two approaches should be differentiated, namely the benefit principle and the ability-to-pay principle [Senante2014]. The former refers to the situation where every taxpayer pays according to the benefits he receives from the public sector, whereas the latter means that every taxpayer should pay according to his means [Barberan2009].
- *Affordability*: water prices should be kept affordable and water be provided free or at minimal cost, at least to the poor, through subsidies [Whittington2002].
- *Simplicity*: water rates should have a simple structure to minimize the management costs and be easy to design, explain and implement [Barberan2009; Senante2014].

There are two main types of tariffs: a *single part* and a *two-part* tariff. The former could be a fixed charge or volumetric charge whereas the latter could be a combination of fixed and volumetric charge.

The fixed charge tariff exists in the absence of metering and refers to the situation where customers are charged with a fixed amount of money every month or year regardless of the amount of water they consume, thereby without providing any incentives for using water efficiently.

In contrast, with the volumetric charge tariff, the customer is charged based on the amount of water he consumes. This type of tariff could take three forms: 1) *uniform volumetric charge*, i.e. a rate per unit volume which is the same for all levels of consumption, 2) *increasing blocking rates*, i.e. a rate per unit volume which increases stepwise according to the level of consumption, 3) *decreasing blocking rates*, i.e. a rate per unit volume which decreases stepwise according to the level of consumption [Hoque2013].

The main advantage of volumetric charges compared to the fixed charges lies on the fact that consumers pay for the amount of water they consume. Uniform volumetric charge is easy for the consumer to understand and if set at appropriate level can guarantee sufficient revenue for the utility as the revenues adjust to the water consumption level.

Increasing blocking rates (IBR), instead, could be used to penalize excessive consumption by charging higher prices for higher consumption levels. A uniform charge seems to be less effective in promoting water conservation compared to IBR and if it (without any fixed charge) aims to cover both fixed and variable costs, the rate might become too high, and consumers might attempt to forgo beneficial water uses and waste time, money and resources in inefficient water saving [Hoque2013].

Decreasing blocking rates are often politically unattractive as it assumes that high volume water users end up in paying lower average water prices and thereby they have been rarely used (see Table 2).

Other volumetric charge tariffs include seasonal tariffs where consumers are charged differently during peak (summer) and off-peak (winter) periods and could take the form of uniform volumetric, increasing or decreasing blocking rates. This form of tariff, mainly apparent in US, could be used in cases of water shortage during dry periods and as long as the overall (annual) bill remains the same.

Overall, both IBR and ST (seasonal tariff) theoretically yield higher welfare benefits than the single-price policy [Krause2003; Rinaudo2012]. Among the aforementioned tariff options, increasing blocking rates has been widely applied and researched in many countries in Europe and overseas, see for instance [Espiñeira2003a; Espiñeira2003b], [Espiñeira2004] in Spain, [Rietveld2000] in Indonesia, [Hajispyrou2002] in Cyprus, [Reynaud2008] in France; [Olmstead2007] and [Mansur2012] in US. Increasing blocking rates can be structured using a limited number of blocks (2 or 3 blocks tariffs as applied in Singapore or in Melbourne) or using more blocks as applied in Cyprus (e.g. Limassol with 4 blocks and Nicosia with 9 blocks). Moreover, IBRs can be adjusted by taking into account customer characteristics and therefore, can be set on household or person basis as applied in Zaragoza (Spain), in Belgium (Wallonia, Brussels), in Israel [RPS2013].

The rationale given for adopting IBRs (apart from the recovery of efficient costs) centers around the belief that IBRs encourage water conservation, because the pricing scheme increases the price of water as consumption increases [Olmstead2007]. Past evidence showed that IBRs could reduce demand by up to 5 per cent on average across year so that less water is taken from the environment [Herrington2007; SouthernWater2014]. Moreover, distribution concerns can also be incorporated by making the initial volumes cheaper, the tariff being used to generate revenue-neutral cross-subsidies [Rinaudo2012]. However, IBRs have been criticized as it doesn't protect low income families with large size if the first block is not well designed [Whittington2002]. In practice, low income households tend to be larger on average, and the initial low cost blocks are thus used sooner, putting the household into the higher price blocks [Zetland2011; Mitchell2015]. For that reason, the IBR design has social implications, and regulators might be reluctant to limit the size of the initial block because of political pressures [Boland2000, SenanteMaziotis2014]. IBRs are also criticized on grounds of cost recovery, as low users pay below cost price; use at higher tiers may cross-subsidize these costs but the tariff structure may need to be steeply raked to do so, thus making revenue unstable and unpredictable [Crase2007; Mitchell2015].

Thereby, there are important factors to consider when designing increasing blocking rates including:

- The number of blocks (social, normal and higher use);
- The volume of water use within each block;
- The prices to be charged for water use within each block;

Finally, a two-part tariff consists of two components: a fixed charge to recover administration and billing costs from metering; a volumetric charge based on any of the aforementioned charging schemes e.g. uniform volumetric or blocking rates. This charging scheme plays an important role for the utility to achieve both cost recovery and economic efficiency principles [Whittington2002]. However, if fixed charges constitute a large portion of the water bill, consumers have limited ability to control their bills, and hence a smaller monetary incentive to conserve water. Table 2 provides a summary of the performance of alternative tariff options against the main design objectives.

Table 2. Summary of performance of pricing structures against design objectives [Whittington2002].

Tariff Structure	Cost Recovery	Economic Efficiency	Equity	Affordability	Simplicity
Fixed Charge (flat rate unmetered)	Adequate: Provides stable cash flow for the utility	Poor: No information about the cost of use of additional water	Poor: Low or high volume water users pay the same	Adequate: However, households can't reduce their bills because they can't reduce consumption	Easy to understand
Uniform Volumetric Charge	Good: if set at appropriate level and utility revenues adjust automatically based on water consumed	Good: if set at or near marginal cost of water	Good: users are charged based on the water they consume	Good: Households can reduced their bills by reducing consumption	Easy to understand
Increasing Blocking Rates	Good: if the size and the number of blocks are well designed	Poor: typically little water is actually sold at marginal cost	Poor: Users do not pay according to the costs their water use imposes on the utility	Poor: Penalises poor families with large households if the first block is not well designed	Difficult to understand if the number of blocks is high
Decreasing Blocking Rates	Good: if the size and the number of blocks are well designed	Poor: typically little water is actually sold at marginal cost	Poor: Users do not pay according to the costs their water use imposes on the utility	Poor: Penalises poor families with low levels of consumption	Difficult to understand if the number of blocks is high

2.4 Pricing schemes and current situation in UK, Switzerland and other EU Member states

2.4.1 Introduction

Before discussing the pricing schemes already implemented in several EU countries, it is of paramount importance to present the regulatory framework and the market structure of the water industry in each country, which can influence the structure of the pricing scheme. OECD [OECD2004] analyzed the institutional framework in terms of public supply (municipal, regional, inter-municipal), ownership (public, private, both), management (public, private, both), economic & environmental regulators (municipal, regional, central/provincial government) in 29 OECD countries. An overall picture of the current situation in Europe (**Table 3**) shows that 48% of the population is served by water supply systems under public management, 15% by public water companies (Germany and the Netherlands), 20% by delegated private management (mostly France and Spain) and only 1% by direct private management (England and Wales) [EEA2013]. Overall, the authority/ability to regulate depends on the legal framework for water resources and its approach for ownership and allocation of water [Akmouch2008]. Several options for regulation exist in EU and overseas water sector such as separate Water Law; provisions in different laws; administrative/executive decrees & regulations; customary or traditional law; court decisions; increasing explicit references in State Constitutions to clarify responsibilities for multilevel governance [Akmouch2008; OECD2004].

Table 3. Institutional framework in selected OECD countries [OECD2003a; OECD2004].

	Public Supply	Ownership[1]	Management	Economic Regulator	Environmental Regulator
EU					
Austria	Municipal	Public	Public	Municipal	Central govt.
Belgium	Inter-municipal	Both	Both	Federal govt. (prices)	Regional
Czech Republic	Municipal	Private	Both	Central govt.	Central govt.
Denmark	Municipal	Public	Public	Municipal	Central govt./muncipalities
Finland	Municipal	Public	Public	Municipal	Central govt.
France	Municipal	Public	Both	Municipal	Central govt.
Germany	Inter-municipal/Municipal/Regional	Both	Both	Municipal/Region	Regional
Greece	Municipal	Public	Public	Central govt.	Central govt.
Hungary	Municipal	Public	Both	Central govt.	Central govt./independent
Iceland	Municipal	n.a.	n.a.	n.a.	Central govt.
Ireland	Regional	Public	Public	Regional	Central govt.
Italy	Municipal	Public	Public [2]	Central and region. Govts.	Central and region. Govts.
Luxembourg	Municipal	Public	Public	Municipal	n.a.
Netherlands	Municipal	Public	Both	Central govt./regional	Central govt./regional
Norway	Municipal	Both	Both	Central govt.	n.a.
Poland	Municipal	Public	Public	Municipal	Municipal
Portugal	Municipal/Regiona	Public	Both	Central govt.	Central govt.

	l				
Spain	Municipal	Public	Both	Central govt.	Central govt./independe nt
Sweden	Municipal	Public	Public	Municipal	Regional
Switzerland	Municipal	Public	Public	Central govt.	n.a.
Turkey	Municipal	Public	Public	Central govt.	Central govt./regional
UK (England & Wales)	Regional	Private	Private	Independent	Independent
Beyond EU					
Australia	Regional/Municipa l	Both	Both	Regional/Inde p.	Provincial govts.
Canada	Regional	Public	Public	Provincial govt.	Provincial govt.
Japan	Municipal	Public	Public[2]	Central govt.	Central govt.
Korea	National/Regional	Public	Public	Central govt./regional	Central govt.
Mexico	Municipal	Public	Both	Central govt.	n.a.
New Zealand	Municipal/Regiona l	Public	Both	Central govt.	Central govt.
United States	Municipal	Both	Both	Independent	Independent

Notes: 1. "Both" means public and private; 2. Private management exists but it is marginal.

As far as the pricing schemes are concerned, they vary across countries from flat fee to constant, volumetric and increasing blocking rates (see Table 4). The most common water-pricing schemes are hybrid models combining fixed and variable components (service charges and volumetric rates) [EEA2013]. The lack of metering infrastructure does not allow the adoption of more complex systems such as blocking rates. Moving from flat fees to volumetric rates, for instance, entails the installation of meters; and changing the structures of volumetric tariffs e.g. changing the number or size of blocks in an increasing-block tariff (IBT) scheme requires that impacts are assessed on the financial sustainability of the provider, the affordability for different consumer groups, short- and long-term impacts of demands; it also requires extensive consultation with the public [OECD2008].

Table 4. Water rate design for domestic use in selected EU countries [IWA2010].

	Types of tariff structures				
	Flat rate unmetered	Uniform rate	Increasing blocking rates	Decreasing blocking rates	Fixed or service charge
Austria		X			
Belgium					
Flanders			X		
Brussels			X		
Wallonia			X		
Bulgaria	X	X			
Cyprus			X		X
Denmark		X			X
Finland		X			X

France		X			X
Germany					X
Hungary		X			
Israel			X		
Italy			X		X
Greece			X		X
Netherlands	X	X			X
Norway	X	X			X
Poland		X			
Portugal			X		X
Slovakia		X		X	X
Spain			X		X
Sweden				X	X
Switzerland		X			X
United Kingdom					
N. Ireland	X				
England & Wales	X	X			
Scotland	X				

2.4.2 UK institutional framework and pricing schemes

The water and sewerage industry in England and Wales was privatized in 1989 as part of Thatcher's privatization program which involved privatization of other sectors such as gas and electricity, telecommunications, railway etc. Prior to privatization there were 10 Regional Water Authorities responsible for the water and sewerage supply and 29 Statutory Water companies, which were already privatized companies and responsible for the supply of water only [Maziotis2012a]. After 1989, the 10 Regional Water Authorities were privatized forming the Water and Sewerage companies (WaSCs) and the 29 Statutory Water companies formed the Water Only companies (WoCs) [Maziotis2014a]. In 2009, after mergers and acquisitions (WaSCs & WoCs and WoCs & WoCs) the number of WoCs reduced to 11, whereas the number of WaSCs remained the same [Maziotis2014b].

Being privatised as natural monopolies, WaSCs and WoCs were subject to price cap regulation which is designed to give firms incentives to increase profits by reducing costs and to eliminate the potential to manipulate output prices [Maziotis2012b]. The economic regulator, the Water Services Regulation Authority (Ofwat), was given the duty to administer an RPI+/- K price cap regime [Senante2014]. The K factor is composed by an efficiency factor (X), which is determined by benchmarking the performance of the water companies and adjusted for a factor (Q) that allows for the cost of capital investment programs mandated by the Drinking Water Inspectorate and Environment Agency [Saal2001; Saal2007]. The K-factors are set separately for each WaSCs and WoCs every 5 year by Ofwat.

The Drinking Water Inspectorate (DWI) and Environment Agency (EA) are the two environmental regulators which are responsible for controlling the drinking water quality conditions and pollution control, licensing and regulation of water abstractions, respectively. Price limits represent changes in revenue needed to enable an efficient company to finance the delivery of services year by year [Ofwat2004]. Figure 1 depicts the general approach by Ofwat to set prices limits in the regulated water industry by taking into account future efficiency gains, enhancements to environmental and drinking water quality, security of supply and service levels, financial functions and past performance[1]. As part of the review of water prices in 2009, new mechanisms were included to calculate price limits such as the Capital expenditure Incentive Scheme (CIS) which allows each company to recover its actual capital expenditure plus or minus an incentive allowance that depends on its forecast of capital expenditure and its actual expenditure in 2010-15 [Ofwat2009b]. Other features include the Overall Performance Assessment (OPA) which was a composite measure of the WASCs levels of service, customer service and environmental performance such as customers' complaints, security of supply, pollution incidents [Cooper2013]. In the future price review, the latter measure is replaced with a new Service Incentive Mechanism (SIM) which uses new measures of customer experience [Ofwat2009a].

Past evidence assessing the impact of regulation on the performance of the UK water and sewerage sector suggests that during the years 1991-2000 price caps were "weak" as prices were high enough for the firms to achieve economic profits despite their low productivity levels [Saal2001; Maziotis2009]. However, after 2001 prices became "catch up promoting" as they required less productive companies to eliminate at least some excess costs in order to eliminate economic losses [Maziotis2009; Maziotis2013]. It is concluded therefore that the English and Welsh water regulator is now more focused on passing productivity benefits to consumers, and maintaining stable profitability than it was in earlier regulatory periods [Maziotis2014a; Maziotis2014b].

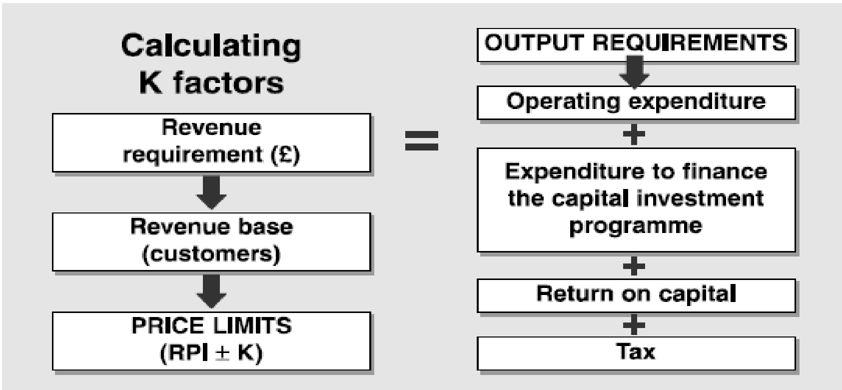

Figure 1. Calculating price limits [Ofwat2004].

Since 2009 a wide range of reforms have been under consideration driven by recent reports by Cave [Cave2009] and [Walker2009]. These reforms, among others, include changes in the current charging system to incentivize efficient use of water resources, increase the metering penetration rate and improve the synergies between water and energy in particular areas such as smart meters and efficiency measures [Walker2009]. Other reforms include for instance retail competition, changes to abstraction licensing, water trading, and mergers between water companies [Cave2009]. Thus far, the water regulator has enacted a mandatory accounting separation regime, requiring companies to provide cost information for different activities and has advanced hypothetical future industry structures, some of which are designed to impose stronger separation aimed at facilitating competitive entry [Ofwat2009; Saal2011a; Saal2013]. Having said that, in August 2009, Ofwat published new accounting requirements for 2009-2010 and on, which could potentially lead to formal accounting separation of the water and sewerage supply chain into 9 separate activities (wholesale vs retail) (see Figure 2) [Saal2011b].

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1 Companies are allowed to retain the benefits of outperformance for five years. After this, benefits are passed back to customers (Ofwat, 1999; 2004; 2009).

Figure 2. Accounting separation (wholesale vs retail) [Ofwat2009].

The wholesale water activities include abstraction and distribution of raw water from water resources, water treatment and distribution of treated water, whereas retail activities refer to billing activities from the provision of water. In analogous manner, the wholesale sewerage activities involve sewage collection and treatment and sludge treatment and disposal, whereas retail activities refer to billing from the supply of sewage. Accounting separation could result in the formal separation of the existing operations of the Water Only Companies (WoCs) and Water and Sewerage Companies (WaSCs), and the imposition of different regulatory price caps for each of the separated activities, i.e. the need for the regulated companies to report separate data for wholesale and retail (billing) activities [Maziotis2012a]. This process is still in progress and any new reported data will be publicly available from Ofwat's website after its formal approval.

These new reporting requirements don't form a change to the formal regulatory accounting guidelines (RAGs) for the water companies to report their data, but are seen by Ofwat as a necessary first step to improve data quality, before such accounting separation could be finalised in updated RAGs. As part of this process and according to the Water Act 2014, business customers will have the option to choose their water and sewerage supplier from April 2017, i.e. retail competition for non-households. The Water Services Regulation Authority (Ofwat), the Environment Agency (EA), the Department for the Environment, Food and Rural Affairs (Defra) and water companies have been working together to develop the market rules, framework, system requirements for an effective non-household retail market.

After having discussed the institutional framework in the UK water and sewerage sector, we now turn our discussion to the pricing schemes situation. The water and sewerage tariff basket is a complex mechanism set up in 1989 and consists of *unmetered* and *metered* charges. More particular, the unmetered water charges for households includes a fixed charge to cover the cost of water supply plus a charge based on the rateable value of the property. If the household property is metered then, the tariff consists of a fixed-metered charge and volumetric charge based on the amount of water consumed. As far as the sewerage charges are concerned, they are twofold; *unmetered* and *metered* and include charges (fixed plus rateable value or fixed plus volumetric) for three sewerage services: foul sewage, surface water drainage (run-off from rainwater that falls onto your property) and highway drainage (run-off from roads and pavements) [Ofwat2013]. The household receives a "unique" bill which is a combination of water and sewerage charges. Figure 3 depicts the change in the average household bill since privatization. It is concluded that during the period 1989-2010 on average the household bill in England and Wales increased by 43%. Until 1999 there has been a substantial increase in the bill by 38% indicating that the first prices reviews were too lax, whereas after 2000 the bill has increased by only 3.9% suggesting tighter price limits for the water companies.

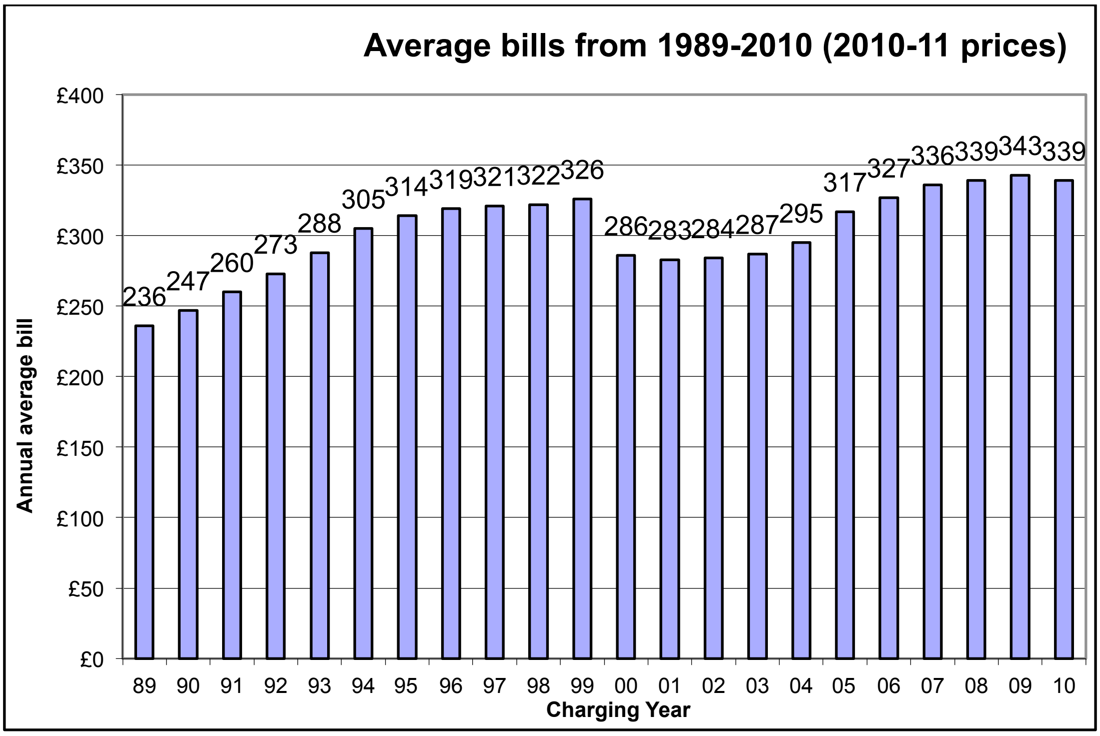

Figure 3. Average household bills from 1989-2010 (£) (Source: Ofwat – www.ofwat.gov.uk).

To reduce the financial burden of water charging for low-income tariffs several types of social tariffs were introduced in the UK. These include: large-user tariffs in Anglian and Mid-Kent Water; high standing charge/low unit rate; the national Vulnerable Groups Regulations (now WaterSure), capping the metered bills of a narrow range of larger lower-income metered households at their company average; Wessex's Ofwat-approved 2007 *Assist* tariff: a scale of low fixed annual payments directed at can't-pay customers (rather than won't-pay) who are taking advice from a debt advice agency and receiving at least one means-tested government benefit [Herrington2007]. Moreover, United Utilities introduced reduced charges for customers who live in the property of a specific Housing Association and agree to have their water charges collected with their rent [Ofwat2013]. The Welsh company introduced several affordability initiatives; Water Direct, where customers in receipt of income based benefits and pay their bills by direct deductions from their benefits (Water Direct) will receive a discount of £25 per year; Water Collect where customers who pay their bills via a participating social landlord or local authority will receive a £10 discount on their bill per year; Water Assist which is based on expanding WaterSure (formerly the vulnerable groups tariff) to unmetered customers and reducing the capped charge [Ofwat2013].

The UK is the only developed country that doesn't have full water metering and therefore the possibility of replacing the existing complex tariff with innovative ones. Metering levels in 2007-08 varied between companies, with meter penetration ranging from 12% to 68%. Several companies, including Anglian, Northumbrian (Essex & Suffolk), South West, Southern, Thames, Wessex, Bournemouth & West Hampshire, Cambridge, Folkestone & Dover, South East, Sutton & East Surrey, Tendring Hundred and Three Valleys, expect to see more than 80% metering well within the 25-year planning horizon [Ofwat2008]. The increase in metering penetrations, i.e. traditional or smart metering, allowed companies to introduce new tariff schemes such as *assessed charges* (e.g. Southern, Thames), i.e. charges based on the amount of water a consumer would likely to use if he had a meter. Moreover meters penetration will allow water utilities to explore innovative pricing schemes such as *seasonal tariffs*, e.g. South East water, Veolia Water Central (formerly Three Valleys Water), Wessex and *increasing Blocking Rates,* e.g. South West Water, Veolia Water Southeast, Wessex.

A recent study by Wessex water explored the impact of metering on change of occupancy, the impact of three new tariff structures (blocking rates, seasonal and peak seasonal tariff schemes) and the potential for investing in new smart meter technology [Warren2012]. The findings from tariff trials so far have suggested that the significant parameters in affecting water demand are tariff type, property-based segment (house type), garden size and direct debit, whereas other parameters such as Water audit or in-house reader, Water Sure/Assist, prior billing status, property ownership or weather did not have a significant impact on water demand [Palmer2012]. It is concluded that on their own, standard meters help a lot with demand and leakage and smart meters provide some extra help. But potentially huge benefits to customers, leakage and network management result when smart meters are combined with smart customer and network information and management [Palmer2012]. Overall, the tariff structure is limited by the meter technology, and any advanced tariff options will only become available with the use of “smart” meters, i.e. replacement of existing metering is required before exploring new tariff options.

Table 5: Wessex water meter trial (2008-2010), adapted from [Palmer2012].

		Additional impact compared to metering alone			
	Metering on change occupier (MCO)	**Rising block (IBR)**	**Simple seasonal**	**Peak seasonal**	**Smart technology**
Reducing customer demand	-15% (rising to 25% in the peak demand week).	additional annual demand reductions compared to standard metered charges of 5% on average 5%	additional annual demand reductions compared to standard metered charges of 6% on average	Did not show a statistically significant reduction in demand.	-
Reducing leakage	Fitting meters externally to customers' properties allow reducing leaks by 30 liters/day.	-	-	-	Smart meters would allow decreasing leaks by additional 9 liters/day.
Affordability of bills	Some customers (nearly 15%) suffered bills more than £100 higher (72% paid lower bills compared to unmetered charges)	Resulted in the widest distribution of both winners and losers (more than 1/3 of customers' bills was > £200 compared to unmetered charges)	2.4.2..1 Bills almost equivalent to the company's existing unmetered tariff. Lower bills than under IBR and standard (flat-rate) metered tariffs	Bills lower than IBR and standard (flat-rate) metered tariffs, and only slightly higher with the simple seasonal tariff***	-
Customer satisfaction	Overall customers' acceptance. Some concerns that MCO may lead to higher bills.	Disquiet to customers and increased num. of complaints*	Disquiet to customers and increased num. of complaints	Disquiet to customers and increased num. of complaints**	-

*Main concern around the concept of varying blocks of water by the number of occupants. Wessex Water considers this as a credible long-term solution [Palmer2012] since '*occupancy information is not available to water companies in the UK, and access to this kind of information is not common within the political culture*'.
** Peak seasonal tariff was found to be the 'least unpopular' among customers since it was perceived to give customers 'the most control in whether they paid a higher unit rate' [Palmer2012].
*** The average bill of a low-income customer (compared to other customers), under simple seasonal and peak seasonal tariffs changes by only 3 percentages (see upper chart in [Palmer2012], page 15).

2.4.3 Switzerland institutional framework and pricing schemes

The responsibilities for water supply and sanitation in Switzerland are allocated to three institutional levels: the municipal, the cantonal, and the federal. The provision of water services, instead, has been traditionally under the jurisdiction of the municipalities. Accordingly, the Swiss water market is highly segmented, with a multitude of local monopolies, subject to hardly any type of competition [Manso2005].

The Confederation, i.e. the federal level, is in charge of establishing the legal framework for the protection of water resources and for the drinking water quality standards. To this aim, a key role is played by the Federal Office for Water and Geology (FOWG), which is responsible for the general coordination of integrated water protection activities. Moreover, the Confederation may participate in financing the development of infrastructures.

Cantons are in charge of assuring the administrative, legal, technical and financial control of the water sector. Moreover, they are responsible for water quality and water source protection as well as provision of water services and water sector regulation in their territory. The responsibilities are allocated to different cantonal water and environmental offices. In addition, cantons are responsible for the construction and operation of the public sewerage systems and treatment plants.

Cantons normally delegate to municipalities the responsibility for the provision of water services, to an extent ranging from mere operation of secondary networks to water quality and price setting.

Municipalities, depending on the degree of delegation they enjoy, choose the structure and organization of the service. Municipalities may choose to provide directly the service or to contract out it to a third entity. In the former case, municipalities operate the water services through an ad-hoc department of the local administration. In the latter case, they transfer the service management for a limited period of time to a public or (rarely) private operator.

The choice among the two modes of delivery is often contingent upon the size of the municipality. In smaller municipalities, the provision of water services is only rarely contracted out to a (private) company compared to the case of bigger municipalities. In the latter case, the water services are often provided by municipally-owned corporatized entities or alternatively they are integrated into local public multi-utility. An alternative solution is represented by the creation of inter-municipal joint-ventures, which can benefit from economies of scale.

Municipalities are also in charge of delivering water sanitation services. Unlike water supply services, water sanitation services must be directly managed by the municipality. The only possible form of indirect management is through an association or syndicate of municipalities.

In Switzerland there is no water sector regulator, and the regulatory functions are attributed to different institutional levels. In general, the majority of the water-related regulatory instruments, in particular the economic regulation – i.e. the awarding of concessions to use water bodies, and the tariffs setting for water use and wastewater treatment - are defined at the cantonal level. In this way, each canton acts indeed as a water sector regulator of its own.

The environmental regulation – i.e. mainly water resource protection - is the only federal regulatory responsibility and is guaranteed by the above mentioned Federal Office for Water and Geology, whose main instrument is the definition of quality standards and technical norms, in turn applied by the cantons and/or by municipalities.

There are mostly three sources of financing in the water supply and sanitation sector: tariffs, fees, and contributions from users; the municipal budget; subsidies.

The tariffs - charged for water supply - and the connection and user fee – charged for sanitation services - are the most important source of financing of the sector. As above mentioned, the responsibility to set water prices rests with the cantons, which they normally delegate to municipalities. Accordingly, the tariffs structure is highly heterogeneous (e.g., some municipalities have fees for connection, for the meter, or for consumption), as is the way of calculating the fixed fee (e.g., some municipalities use tax estimations and others the number of connections). Recently, in many municipalities, more innovative pricing schemes have been introduced, mainly increasing block rates.

In practice, water prices vary from municipality to municipality, depending on contextual factors, such as the availability of the water resource, the topography, and the characteristics of the infrastructure. Currently, water tariffs have a rising tendency due to a relatively old network, which consequently requires investments. The introduction of increasing block rates is consistent with the latter issue.

Even if water economic regulation is a competence conferred to cantons, it is worth mentioning that, at the federal level, the Federal Department of Economics has established the Price Supervisor, an entity whose main responsibilities is monitoring the evolution of tariffs in the Swiss territory to avoid the charging of excessive water prices.

The municipal budget is especially important for financing sanitation services. In fact, according to their competencies, municipalities have to gather the financial resources necessary for the sanitation sector. The municipalities are allowed to take loans at market conditions to finance infrastructure investments and include the expenses in their operational budget.

Subsidies in general, and in particular those at the federal level, can be used only to finance sanitation services, as water supply must be financed through full cost recovery pricing. However, at the municipal level, since the accounts of the communes are generally not really transparent, the possibility that there are some cross-subsidies among different sectors or services within the communes cannot be ruled out. An exemption is provided for the extension of the water supply infrastructures. In this case, some subsidies are indeed available. The sanitation services, instead, benefit from more subsidies at the federal and cantonal level, essentially meant to motivate and empower measures aimed at the environmental protection.

2.4.4 Other countries institutional framework and pricing schemes

Italy

The Italian water sector is characterized by a multi-level governance, which has been defined as a result of an ongoing normative flow. The current regulatory framework comprises a national regulatory authority, the AEEGSI (Autorità per l'Energia Elettrica, il Gas e il Sistema Idrico) and a set of local regulatory authorities, AATOs (Autorità d'Ambito Territoriale Ottimale), beside the Ministry of the Environment, responsible for the protection of water resources.

The AEEGSI, as a national regulator, assures the accessibility and quality of the water services throughout the country and establishes a water tariff scheme aimed at guaranteeing efficiency and economic sustainability as well as implementing the "full cost recovery" principle promoted by the European Union.

The AATOs, one for each "optimal management areas" (Ambiti Territoriali Ottimali or ATO), defined both to ensure geographic division on the basis of natural water basins and also to avoid the excessive fragmentation of services, have three main objectives. The first is to contract-out the management of the water supply and sanitation services to one integrated water system operator, who is required to sign an agreement defining the forms of supervision and control used by the local authority. The second is to define a technical, financial and operating plan, assigning specific objectives to individual water utilities in terms of investments and water and service quality. Finally, the third objective is to monitor the implementation of planned strategic objectives and actual results obtained by the utilities through detailed analysis [Guerrini2011]. There were 92 AATOs at the end of 2012. The number of AATOs dropped to 71, after a law was passed in 2010 mandating the deletion of the AATOs and conferring their functions onto the regions.

As far as the water market is concerned, it has been subject to an ongoing restructuring process, started in 1994 with the promulgation of the Galli law (law n. 36 of 1994). This law was devised to integrate water services (water supply and sanitation) and put an end to in-house delivery. In addition, the Galli law allowed the entry of private operators to increase the average scale of the industry [Bognetti2007; Carrozza2011Carrozza2008; Guerrini2011Guerrini2013; Massarutto2013]. More than twenty years after the Galli law was passed, the Italian water industry still shows a high degree of fragmentation. According to the AEEGSI, approximately 1,235 firms and public bodies were involved in the provision of water services at the end of 2013, 75% of which are municipalities and other public bodies providing water supply and/or sanitation services “in house”. Moreover, only approximately 32% of the 1,235 firms are integrated water service operators.

As above mentioned, water service tariffs are regulated by the AEEGSI since 2012. Traditionally, the water service tariffs were negotiated between the AATOs and the water service operators by applying a tariff scheme issued in 1996 by the Ministry of Public Works. This tariff scheme was based on an *ex-ante regulation,* which determines a revenue cap on the basis of planned investments. In 2012, the AEEGSI provided a new paradigm for the water tariff setting. The new tariff scheme allows water utilities to cover not only operating and service costs but also environmental and resource costs not included in other tariff components (consistently with EU standards). In addition, capital costs are covered through an *ex-post regulation,* by including only those costs related to actual investments.
Turning to the pricing schemes, the most common mechanism entails a two-part tariff, composed by a fixed and a volumetric part. The volumetric part has a different structure depending on the service. Water supply services are charged through an increasing block rate (IBR), with a first block generally cross-subsidized by the others. The volumetric part in the water sanitation services, instead, is generally characterized by a single rate.

Germany

The water and sewerage industry in Germany is highly fragmented: approximately 6,211 water utilities existed in 2007 of which 5,972 delivered water to the final customers [Zschille2013]. It is organized in a three level governance including the Federal Government, the federal states (“Länder”) and the municipalities.

The Federal Government through the Ministry of Economy and Employment regulates the water and sewerage sector, whereas the Ministry of the Environment, Protection of Nature and Safety of Reactors is responsible for the protection of the water resources and management of the river basins; finally, the Ministry of Health regulates the drinking water quality standards [Caliman2012]. The federal states regulate the water services in their relevant territories, whereas the municipalities are responsible for the water and sewerage supply.

Municipalities are free to choose between self-supply and third-party supply and different legal forms of the own water supplying entity exist such as publicly-owned companies, municipal utilities, public-law institutions, mixed-economy companies [OECD2004].

If water services are provided by public law entities then prices surveillance is subject to the federal states. In contrast, if private law entities provide water services, then prices are subject to the control of the competition authorities, which can sanction abusive practices and punish excessive pricing [OECD2004]. As far as the sewerage services are concerned, they are publicly owned. After an intense debate about the deregulation and further liberalization of the water markets, the German parliament decided against this in 2002 [Schleich2009].

Moreover, a national strategy was adopted to improve the performance of water and sewerage companies, the quality of service to customers and water quality standards. As a key instrument to achieve these goals, utilities are to be benchmarked against each other in terms of prices and services [Schleich2009]. Past evidence showed that in 2007 the costs of water supply and sewage services in Germany amounted to €213 per year for the average customer, water losses had the lowest rate among EU countries, whereas the customer satisfaction with the provision of public water supply was high, mainly driven by the high quality of tap drinking water [Wackerbauer2011; Fraternali2014].

Portugal

A similar fragmentation of water utilities is evident in Portugal. The provision of water and waste services lies with the jurisdiction of municipalities. They can opt for different arrangements including the establishment of private companies by means of concession contracts, municipal companies which can encompass or not a (minority) private shareholder, semi-autonomous organizations (with some kind of autonomy) and the direct supply by the municipalities [Witte2010].

The last seventeen years the water and sewerage sector has undergone several reforms. In 1993 only vertically integrated companies existed whereas by 2008 the water structure consists of wholesale, retail and vertically-integrated companies.

Regarding economic regulation, Portugal has its own national water regulator, the Institute for Water and Waste Regulation (Instituto Regulador de Águas e Resíduos, IRAR). IRAR is responsible for ”promoting evaluation of the service levels of managing bodies” and “distributing information on specific cases that stand as a reference for quality of design, implementation, management and operation in multi-municipal and municipal systems.” [OECD2004]. In particular, IRAR determines a set of performance indicators for each operator and compares and displays publicly the results (i.e., sunshine regulation) [Marques2008; Simoes2010]. In this case, companies that outperform are awarded, whereas companies with poor performance are penalised.

Its power in the field of setting prices is limited to issuing non-binding opinions about price regimes, based on an allowed rate of return, and only when it comes to wholesale activity [Martins2006]. Consumers are subject to the following tariffs; the fixed tariff to cover the operational and maintenance (O&M) costs, the volumetric tariff based on the amount of water consumed and the type of consumer use (domestic, industrial) and tariffs for other services [OECD2004]. However, the current tariff scheme does not allow the fully recovery of costs from the provision of water and waste services. There is, therefore, a degree of consensus about the need to change the way tariffs are set, in order to overcome the economic and financial deficit in the sector and to meet the principles, such as the user and polluter pays principle, contained in Directive 2000/60/EC, the Water Framework Directive (WFD) [Martins2006; Simoes2010; Marques2011].Figure 4 below shows a schematic of the regulatory framework in Portugal.

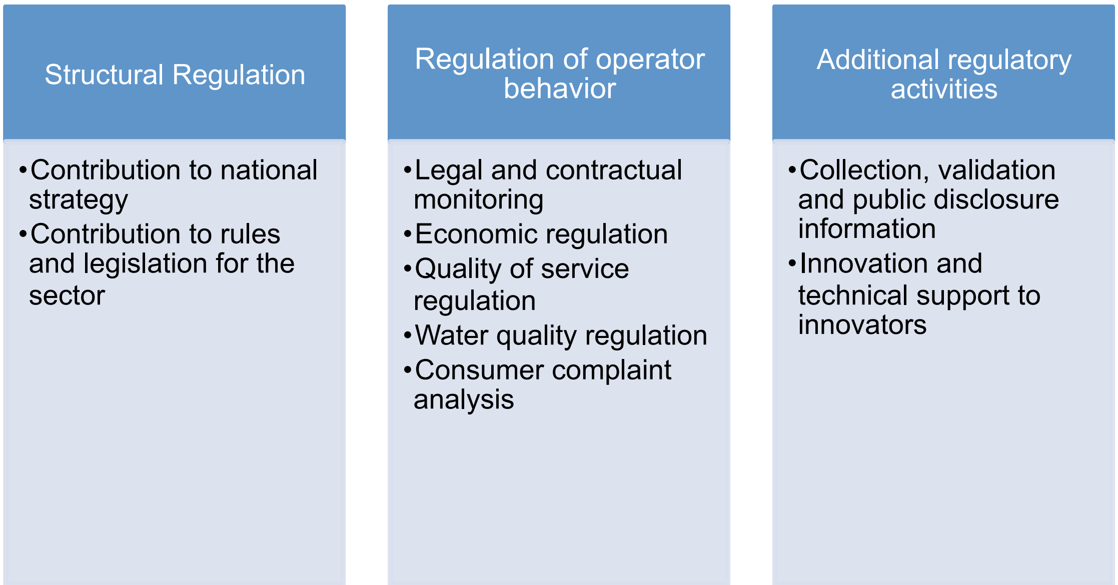

Figure 4. The regulatory model in the water sector in Portugal - IRAR [Palma2012].

France

A massive fragmentation of water sector exists in France where 36,600 municipalities and 4,500 inter-municipal bodies are responsible for water and sanitation services. The delivery modes can be direct public management or forms of concession to private firms, i.e. Public-Private Partnerships (PPPs) or delegated management contracts. Barraque and Les Bris [Barraque2007] quote three types of PPP or delegated management contracts which are renegotiated every five years: *régie intéressée*, where the delegate operates and maintains the assets built by the public authority and receives a proportional fee based on the volume sold; *affermage*, the most frequent type of delegation, where the delegate operates and maintains the assets built by the public authority, but receives its revenue from the users and transfers a fee (surtaxe) to the public authority in accordance with the depreciation of the assets; and *concession*, where the delegate builds, operates and maintains the assets and receives its revenue from the users [Fraternali2014].

The 1992 and 2006 French Water laws obliged water utilities to design tariffs which provide higher conservation incentives (environmental objective) while allowing water utilities to cover their costs (economic sustainability), i.e. to comply with the WFD objectives [Rinaudo2012]. To achieve these objectives, water utilities need to simultaneously adjust fixed (i.e. decrease) and volumetric charges (i.e. increase) leading, however, to negative social effects. As a result, alternative tariff schemes have been introduced or will be explored such as IBRs and seasonal tariffs so that reduction in water demand, improvements in equity and revenue-neutral objectives are simultaneously fulfilled.

Additionally, in 2007 the French National Agency of Water and Aquatic Environments (ONEMA) was established as a tool to regulate the water services by assessing their performance (i.e. sunshine regulation). This is carried out by collecting performance indicators for each operator and by displaying publicly the results – a situation similar to the Portugese water sector.

Public and private efficiency of French water utilities is being debated. For instance, in 2009 the mayor of Paris decided not to renew the contract with a private operator for the provision of water services to the citizens of Paris due to its past poor performance. After two years of public management, it was reported that the good performance of the public operator (i.e.

improvement in productivity, drinking water quality, quality of service) would result in a substantial decrease in water prices for citizens of Paris [Lannier2013]. Therefore, the need for collecting performance indicators at local and national level to assess the performance of operation is of outmost importance as it will allow stakeholders to make decisions on investments and costs and subsequently prices charged to customers.

Finally, past evidence on the development of water charges in France showed that they were 27% and 23% higher on average when the water service is provided by a private operator in cities supplying less than 10,000 inhabitants and more than 10,000 residents respectively [Saussier2013]. A similar finding was previously reported by Carpentier et al. [Carpentier2006] who compared public and private water utilities in France and suggested that prices are higher under private management mainly because they face harder operating environments [Garcia2013].

Spain

The institutional framework of the water sector in Spain is similar to the one applied in France, which means the co-existence of public, private and public-private partnerships to the management of urban water services.

In Spain the Water Directorate General for Water of the Ministry of Environment, and Rural and Marine Affairs –MARM- (including agriculture) determines the overall national policy for water protection together with river basin organisations (Confederaciones Hidrográficas). Drinking water quality standards are under the control of the Ministry of Health [EMWIS2008]. The Confederaciones de Cuencas Hidrográficas are responsible for the planning and implementation of large-scale works and infrastructures such as dams; they draw up the Basin Plans, establishing the quality objectives of the water bodies and monitoring the actions taken in order to achieve them [Caliman2012].

The municipalities are responsible for the provision of water services. They could choose to provide the services by themselves (in-house) or outsourcing to an external company (externalised), which could be either public or privatised. In the latter case, the management of the service may be either *fully privatised*, i.e. *contractual* public-private partnerships (PPPs), or *partially privatised*, i.e. *institutionalised* PPPs (see Figure 5 [Valiñas2013]).

When the provision of water services is under public management, water tariffs are regulated by public authorities. This implies that any changes in tariffs requires the approval of the city council and depending on the region, the approval of the price board dependent on the Ministry of Economy and Finance of the regional government, or of water agencies recently created in several regions and dependent on the Departments of the Environment of the regional governments [Espiñeira2012]. In contrast when the management of water services is controlled by private firms, then these firms might change the tariff structure in order to get higher revenues [Espiñeira2009].

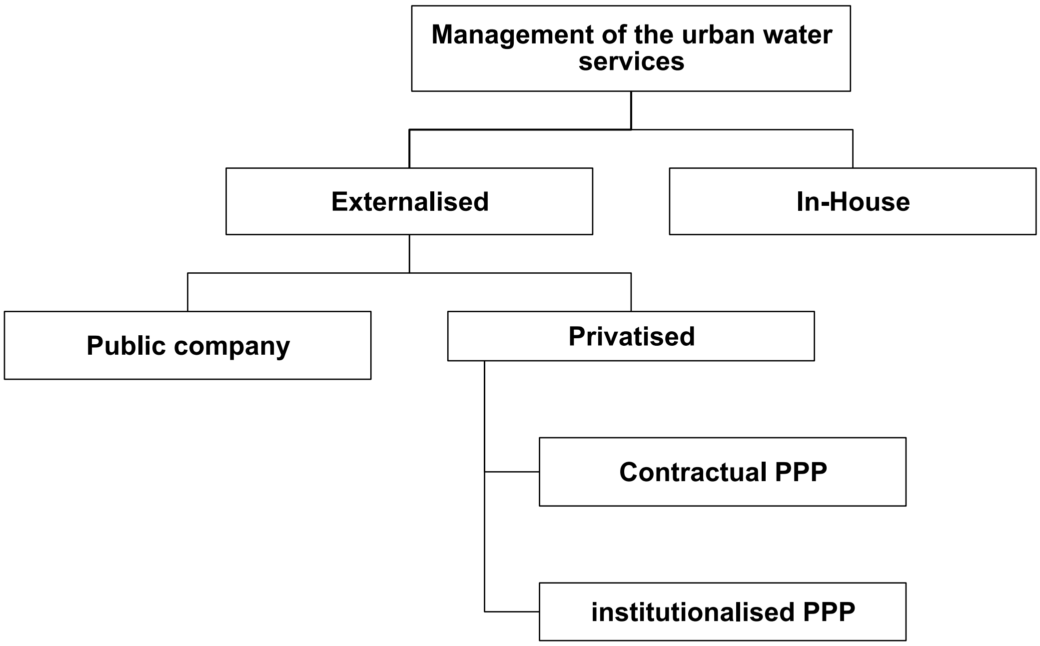

Figure 5. The institutional framework in the water sector in Spain [Valiñas2013].

The majority of the regions/cities in Spain have adopted a two-part tariff, involving a fixed component and a variable component, combined with an increasing blocks rate mechanism. Prices charged to the customers by the aforementioned management structures could be heterogeneous. This is attributed to the fact that although price regulations to control the behaviour of private firm exist, these are based more on formal criteria than on economic or technical ones [Espiñeira2009]. The same authors state that the regulatory boards are managed by experts in financial law and formal processes rather than water economics and engineering. As a result, prices charged to the customers could differ substantially among the Spanish regions based on the management structure of water supply services making difficult any benchmarking comparison. Martínez-Espiñeira et al. [Espiñeira2009; Espiñeira2012] concluded that private or mixed firms set higher average price levels that public ones in Northern Spain. Different results are reported in a study by García-Valiñas et al. [Valiñas2013], who found that in the region of Andalusia the price is noticeably lower when water is provided in-house than when the service has been externalised; public companies charge higher prices for water than private companies and institutionalised PPPs set higher prices than contractual PPPs. These studies underlined that the design of tariffs should therefore take into consideration important aspects such as the number of blocks of the structure of the tariff, consumption volumes per block, the establishment of the first to meet minimum needs, ownership and the climatic diversity of the different parts of Spain. The lack of clear guidelines on how tariff rates should be designed does not allow the full recovery of service costs.

Among EU countries, the Spanish annual water bill is among the lowest ones, suggesting that the recovery of the costs for the supply, sewerage and treatment service are low, ranging from 30% to 90% for most cities/regions [Caliman2012; IWA2010]. Regulations, pricing measures, education and awareness campaigns and incentives to stimulate the introduction of low-consumption technologies are some instruments that have been applied in recent years in several regions/cities in Spain to improve efficiency use of water [Arbués2015; Valiñas2010; Valiñas2013; Senante2014; Urdiales2014; Espiñeira2014; Espiñeira2013].

3. Review of the state of the art: Water demand by user

3.1 Introduction

The future social, economic and environmental costs of meeting the water needs of human populations and supporting economic development will depend on our ability to understand and manage water demands [Dziegielewski2003]. Demand management strategies such as pricing, water re-use, water efficiency, leakage reduction can improve demand-supply balance in water stress areas and benefit both customers and stakeholders. More particularly, past evidence suggested that pricing policies can be more effective and longer-lasting than other demand side management efforts such as public information campaigns, education, and voluntary or mandatory watering restrictions [Olmstead2009; Coleman2009; Mansur2012]. Important component when designing a tariff scheme is the price elasticity of water demand which measures the responsiveness of demand to changes in prices. This section discusses the studies that estimated water demand for households, by focusing on the drivers and their impact on household water consumption.

3.2 Household water demand studies: variables and data

3.2.1 Unit of analysis and data source

The estimation of residential water demand has been widely researched in the literature. Early studies by Boland et al. (1984) offer a comprehensive literature review on the effect of prices, rate structures and pricing policies on municipal and industrial use. Later studies exploring the drivers that affect water demand and efficient use of water in areas affected by water scarcity were by Arbués et al. [Arbués2003], Olmstead et al., 2007 [Olmstead2007], Mansur & Olmstead [Mansur2012] and Martínez-Espiñeira et al. [Espiñeira2014]. Moreover, meta-analysis of the determinants of price and income elasticities of water demand by Esprey et al., [Espey1997], Dalhuisen et al. [Dalhuisen2003], Worthington and Hoffman [Worthington2008], is another source of information.

Until the 1980's, studies conducted using US data dominated the literature, but since the 1990's and especially after the turn of the century, a great number of analyses from other parts of the world have been published, especially from Europe [Monteiro2010]. For example, Worthington and Hoffman [Worthington2008] reviewed 37 studies worldwide, 56% of which were based on US, 24% on Europe and 16% on Australia samples. Nauges and Whittington [Nauges2009] provide a literature review on the household water demand for less developed countries. Romano et al. [Romano2014] include 21 studies from Europe and most recently, Sebri [Sebri2014] offers a recent meta-analysis of price and income elasticities of water demand for both developed and less developed countries.

Regarding price elasticity of water demand for urban use, Espey et al. [Espey1997] stated that price elasticity estimates ranged widely from -0.02 to -3.31, with an average of -0.51; Worthington and Hoffman [Worthington2008] found that price elasticity estimates range from -0.5 to 0 in the short run, and -0.50 to -1.00 in the long run. Dalhuisen et al. [Dalhuisen2003] found that average price elasticity estimates are -0.41. Sebri et al. [Sebri2014] reported that the mean value of price elasticity estimates was about -0.34 in developing countries, while it stands at around -0.38 in developed countries. Typically estimates lie in the range between -0.25 and -0.75 [Billings1980; Chicoine1986a; Gaudin2001; Espiñeira2003a; Dharmaratha2010]. Monteiro and Roseta-Palma [Monteiro2011] estimated a price elasticity of demand for the Portuguese water sector which varies from -0.133 to -0.051 depending on the functional form of the water demand which is lower than the value of -0.558 estimated by Martins and Fortunato [Martins2007] but similar to the values estimated by Martínez-Espiñeira and Nauges [Espiñeira2004] and Martínez-Espiñeira [Espiñeira2002] for Seville and Galicia respectively. Schleich and Hildebrand (2009) find a price elasticity of demand in Germany around -0.24 and Romano et al. [Romano2014] a value of -0.169 in Italy, while Arbués and Villanua [Arbués2006] estimate a price elasticity of -0.08 in Spain.

Taking into account North-American studies, Olmstead and Stavins [Olmstead2009] reported a price elasticity of demand at the level of -0.64 in seven urban areas in the United States and Canada, and Mansur and Olmstead [Mansur2012] reported separate elasticity estimates for indoor and outdoor use and by summer and wet period. More particularly, the price elasticity for indoor water use was around -0.093; it is found to be -0.086 during the summer and -0.120 during the wet season. In contrast, the authors found higher price elasticity for outdoor use (-0.62); at the level of -0.67 during summer period and -1.12 during wet season. More recently, Yoo et al [Yoo2014] reported that in California and Texas the short-run price elasticity was around -0.66, whereas the long run price elasticity was -1.16. Therefore, price elasticity estimates differ across geographical locations which could be attributed to the high outdoor use (US vs Europe) or to the fact that households may rely, in addition to the metered water, on other type of sources (developed vs developing countries).

As far as price sensitivity is concerned, past evidence showed that the elasticity in the long-run is significantly higher than in the short-run [Sebri2014]. For instance, Martínez-Espiñeira [Espeneira2003a] found that the short-run and long-run price elasticity of demand was estimated around -0.1 and -0.5 respectively using monthly time-series data for the period 1991-1999 from Seville, Spain. Similar findings were reported in Musolesi and Nosvelli [Musolesi2007] where the authors reported long-run and short-run price elasticity estimate of around -0.47 and -0.27 respectively on a sample of 102 Italian municipalities during the period 1998-2001. Same level of elasticities in the long and short run (-0.40 vs 0.26) were also reported in Nauges and Thomas [Nauges2003] on a sample of 116 communities from Eastern France during the period 1988–1993.

A first feature when estimating a price elasticity of household water demand is the distinction between aggregated vs. household level data. Schefter & David [Schefter1985] and Saleth & Dinar [Saleth2000] suggested that the estimation of residential water demand functions within a micro setting using household level data is the preferred approach. However, this requires detailed information on micro components like income which might be difficult to obtain [Arbués2003]. Esprey et al. [Espey1997] and Dalhusien et al. [Dalhusien2003] found that among others, household and aggregation level data are related to different elasticity values and the direction and significance of these effects is, however, not yet robust. [Sebri2014] showed that studies using disaggregated data (i.e. household or individual) report a demand for water which is more price-elastic than those using aggregated data. The same authors concluded that it is of high importance for policy makers to count on micro-level data to formulate suitable pricing policies because individual-level data better reflect the heterogeneity of households' preferences towards water consumption. Example of studies that used aggregated data comes from García-Valiñas et al [Valiñas2010] in Spain, Schleich and Hillenbrand [Schleich2009] in Germany, Romano et al. [Romano2014] in Italy, whereas household data were employed by Arbués and Villanua [Arbués2006] and García-Valiñas [Valiñas2006] in Spain, Hajispyrou et al. [Hajispyrou2002] in Cyprus, Omstead et al. [Olmstead2009] and Mansur and Olmstead [Mansur2012] in US.

Water demand can be estimated using cross-section, panel or time series data techniques. The first few research efforts relied mostly on annual cross-section data for water utilities and on limited information on the water tariffs (having access to the unit price for a specific consumption amount instead of the entire rate schedule, for example) [Monteiro2010]. Cross-section techniques are employed frequently [Hajispyrou2002; Chen2009]. When the socioeconomic characteristics of the different groups analyzed are very relevant and the elasticities estimated are supposed to represent their long-term value, panel data techniques are commonly used [Billings1980; Gaudin2001; Espiñeira2002; Espiñeira2003a; Arbués2004], whereas time series are less frequently used [Gaudin2006; Fullerton2006].

3.2.2 Dependent variable

Depending on the frequency of metering data information water consumption could be specified in several ways. These include daily/monthly/quarterly/annual data on water consumption.

Daily water consumption per capita was employed in several studies by Schleich and Hillenbrand [Schleich2009] in Germany, Bell and Griffin [Bell2008] in Texas, Reynaud [Reynaud2008] in France, Olmstead et al. [Olmstead2007] in US and Canada, Arbués et al., [Arbués2004] and Arbués and Villanua [Arbués2006] in Spain, Hanemann and Nauges [Hanemann2006] in California, Babel et al. [Babel2007] in Nepal, Gaudin et al. [Gaudin2001] in Texas.

Monthly water consumption per capita was used by Martins and Fortunato [Martins2007] and Monteiro [Monteiro2010] in Portugal, Martínez-Espiñeira [Espiñeira2003b] and Martínez-Espiñeira and Nauges [Espiñeira2004] in Spain, Ruijs [Ruijs2009] in Brazil, Yoo et al. [Yoo2014] in California and Texas, Reynaud et al. [Reynaud2005] in Canada and Strand and Walker [Walker2005] in Central America and Venezuela.

Moreover, quarterly water consumption per capita was used in several studies, such as García-Valiñas [Valiñas2005; Valiñas2006], Domene and Sauri [Domene2006] in Spain, Hoffmann et al. [Hoffmann2006] in Australia, Sebri [Sebri2013] in Tunisia, García-Valiñas et al. [Valiñas2013] in Australia, whereas annual water consumption was employed by Musolesi and Nosvelli [Musolesi2007] and Romano et al. [Romano2014] in Italy, Nauges and Thomas [Nauges2003] in France, [Gaudin2006] in US, Domene and Sauri [Domene2006] and March et al. [March2012] and March & Sauri [March2010] in Spain. In addition, other studies by Mansur and Olmstead [Mansur2012] further disaggregate residential water consumption into indoor and outdoor use to assess the sensitivity of indoor/outdoor use in price changes.

3.2.3 Drivers: Price variables

Water price is the most common tool to manage water demand and according to the law of demand, water consumption should be inversely related to water price; as a commodity with almost no substitutes, the price elasticity of water demand should also be inelastic. Having different tariff structures allows the specification of different demand models and their impact on water demand remains mixed [Arbués2003].

Earlier studies by Nieswiadomy and Molina [Nieswiadomy1989] and Young et al. [Young1983] reported high price elasticity of demand for IBR whereas Stevens et al. [Stevens1992] concluded that there was no statistically significance under uniform, IBR or DBR. Dalhuisen et al. [Dalhuisen2003] and Espey et al. [Espey1997] found that the tariff structure plays an important impact on residential water demand. In their meta-analyses, IBR has a statistically significant impact on the residential demand for water, making it more price-elastic, whereas the impact of DBR was found statistically insignificant. The above findings were contradicted by Sebri [Sebri2014] where IBR, DBR and flat tariff did not have a significant impact on water demand after having performed a robustness check on their results from meta-analysis. Moreover, Rosenberg [Rosenberg2010] simulated the residential water demand response under several tariff structures such as uniform increasing block rates and linear rate in Amman (Jordan). The author concluded that at low prices all rates structure produce an inelastic demand whereas at higher prices, uniform or IBR structures show the most elastic price responses with a calculated elasticity to vary depending on the price specification (average or marginal).

A large number of studies have examined residential water demand under increasing and decreasing blocking rates. Most of these studies focus on areas of US. Billings and Agthe [Billings1980], Gaudin et al. [Gaudin2001], Olmstead et al. [Olmstead2007], Olmstead [Olmstead2009] and Mansur and Olmstead [Mansur2012] have analysed increasing block structures, whereas Chicoine et al. [Chicoine1986b] explored decreasing blocks. Both increasing and decreasing block schemes have been examined by Schefter and David [Schefter1985] and Nieswiadomy and Molina [Nieswiadomy1989].

In Europe, increasing block rates have been researched in Spain [Espiñeira2003a; Espiñeira2003b; Espiñeira2004; Senante2014]; Cyprus [Hajispyrou2002]; Portugal [Monteiro2010; Martins2007; Monteiro2011], while flat rate structures have been studied in France [Nauges2003] and Australia [Higgs2001; Hoffmann2006].

Examples of estimates of price elasticity of demand under different tariff structures can be found in several studies. such as a value of -0.16 and -0.66 under a two-part tariff (fixed and volumetric charge) scheme in France and Phoenix, respectively [Valiñas2009] and [Yoo2014], from -0.292 to -0.642 under IBR (2 blocks and 4 blocks) in US and Canada [Omlstead2009], ranged between -0.20 and -0.28 and from -0.680 to -0.683 under IBR (5 blocks) in Brazil and Tunisia, respectively [Ruijs2009; Sebri2013], from -0.252 to -0.23 under uniform price in Germany [Schleich2009], from -0.41 to -0.125 under uniform price and IBR in Phoenix [Strong2008], -0.07 (indoor use) and -0.68 (outdoor use) under uniform price and IBR in US [Mansur2012], ranged between -0.058 and -0.029 and from -0.13 to -0.07 under fixed charges and IBR in Zaragoza and Seville, respectively [Arbués2004; Espiñeira2004], -0.46 to 0.55 under fixed charge and IBR (3 blocks) in Seville [Valiñas2005], from -0.79 to -0.39 under fixed charges and IBR (3 to 7 blocks) in Cyprus [Hajispyrou2002], and ranged between -0.051 to -0.124 under fixed charges and IBR (5 blocks) in Portugal, respectively [Monteiro2011]. Finally, Reynaud et al. [Reynaud2005] reported a value of -0.02, -0.11, -0.25 and -0.10 under flat, uniform, IBR and DBR respectively in Canada.

When estimating the residential water demand the price specification is of paramount importance. Studies consider several pricing specifications: average/marginal price, Shin price (i.e. combination of average and marginal price) and a difference variable [Nordin1976; Taylor1975]. Throughout the years, marginal price has for the most part replaced average price as the specification of choice, but either because of data availability concerns or because the researcher believes that the price specification is an empirical question, due to the fact that consumers may not have full information on the rate schedule, average price specifications are still used or tested against marginal price [Monteiro2010]. However, the use of average or marginal price in water demand modeling remains inconclusive [Schleich2009; Ruijs2008]. An estimation of water demand function under a single volumetric charge (e.g. average water price) is straight forward see for instance Schleich and Hillenbrand [Schleich2009] and Romano et al. [Romano2014] where the authors employed a logarithmic or linear form to estimate a water demand model in Germany and Italy. Difficulties arise when the tariff structure has the form of IBR or DBR, i.e. discontinuous tariffs where a fixed quota and/or a free allowance is used where average or marginal prices may differ. Average or marginal prices are not sufficient under block tariffs as consumers react not only to marginal prices, but also to the changes in income as a result of moving from one block to the other, and that these intramarginal effects should be included in the demand equation [Taylor1975]. Nordin [Nordin1976] complements Taylor's statement by suggesting the inclusion in the water demand modeling the use of marginal price and a difference variable which captures the income effect. The difference variable is the difference between the total bill and what the user would have paid if all units were charged at the marginal price [Espiñeira2002]. In the case of increasing (decreasing) block pricing, the difference variable represents a saving (additional cost) to the consumer and thereby provides an implicit subsidy (tax) for water consumed in the intra-marginal blocks [Billings1980; Dharmaratha2010]. Average prices were employed by Gaudin et al. [Gaudin2001]; Arbués et al. [Arbués2004]; García-Valiñas [Valiñas2005], while marginal prices by Schefter and David [Schefter1985]; Hajispyrou et al. [Hajispyrou2002] and Martínez-Espiñeira [Espiñeira2003a]; Olmstead et al. [Olmstead2007]; Mansur and Olmstead [Mansur2012]. Shin price specification was employed by Nieswiadomy [Nieswiadomy1992], while prices with Nordin's specification (i.e. marginal price and difference) were studied by Martínez-Espiñeira [Espiñeira2002; Espiñeira2003b]; Monteiro and Roseta-Palma [Monteiro2011], Martins and Fortunato [Martins2007]; Sebri [Sebri2013]. Nieswiadomy [Nieswiadomy1992] indicated that consumers react more to average prices than marginal prices in all major cities in US. Martínez-Espiñeira [Espiñeira2002] suggested that the values of price elasticity under the average/marginal price and Nordin's specification were not significantly different. The above finding was also confirmed by Monteiro and Roseta-Palma [Roseta2011] who suggested that this can be attributed to the fact that consumers are not aware of the block subsidy effect or simply do not react to it since it is small in comparison to their household income. Arbués et al. [Arbués 2003] concluded that some elasticity values (or value ranges) showed that the choice of price specification (average, marginal or Nordin's difference) did not greatly affect the results, while some suggest that demand is more responsive to average price. Moreover, Dallhuisen et al [Dallhuisen2003] found that the nexus of average and Shin prices increases the absolute value of the elasticities as compared to marginal prices. Finally, [Sebri2014] stated that for the price elasticity, there is no significant difference when including the average or marginal price, while the Shin or any other price specification makes the demand more price-elastic.

3.2.4 Drivers: Other policies

The literature on residential water demand has shown that in general, the water demand is price inelastic and pricing policies are a major tool to manage water demand. However, some studies suggest that there is a minimum amount of water demanded, which is not affected by economic variables [Valiñas2010] and is insensitive to change by means of price (or income) variations [Valiñas2014]. As a result, considerable research has focused on non-price policies such as education, information campaigns, voluntary measures and restrictions that could promote water conservation. Duppont and Renzetti [Dupont2013] assessed the impact of price and non-price policies on household's decision-making with respect to indoor and outdoor water conserving behavior in Canada. Non-pricing policies were proxied by 5 variables: i) Lead by example – efficient municipal/company facilities; ii) Media; iii) Outdoor advertising (billboards, buses etc.); iv) School curriculum programs; v) Water use by laws for lawn watering, and finally vi) Voluntary measures/restrictions. The authors concluded that the existence of non-price water conservation measures by local water agencies did not have a strong effect on watering frequency undertaken by households with the exception of garden watering. Other studies by Nieswiadomy [Nieswiadomy1992] in major cities in US showed that regions (e.g. South and West) which have a greater awareness of the scarcity of water, they also have higher price elasticities, and most importantly public education appears to have reduced water use in the West. Renwick and Archibald [Renwick1998] using detailed household-level panel data for two California communities found that both price and non-price measures (e.g. water allocation, quantity restrictions and subsidies for water efficient technologies) reduce household water use although their relative impact is a function of household structural features (size of lot, etc.) and characteristics (income) [Dupont2013]. Moreover, Corral et al [Corral1999] showed that in San Francisco Bay pricing can be effective in reducing water consumption, particularly during the annual dry season and this effect is mitigated when non-price conservation programs are included in the analysis. A recent study focusing on the areas of US by Mansur and Olmstead [Mansur2012] suggested that raising the price of consuming water would be much less costly than restricting outdoor water use and achieve the same benefits, i.e. to reduce water consumption. García-Valiñas et al. [Valiñas2014] found that in Brisbane the adoption of some water-efficient technologies and education had a strong effect on reducing water consumption. Promoting certain pro-saving habits such as turning off the tap when washing dishes, reducing the length of shower/bath, using less water in the garden could also bring about a reduction in indoor and outdoor water usage. Moreover, Arbués et al. [Arbués2015] evaluated the attitudes of Spanish households towards water conservation suggesting that water saving programs should target households with low tendency to save water in small cities in wet areas, and to households with positive attitudes towards water conservation but low education level in small cities in dry areas. Evaluation of households' attitudes towards water conservation was conducted by Clark and Finley [Clark2007] in Bulgaria. The authors concluded that knowledge of climate change and education were significantly associated with intentions to conserve water, while environmental attitudes and concern over future shortages were also significant but relatively weak drivers. Overall, non-price policies appear to have an impact on water consumption and further research is anticipated in this area.

3.2.5 Socio-economic characteristics of customers

In addition to price and non-price policies, a large number of studies included several socio-economic characteristics in water demand modeling. An important factor to consider is the household income, which for normal goods the higher the income the more the consumption. In case of water, water bill accounts for a small amount of households' income and existing literature suggests that the income elasticity of residential water demand is low [Arbués2003]. If however household income (measured in monetary terms per capita or per household) is not available, then other variables could be used as proxy for household income based on based on the educational level of the head of the household, car ownership, and the assessed property value and age of the residence [Arbués2003]. In addition, because income can approximate wealth, income (from taxation, census and survey data) can also be used to proxy other normal and luxury goods associated with household water consumption where data may not be as easily obtainable, including swimming pools and spas, in-ground garden irrigation systems and dishwashing machines [Worthington2008].

Examples of estimates of income elasticity of demand under different tariff structures can be found in several studies such as a value of 0.036 under a two-part tariff (fixed and volumetric charge) scheme in Phoenix [Yoo2014], ranged between 0.1865 to 0.683 under IBR (2 blocks and 4 blocks) in US and Canada [Omlstead2009], ranged between 0.19 and 0.28 and from 0.23 to 0.29 in Tunisia under IBR (5 blocks) in Brazil [Ruijs2009; Sebri2013], 0.355 under uniform price in Germany [Schleich2009], from 0.105 to 0.199 under IBR in Italy [Statzu2008], 0.62 under uniform price and IBR in Phoenix (Strong and Smith, 2008), ranged between 0.072 and 0.208 and from 0.07 to 0.13 under fixed charges and IBR in Zaragoza and Seville, respectively [Arbués2004; Espiñeira2004], 0.58 under fixed charge and IBR (3 blocks) in Seville [Valiñas2005], from 0.22 to 0.48 under fixed charges and IBR (3 to 7 blocks) in Cyprus (Hajispyrou et al. [Hajispyrou2002]), and ranged between 0.032 to 0.087 under fixed charges and IBR (5 blocks) in Portugal [Monteiro2011]. Overall, past evidence showed that estimates of income elasticity are almost universally income inelastic (less than one) and small in magnitude.

In addition to income, tariff structure and non-price policies, Romano et al. [Romano2014] and Arbués et al. [Arbués2015] underlined that water consumption could be affected by many other factors, such as population characteristics [Espiñeira2002; Schleich2009], population density [March2010], the presence of immigrants [March2012], household features [Martins2007; Valiñas2005], or house characteristics [Domene2006; March2012].

3.2.6 Exogenous determinants and controls

Weather and seasonal factors have been included by a large number of studies. These factors were specified as daily or annual average temperature (measured in ^{o}C) [Olmstead2009; Ruijs2009; Romano2014; Monteiro2011], annual average precipitation (measured in mm) [Strong2008; Romano2014; Monteiro2011] or the number of rainy days [Hoffmann2006] or average number of days with precipitation>1mm in spring and summer months [Schleich2009], evapotranspiration rate less precipitation [Olmstead2009; Mansur2012; Olmstead2007] or seasons (arid vs wet) [Mansur2012; Valiñas2005; Yoo2014]. Empirical evidence from Spain suggested that water use appeared to be high during the summer (Domene and Sauri, 2006) or to be less when the number of rainy days increased [Espiñeira2002]. The latter was also confirmed by Scheich and Hillenbrand [Schleich2009] in Germany. In the city of Zaragoza, Arbués and Valanua [Arbués2006] showed a decrease of water consumption when temperature was high and in the city of Seville, García-Valiñas [Valiñas2005] showed a higher price elasticity in peak (summer) than in off-peak periods (all other seasons) [Romano2014]. In 11 urban areas in the United States and Canada, Mansur and Olmstead [Mansur2012] reported higher price elasticities for outdoor use in wet seasons rather than indoor use in arid seasons. Researching in US, Yoo et al [Yoo2014] showed that low water consumption is related to high temperature and low rainfall in Phoenix and the impact of climate decreases as water use increases, indicating that higher water users are less responsive to a change in rainfall or temperature than low water users. In Italy, studies by Romano et al. [Romano2014] suggested that water consumption increased in periods of droughts and dry years. In Portugal, Martins and Fortunato [Martins2007] and Monteiro and Roseta-Palma [Monteiro2011] reported that high temperature result in increases in water use, however, precipitation did not have any statistically significant impact on demand for water. Moreover, in meta-analyses, Esprey et al. [Espey1997], Dalhuisen et al. [Dalhuisen2003] and Sebri [Sebri2014] found that the inclusion of temperature affects only the price elasticity (positive effect), precipitation results in significantly less elastic estimates of the price elasticity of demand.

3.3 Household water demand studies: econometric models and estimation

Water demand can be estimated using several econometric techniques based on the data availability. Cross-section techniques are employed frequently [Hajispyrou2002; Chen2009]; panel data techniques are commonly used [Billings1980; Gaudin2001; Espiñeira2002; Espiñeira2003a; Arbués2004], whereas time series are less frequently used [Gaudin2006; Fullerton2006]. For cross-sectional data, estimation techniques include Ordinary Least Squares (OLS), Generalised Least Squares (GLS), instrumental variables" techniques, such as two-stage least square (2SLS) or three-stage least square (3SLS) [Monteiro2010; Worthington2008]. For time series data, estimation techniques include vector autoregressive models and cointegration techniques whereas for panel data, OLS, GLS, Maximum Likelihood (ML) and 2SLS techniques [Arbués2003].

Within the estimation techniques, the choice of functional form is of great importance. The literature has identified 5 types of functional forms: linear [Espiñeira2002]; double-log (i.e. Cobb-Douglas) [Schleich2009]; semi-logarithmic (lin-log or log-lin) [Schleich2009; Arbués2006] and Stone-Geary [Espiñeira2004]. The former is the easiest form which can be employed for water demand estimation and assumes that the change in quantity demanded in response to a price change is the same at every price level, whereas the latter produces estimated coefficients which are interpreted as elasticities of demand [Worthington2008]. In semi-logarithmic forms (log-lin) water price could be included as explanatory variable in levels and not in natural logarithmic and water consumption is expressed in natural logarithmic and included as dependent variable. Thus the price elasticity of demand is assumed to be higher for higher prices. In semi-logarithmic form (lin-log) water price enters in natural logarithmic as independent variable and water consumption in levels as dependent variable. Hence, the price elasticity of demand decreases as water consumption increases [Schleich2009].

Arbués and Villanua [Arbués2006] employed panel data techniques to compare three functional forms, i.e. linear, log-log and semi-logarithmic to estimate residential water demand in the city of Zaragosa in Spain. The results indicated that average price and linear functional form are most appropriate specifications. Researching in Portugal, Monteiro and Roseta-Palma [Monteiro2011] tested the efficiency of the current tariff structure, IBR using several functions forms. After having conducted appropriate specification tests, the authors were left with an inconclusive choice between a semi-log, lin-log functional form and a double-log specification: the former favors IBT, while the latter favors two-part tariffs. Schleich and Hillenbrand [Schleich2009] employed OLS and instrumental variable techniques to estimate two functional forms (log-log and semi-log) for the residential water demand in Germany using cross section data. The results from the different functional forms were similar with a price elasticity of −0.242 for the log–log model and of −0.230 and −0.252 for the semi-log models suggesting that water demand is rather price inelastic. Another study by Ruijs et al. [Ruijs2008] compared linear and log-lin functional forms using similar techniques to estimate water demand in Sao Paolo. The authors concluded that for the average and marginal price models are very similar, both for the linear and log-linear specification reporting values for the price elasticity of demand around -0.45 and -0.50 respectively. The Stone-Geary functional form to estimate water demand was employed by Martínez-Espiñeira and Nauges [Espiñeira2004] in Seville, Spain. The authors offered a dynamic evolution of the threshold by following two approaches. Firstly, the amount of basic level of water consumed was assumed to be constant, and secondly, it assumed to vary according to past information, i.e. past levels of consumption [Valiñas2014].

Regarding econometric techniques, a large number of studies have employed OLS techniques. However, one particular problem when using data with block rate pricing is simultaneity: that is, when consumers select the quantity of water to be demanded, they also select the price, i.e. prices (average and marginal prices) are endogenously determined by quantity demanded [Ruijs2008]. As a result, OLS estimation of block rate pricing models may yield biased and inconsistent estimates, i.e. explanatory variables and error may be correlated [Worthington2008]. Therefore alternative techniques could be used such as instrumental variable techniques i.e., 2SLS or 3SLS. Ruijs et al. [Ruijs2008] used 2SLS techniques where prices at different consumption blocks were treated as instruments to test any endogeneity problem. Similarly, Renwick and Archibald [Renwick1988] employed a two-stage procedure to jointly estimate the adoption of water conserving technologies (low-flow toilets and shower heads, new irrigation methods) and the structure of household water demands. The estimated equations are then used to assess the impact of price and non-price policies on the water demand. Although OLS techniques may give similar results with alternative ones (see for instance [Schleich2009; Ruijs2008] there are cases where OLS estimates produced biased results (see for instance [Nieswiadomy1989]). Testing for simultaneity by using a Hausman test [Billings1980] easily shows whether simultaneity is present and whether instrumental variables techniques should be used [Ruijs2008]. Other techniques that could be used to deal with the simultaneity problem in the case of multiple tariffs include MLE, specific time-series techniques, structural equation model and more frequently panel data techniques such as fixed effects (FE), random effects (RE) and Generalised Method of Moments (GMM). Duppont and Renzetti [Dupont2013] used a structural equation model to assess the role of price and non-price policies as well as other socio-economic characteristics on households' decisions regarding indoor and outdoor conservation practices. In the city of Seville, García-Valiñas [Valiñas2005] employed panel data techniques (e.g. GMM) to analyze the economic welfare of tariff system in Seville using micro-household data over the period 1991-2000. The results indicated that tariffs based on seasonal demands tend to improve welfare for all user groups.

Another problem in specification and estimation of water demand models is associated with possible shifts in the distribution of consumers among price blocks and consequently [Arbués2003]. First, the consumer selects the optimal consumption level in each block, and then chooses the block that maximizes his utility function, subject to piecewise budget constraint [Omlstead2007; Olmstead2009; Sebri2013]. This technique is well known as the discrete/continuous (DCC) choice approach, since the choice of block is discrete whereas the amount of consumption is continuous [Monteiro2010; Sebri2013]. Olmstead et al. [Olmstead2007] estimated the price elasticity of water demand among urban households of North America facing IBR and uniform marginal prices, using a structural DCC model. The authors estimated a value of -0.33 for a single unconditional demand (overall consumers' choice) and the separate values of price elasticity of demand for IBR (conditional) and uniform prices were around -0.589 and -0.3258 respectively.

After having discussed different several functional forms and estimation techniques for estimating water demand, the question that arises is which functional form and techniques could be appropriate? The answer is that the economic literature does not contain any evidence that justifies which is the most adequate functional form for residential water demand [Arbués2006; Arbués2003] and regarding estimation techniques any simultaneity problem could be examined with the use of certain specification tests e.g. Hausman test [Ruijs2008]. In a recent meta-analysis by Sebri [Sebri2014] it was concluded that compared to the baseline OLS, all other estimation techniques (instrumental variables, fixed and random effects, etc.) appear to make the residential water demand more price elastic and further research is recommended regarding the use of the discrete/continuous choice approach and the Stone-Geary demand function.

3.4 Summary of findings

This section offers a review of the existing literature regarding residential water demand. It illustrates estimates of price elasticity of demand and drivers that may impact water consumption. Even though it would be imprudent to make generalized statements about residential water demand and its drivers, the following conclusions can be drawn:

- Estimates of price elasticity of water demand for residential use is inelastic. Existing literature suggests estimates ranging between -0.25 and -0.75.

- Long-run estimates of price elasticity of demand are higher than short-run estimates.

- Estimation of residential demand can be carried out with aggregated or household level (most preferred approach) data depending on data availability.

- The precise drivers and their impact on household water consumption depend on factors such as the geographical location, the socioeconomic structure or the specific characteristics of households. More particularly:
    - Price elasticity estimates differ across geographical locations which could be attributed to the high outdoor use (US vs Europe) or to the fact that households may rely, in addition to the metered water, on other type of sources (developed vs developing countries).
    - Having different tariff structures (e.g. IBR, DBR, flat) allows the specification of different demand models but their impact on water demand is not certain. Studies showed that IBR has a statistically significant impact on the residential demand for water, making it more price-elastic, whereas the impact of DBR or flat tariff was found insignificant.
    - Some elasticity values (or value ranges) show that the choice of price specification (average, marginal or Nordin's difference) did not greatly affect the results, while some suggest that demand is more responsive to average price.
    - Income elasticity of residential water demand is low as water bill accounts for a small amount of households' income.
    - Non-price policies (e.g. education, information campaigns) appear to have an impact on water consumption and further research is anticipated in this area.
    - Past evidence showed that residential water use was usually shown to be highly sensitive to weather and seasonal fluctuations.

- The economic literature does not contain any evidence that justifies which is the most adequate functional form for residential water demand.

- Compared to the baseline OLS, all other estimation techniques (instrumental variables, fixed and random effects, etc.) appear to make the residential water demand more price elastic.

4. Water demand for the case studies

This section provides a water demand baseline for the two case studies: London, UK and Ticino, CH. Subsection 4.1 shows some relevant figures about fresh water consumption in the two selected areas, and tracks the evolution of water demand overtime. Where available, the price evolution has been reported as well. Subsection 4.2 presents and describes the econometric model employed to get statistics of price elasticities in the two areas, which constitute the focal elements to build up a baseline water demand.

4.1 Water demand evolution in the case studies

4.1.1 London

Water consumption

The Thames Water Resources Management Plan (WRMPs) tables can be used to derive a demand baseline for the London case study. WRMPs are published by the water utilities in England every five years (i.e. for each periodic review period). Demand forecast are made over a period of 25 years, based on requirements specified in the Environment Agency's Water Resources Planning Guideline [EEA2012].

Thames Water adopts mathematical models that follow standard methodologies [UKWIR/NRA1995; UKWIR/NRA1997; UKWIR2006; UKWIR2012] based on population and property projections, water use data and historical trends. Both 'upward' (population increase, decreasing household size, or increasing water use per person) and 'downward' pressures on the demand forecast (modern low volume toilet cisterns, modern water efficient dishwashers or washing machines) are considered. The baseline demand forecast included in the latest WRPM tables [ThamesWater2014] also includes demand reduction strategies such as water efficiency, leakage reduction and metering activities assumed in the price limits up to 2015. Beyond year 2015, the water efficiency programme was assumed to continue at the target level set by Ofwat, the economic regulator, for the 2010-2015 period.

The breakdown of water demands into its main components is also considered. These include household use (water used in the home and garden), non-household use (water used by businesses), operational use (water used maintaining the network), water lost from the distribution system and water used without charge (either legally such as fire hydrant use, or illegally such as usage in a property declared as void).

Demand forecasts are developed for three scenarios, following the Water Resources Planning Guideline from the Environment Agency [EEA2012]. The 'Dry Year Annual Average' scenario (DYAA) is the forecast for a dry year (period of low rainfall) with no demand restrictions while the 'Average Day Peak Week' scenario is the average daily demand recorded a 'peak demand period', typically a week. Finally, the 'Weighted Average' Average Demand scenario is the demand that is likely to be experienced on average taking into account a mixture of 'normal' years, 'dry' years and 'wet' years. Figure 6 shows the demand estimate for period 2015-40, under the 'Weighted Average' Average Demand scenario and for the London water resource zone.

The 'Weighted Average' demand estimate can be used as a baseline for later analyses to test the impact of smart metering on the level of consumption of household and non-household customers. Not all years in the planning horizon may be 'dry' or 'normal'. Therefore assuming normal year (annual average) demands or dry year weather patterns may result in understating or overstating the company's level demand. The demand level that the company is most likely to face on average in the planning horizon reflects a mix of demand in normal years, dry years, wet years. For this reason the weighted average demand scenario (and the consequent supply-demand deficit occurring under this scenario) is the one currently used by Ofwat, the economic regulator, to make forecasts of water companies' costs included in price limits.

The London area is chosen as study. This zone is of particular interest as it is classified as 'seriously water stressed' (i.e. demand for water already exceeds available water supplies in some areas). Furthermore, the average consumption in the London area is 10% higher than in other parts of the UK. Thames Water began a trial of smart metering technology in 2011 and is planning to install the first smart metering schemes in London.

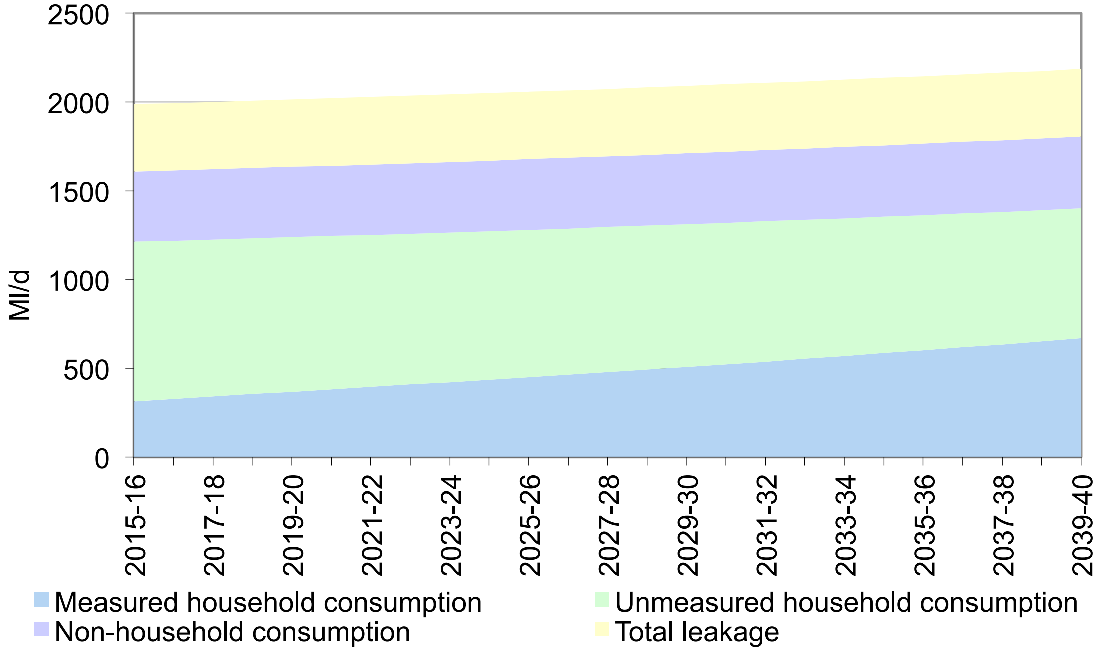

Figure 6. Baseline components of demand under the 'Weighted Average' demand scenario, for the London water resource zone. Data are in Ml per day.

Water pricing

Water companies in England use a flat rate charge for unmetered customers and a two-part tariff (fixed charge and volumetric charge) for metered customers. When determining the total level of charges, customers are also split into household and non-household.

Unmetered water charges are calculated by multiplying 'a rate per pound' to the rateable value (RV) of the customer's house. The rates are unrelated to the amount of water use or the number of people living in the house, and only depend on where the house is located. The 'rate per pound' in central London is currently equal to 58.25 pence for both household and non-household customers [ThamesWater2015a, ThamesWater2015b]. The rateable value is set by the Valuation Office Agency, based on the assessment of how much the property could be let for. For example, if the rateable value of the customer's house is £150 and the rate per pound for water is 58.25 pence, then the bill would be 150 x 0.5825, equalling £87.37. On top of this bill, unmetered customers pay a fix charge which includes the costs of producing bills, processing payments and answering queries. For household customers in London, the fixed charge is currently £30.70 [ThamesWater2015b] for water services, while for non-households this is equal to 42.15 (see Table 6).

Metered household customers pay a fixed charge (21.25£ for customers served by Thames Water) and a volumetric charge (126.29 pence/m^3, see Table 7). For metered non-household customers the fixed and volumetric charge depends on their assessed water usage (m^3 per year).

Table 6: Water charges in year 2015/16 for unmetered household and non-household customers served by Thames Water. Both unmetered household and non-household customers also pay a 'rate per pound' to the 'rateable value' (annual rental value) of their property.

	Unmetered customer
	Fixed charges (£/year)
Household	30.70
Non- Household	42.15

Table 7: Water charges in year 2015/16 for metered household and non-household customers served by Thames Water.

	Metered		
	Assessed usage (m3 per year)	Fixed charge	Volumetric charge
		(£/year)	(pence/m^3)
Household	N/A	21.25	126.29
Non-Household	0-500	23	131.37
	500-1000	34.62	132.16
	1000-5000	120.91	127.08
	5000-20000	344.25	127.08
	20000-50000	953.67	116.35
	50000-100000	2933.26	95.51
	100000-250000	2933.26	95.51
	Over 250000	11443.84	76.57

Historical data are available on the Ofwat website for metered and unmetered household customers (see tables below).

Table 8: Water charges in years 2001-2011 for metered household customers served by Thames Water.

	2001	2002	2003	2004	2005	2006	2008	2009	2010	2011
Volumetric price (pence/m^3)	61.59	62.21	63.27	65.48	88.85	95.1	99.18	107.09	113.13	115.83
Fixed charge (£/year)	16	16	17	17	22	23	24	25	26	26

Table 9: Water charges in years 2001-2011 for unmetered household customers served by Thames Water.

	2001	2002	2003	2004	2005	2006	2008	2009	2010
Rateable value RV charges (pence/£RV) -Zone 1 London	64.38	64.27	67.61	70.05	78.08	81.08	85.47	88.89	93.03

Fixed charge (£/year)	16	16	17	18	23	24	25	26	27

4.1.2 Ticino

Water consumption

The water consumption in Ticino is among the highest in Switzerland. In 2012, it amounted to approximately 240 liters/EI/day, almost 23% higher than the average figure for the Switzerland as a whole. However, time series starting from 2003 show a decreasing trend, which in the long-run is expected to close the gap.

Table 10 reports data on household water consumption in Ticino (average and maximum) and makes a comparison with the Switzerland figures.

Table 10: Average and maximum water consumption in Ticino and Switzerland.

Water consumption in Ticino and Switzerland				
Years	**Average Consumption (l/El/d)**		**Maximum Consumption (l/El/d)**	
	Ticino	**Switzerland**	**Ticino**	**Switzerland**
2003	315	265	935	623
2004	304	233	945	562
2005	302	228	788	545
2006	306	228	781	542
2007	288	222	685	494
2008	309	214	690	485
2009	264	202	721	479
2010	249	195	658	494
2011	248	190	662	465
2012	238	184	765	463

The following graphs depict the trends in the Ticino and Swiss water consumption in the last decade. The improvement in terms of water efficiency in the last years comes from a reduction in leakages through the water network infrastructure, and prominently from a more parsimonious water usage.

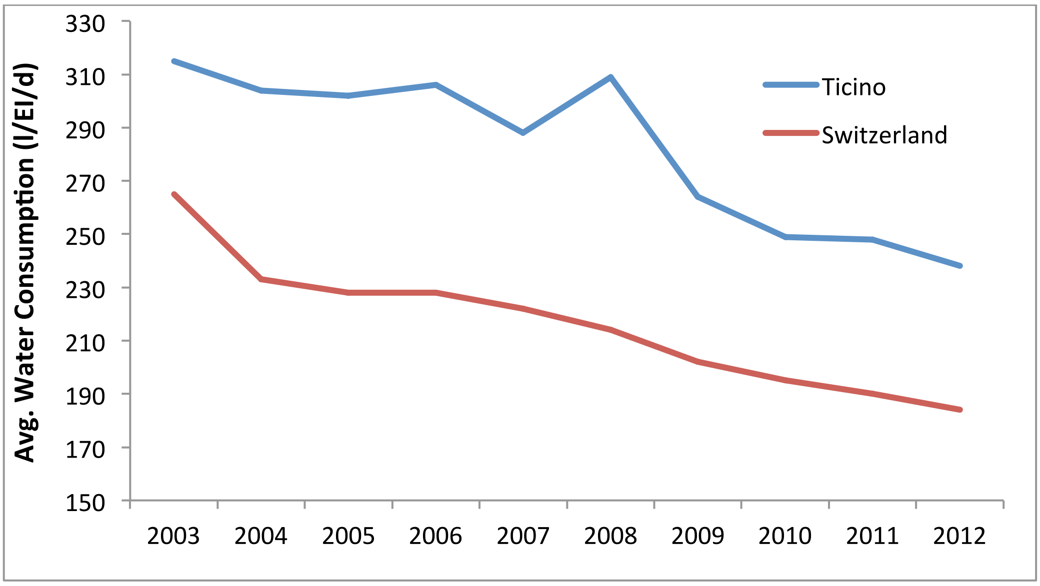

Figure 7. Average Water Consumption in Ticino and the whole Switzerland (l/El/d).

The same can be said about peaks in water consumption (**Figure 8**), which are very relevant for the water infrastructure dimensioning. In this case, the gap between Ticino and Swiss figures has remained unchanged over the years, getting even more sharp in the last available year.

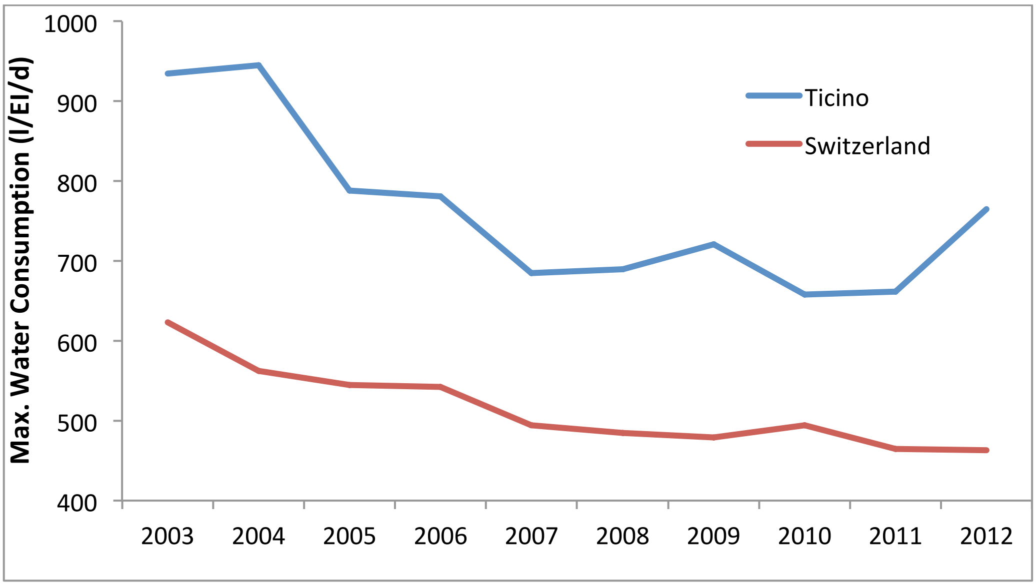

Figure 8. Maximum Water Consumption in Ticino and the whole Switzerland (l/El/d).

The maximum daily water consumption in Ticino can be broken up in the following components:

• Household consumption	38%
• Public service and buildings (schools, fountains,…)	6%
• Garden irrigation	48%
• Leakages	8%

The figure related to the garden irrigation is the most significant. To this end, it should be recalled that the most of the Ticino territory served by water mains is characterized by residential areas not so densely populated, whereas mono-familiar houses account for approximately 70% of the residential buildings (see 'Statistica ticinese dell'ambiente e delle Risorse naturali', STAR 2008). These mono-familiar houses are often provided with garden areas, which need adequate irrigation especially during dry seasons.

Water pricing

The very fragmented water service management in Ticino and in the Switzerland in general, makes it very difficult to provide an overview of the water prices. As at length explained in Section 2, according to the Swiss institutional setting, the Cantons are in charge of setting water prices, a regulatory power they usually delegate to municipalities.

Bearing this in mind, some considerations can still be done about the water pricing structure currently adopted and the average level of water tariffs. In Switzerland, the average price of tap water can vary between CHF 0.50 and CHF 3.50 per cubic meter, with the average being CHF 1.60 [SSIGE].

In Ticino, overall statistics are not available, but data relative to the two most populated municipalities, i.e. Bellinzona and Lugano, are provided by the Federal Department of the Economy. In Bellinzona, the average tap water yearly bill amounts to CHF 350, whereas in Lugano it amounts to approximately CHF 400.

Most of the municipalities uses traditional pricing structures, e.g. fixed fee plus volumetric fixed rate. This is, for instance, the case of Chiasso, where households are charged according to a two-part tariff. In Chiasso, the fixed fee cannot be lower than CHF 20/semester and it is dependent on the water consuming elements the house is equipped with. As far as the volumetric part is concerned, the rate applied amounts to CHF 0.80.

Some municipalities, on the other hand, have started to experiment more innovative pricing schemes, mostly increasing block rate. **Table 11** reports the IBR mechanisms applied so far in Ticino.

Table 11: IBR structures in Ticino.

IBR structures in Ticino						
Municipality	**Fixed fee**	**I block**	**II block**	**III block**	**IV block**	**V block**
Bedigliora	CHF 50.00	0-300 cm CHF 1.00	301-600 cm CHF 2.00	>600 cm CHF 2.00	-	-
Capriasca	CHF 160.00	0-200 cm CHF 0.80	201-400 cm CHF 0.90	>400 cm CHF 1.00	-	-
Croglio*	-	0-200 cm CHF 1.30	201-400 cm CHF 1.50	>400 cm CHF 1.70	-	-
Cugnasco-Gerra	CHF 180.00	0-100 cm CHF 0.70	101-200 cm CHF 1.00	201-300 cm CHF 1.25	301-500 cm CHF 1.55	>500 cm CHF 1.85
Gordola	CHF 70.00	0-300 cm CHF 0.80	301-400 cm CHF 1.00	401-500 cm CHF 1.20	>500 cm CHF 1.40	-
Manno	CHF 50.00	0-250 cm CHF 0.90	>250 cm CHF 1.00	-	-	-
Maroggia	CHF 70.00	0-60 cm CHF 0.00	>60 cm CHF 0.50	-	-	-
Osogna	CHF 64.00	0-73 cm/p CHF 0.35	>73 cm/p CHF 0.70	-	-	-
S. Antonino	CHF 100.00	0-150 cm CHF 0.00	151-200 cm CHF 0.40	201-1000 cm CHF 0.60	>1000 cm CHF 0.80	-
Sessa	CHF 55.00	0-200 cm CHF 0.80	201-500 cm CHF 1.35	>500 cm CHF 2.00		

*Blocks are applied for semester.

[Source]: Rapporto del Consiglio di Stato 6766 del 27/03/2013 sulle mozioni: 24 settembre 2012 presentata da

Bruno Storni e cofirmatari “Basi legali per promuovere il risparmio d’acqua potabile”; 10 novembre 2008 presentata da Francesco Maggi e cofirmatari “Gestione più sostenibile dell’acqua potabile e contro sprechi di soldi pubblici in acquedotti sovradimensionati e spese di depurazione inutili”

As can be easily noted, when adopted, IBR mechanisms in Ticino are very diverse. They generally encompass a fixed part (except for one case), which ranges from CHF 50 to 180, and a variable number of blocks, ranging from 2 to 5. The rates applied to each block can vary from CHF 0.35 to 2. In two cases, the first block is a no-tariff area.

4.2 The econometric model

Given the impossibility to conduct ad-hoc experiments in the geographical areas selected for the case studies, it has been decided to side for a meta-analysis.

Meta-analysis refers to the statistical analyses that are used to synthesize summary data from a series of previous studies. If the effect relative to the investigated relationship is consistent across all the studies in the synthesis, then the meta-analysis yields a combined effect that is more precise than any of the separate estimates, and also allows to conclude that the effect is robust across the kinds of studies sampled. By contrast, if the effect varies from one study to the next, the meta-analysis may allow to identify the reason for the variation and report, for example, that the effect relative to the investigated relationship is stronger under particular circumstances.

In the field of **water demand studies**, meta-analysis is devised as a tool to identify factors explaining the variation in estimated **price elasticities** of residential water demand. Factors are usually *study-specific* (used data, specifications, estimation methods, etc), but may refer to contexts as well. The most relevant *context-specific* factors are mainly concerning institutional arrangements and socio-economic aspects (regulatory framework, water pricing mechanisms, income, etc) and/or natural characteristics (temperature, rainfalls, etc). **Figure 9** provides a snapshot of the methodological strategy.

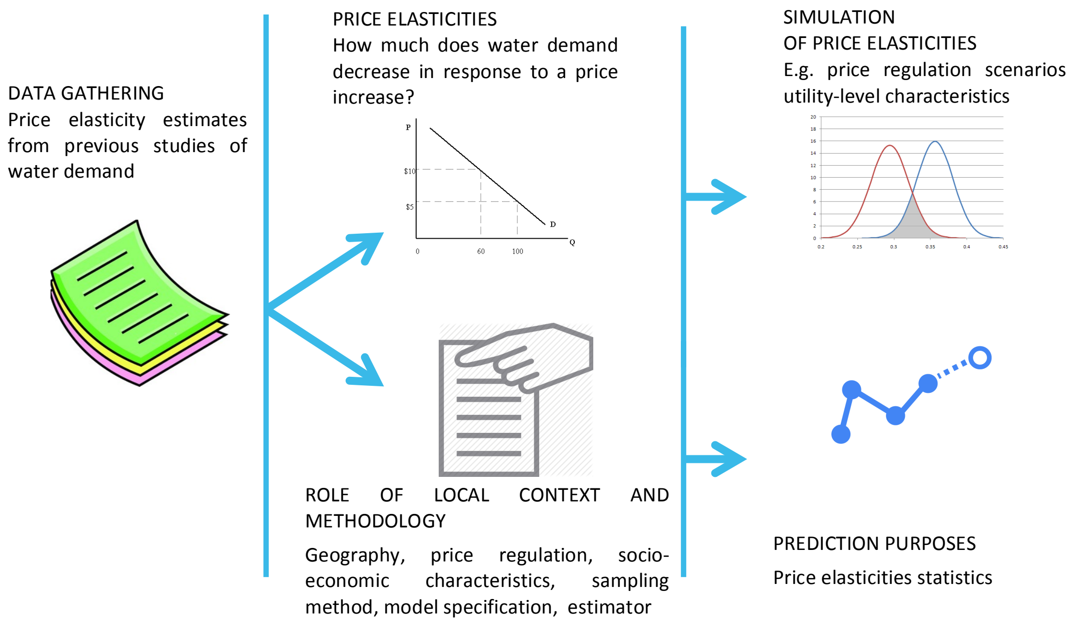

Figure 9: Methodological strategy.

After having collected data on estimated price elasticities reported in a sample of previous water demand studies, along with information on study-specific and context-specific factors, a meta-regression is run, where the dependent variable is represented by the price elasticity (PE) and the independent ones are the above mentioned explanatory factors.

Accordingly, the econometric model is the following:

$$PE_{is} = \alpha + \beta X_{is} + \gamma Z_{is} + \varepsilon_{is} \tag{1}$$

where PE_{is} is the price elasticity i coming from study s, X_{is} and Z_{is} are two vectors of study-specific and context-specific characteristics respectively, β and γ are two vectors of coefficients to be estimated and ε_{is} is an idiosyncratic error term.

The list of variables to be included in the model is reported in Table 12.

Table 12: List of variables included in the meta-analysis

List of variables included in the meta-analysis		
Variable type		**Variable description**
Study-specific variables	Study	Published or unpublished study*
		Publication year
		Number of observations
	Price measure employed	Average price used as explanatory variable*
		Marginal price used as explanatory variable*
		Shin price used as explanatory variable*
		Fixed price used as explanatory variable*
	Type of est. price elasticity	Long run elasticity*
		Segment elasticity*
	Data disaggregation level – overtime	Daily data*
		Monthly data*
		Annual data*
	Data disaggregation level – over-users	Household data*
		Aggregate data*
	Data period	Summer data*
		Winter data*
	Data structure	Cross section data*
		Time series data*
		Panel data*
	Type conditioning variables	Number of conditioning variables in water demand model
		Lagged dependent variable in specification*
		Evaporation rate in specification*
		Season accounted for in specification*
		Household size in specification*
		Population density in specification*

		Income level in specification*
		Commercial use included*
		Temperature in specification*
		Rainfall in specification*
	Type estimator used	Ordinary Least Squares (OLS)*
		Instrumental Variables (IV)*
		Two Stage Least Squares (2SLS)*
		Three Stage Least Squares (3SLS)*
	Specification	Specification is semi-logarithmic (x is logarithmic)*
		Specification is semi-logarithmic (y is logarithmic)*
		Specification is double logarithmic*
		Specification is linear*
		Specification is flexible functional form*
		Difference variable included as explanatory variable*
		Regression based on discrete/continuous choice*
Context-specific variables	Tariff structure	Tariff structure is a decreasing block rate*
		Tariff structure is an increasing block rate*
		Tariff structure is a fixed rate*
	Socio-economic factors	Gross Domestic Product per capita
	Natural aspects	Rainfall in the area
		Temperature in the area
	Location	Location in the United States*
		Location in Europe*
		Location in other parts of the world*

- Dummy variable

In order to estimate the model (1), we use approximately 120 water demand studies, issued from 1963 to 2013. Our database of previous studies is built by extending the database provided by [Dalhuisen2003], which is focused mainly on US-based analyses.

Once the coefficients for each independent variable included in the model have been estimated, it will be possible to run simulations to get statistics of price elasticities in the areas selected for the case studies, i.e. London and Ticino. This will be accomplished by setting study-specific variables to their respective means, and by allowing context-specific variables to take the value they would take on in each of the two case studies.

To this aim, the table below provides the value taken on by the context-specific variables in London and in Ticino areas.

Table 13: Value for context-specific variables in the two case-studies.

Value for context-specific variables in the two case studies		
Context-specific variable	**London**	**Ticino**
Tariff structure is a decreasing block rate*	0	0
Tariff structure is an increasing block rate*	1(for metered non-household)	1 (in 10 municipalities)

Tariff structure is a fixed rate*	1 (for unmetered non-household and all households)	1 (in the rest of Ticino)
Gross Domestic Product per capita	37.446**	CHF 66.611^
Rainfall in the area (mm)	1828***	1685^^
Temperature in the area (degree C)	11.9	12.4^^^
Location in the United States*	0	0
Location in Europe*	1	1
Location in UK*	1	0
Location in other parts of the world*	0	0

^USTAT – Ufficio di Statistica, Repubblica e Cantone Ticino

^^Annuario idrologico del Canton-Ticino, SUPSI. The Chiasso figure has been provided as an example

^^^Rapporto sul clima- Cantone Ticino, Ufficio federale di meteorologia e climatologia MeteoSvizzera

**Organisation for Economic Co-operation and Development –OECD

***https://www.gov.uk/government/statistics/annual-average-rainfall-and-temperature

Deliverable D5.2 will provide the estimates of the model. With the price elasticities on hand, the baseline water demands for the two case studies will be available.

5. Innovation in water industry

This section focuses on the role of innovation in water conservation. Firstly, the role of smart water metering systems is discussed, with particular regard to benefits and costs, current stage of development and deployment and customers' feedback (section 5.1). Secondly, an overview of innovative pricing schemes is provided, along with relative pros and cons and current evidence on customers' response, referring mainly to energy sector applications (sections 5.2 and 5.3). Thirdly, a preliminary picture of the increasingly pivotal role online communities and web and gamified applications are playing in the resource conservation efforts is offered (section 5.4).

5.1 The role of smart metering for water efficiency

The aim of improving water efficiency has been widely recognized to stand on the viability and effectiveness of different strategies of water demand management. The adoption of innovative pricing schemes, and even before, the chance to use pricing mechanisms as a tool to get water conservation, rely upon the possibility to accurately measure water consumption at single household level. In this fashion, water meters are the relevant prerequisite to assure water conservation, and make the adoption of pricing schemes to get water efficiency valuable instruments.

Water meters may allow water utilities to meter water consumption at building and/or more appropriately at household level. Traditional mechanical meters (TMMs), in particular, are able to indicate the total water consumption since they were installed and need periodical house-to-house readings in order to estimate the water consumption and accordingly compute the water bill.

Although useful to introduce early forms of economic incentives, at least having an impact on water consumption levels aggregated over metering intervals, TMMs do not allow for more sophisticated forms of water demand management, including innovative pricing mechanisms.

To this end, water metering technologies have been subject to an impressive evolution driven on the one hand, by the diffusion of information and communication technologies, and on the other hand, by the possibility to get higher and higher performance in the data management activities. As a consequence, smart water metering systems (SWMS), introduced by exploiting paradigms developed in the energy and gas sectors, are getting more used in US and EU countries.

The first step towards smart metering systems adoption was represented by the deployment of Automatic Meter Reading (AMR) systems. In this way, meters communicate monthly or daily water consumption figures to a central collector using one of a number of different communications techniques, such as radio signals, power-line communications, or satellite reads. In other words, they are designed to replace house-to-house meter readers with centralized collection. These measurements can be effective to provide information to customers and in some conservation programs, such as leak detection.

Nowadays, AMR systems are to be supplanted by truly smart metering systems or Advanced Metering Infrastructure (AMI), which provide more detailed information and allow for additional features. The rest of the section will refer to smart metering systems and will highlight their benefits and the link between them and the adoption of innovative measures aimed at achieving water efficiency.

5.1.1 Smart water metering systems: benefits and costs

A SWMS entails a smart metering device that collects data (water consumption, leakages, etc) at household level and transmits via a Local Area Network (LAN) to a data collector. This transmission can occur on a high-frequency basis or not according to the use of the data. The collector retrieves the data and may or may not carry out any processing of the data. Later, data are transmitted via a Wide Area Network (WAN) to the utility central collection point for processing and use by business applications. Since the communications path is two-way, signals or commands can be sent directly to the meters, customer premise or distribution device.

Smart metering systems are devised to provide a large array of services based on an uninterrupted two-way connection between the water utility and the customers. A non-comprehensive list of these services can be as follows:

- High-frequency data collection
- Service activation/interruption
- Water consumption level setting
- Detection of tampering and theft attempts

Quasi real-time data collection constitutes a benefit both for water utilities and customers for several reasons. Firstly, it reduces the cost of incremental reading and more importantly eliminates the need for bill estimates. This, in turn, makes it easier for customers to meet financial requirements once bills are carried out and accordingly reduces the water utility's cost of handling disputes and complaints. In addition, more frequent water billing, made possible by high-frequent reading, facilitates customers' financial management as it enables water utilities to detect the riskiest customers and put in place proper actions (warnings, water saving suggestions, etc).

Secondly, highly-frequent water consumption data collection, as above mentioned, is the prerequisite to implement innovative pricing mechanisms aimed at achieving water saving goals. *Time-of-use tariffs*, for instance, can be used only if information on the time of consumption is available. In this way, customers can be charged based on the cost-opportunity related to the water consumption within that particular time interval.

Thirdly, high-frequency water consumption data, if available to customers by making continuous monitoring of consumption and simulated expenditure possible (through an easy-to-read display or a web platform), foster customers awareness about cost and environmental impact of water usage, with a direct influence on water saving effort. Displays located prominently serve as a constant reminder about the need for water conservation. They can help parents devise games for children around the readings aimed at teaching water-conservation habits. They also enable local policy makers to gain customer compliance with water-use tips, such as a weekly recommended use per occupant.

Water saving effort driven by customers' awareness is a benefit for water utilities also because it provides security of supply in areas where water resources availability is highly variable. This, in turn, makes possible to defer capital investments, which, on the one hand, may be extremely costly and, on the other hand, would entail unwelcome price increases.

The two-way communication link between water utility and customers allow the utility not only to get meter reads on demand, but also to determine whether water has recently been flowing through the meter and onto the premises, and to issue commands to the meter to perform specific tasks such as disconnecting or restricting water flow. Remote-disconnect meters reduce the costs to send technical crews to the premises of customers who have either requested a disconnect or who are being disconnected (or ratcheted back) for bill non-payment.

Another feature of smart metering systems is represented by the possibility to check meter status ("ping the meter") prior to sending a repair crew in response to a customer call. These checks can sometimes prevent needless field crew dispatch to customer sites where problems are not the utility's responsibility.

Finally, smart meters make detection of tampering and theft attempts quicker. Expectation of quick detection of and reaction to theft attempts may discourage such misbehaviour and reduce water supply costs.

Despite the above summarized evident benefits of smart metering systems deployment, they exhibit costs, which could be obvious and/or less immediately apparent. Among easy-to-identify costs, there are costs to install meters and related infrastructures and put them at work.

Less immediately apparent are costs to: i) implement and support smart meters and the huge amount of data they generate; ii) modify or replace the customer information system (CIS); iii) pick up software to manage data and use them for business purposes; iv) upgrade or acquire additional hardware to store and process interval usage data; v) commit customers with the meter replacement activities, including its anticipated costs and benefits; vi) research and design new pricing schemes; vii) train staff to install, maintain and operate smart meters and new infrastructure.

5.1.2 Smart water meters: deployment

The deployment of smart water meters is currently at an early stage, if compared with counterparts in the energy and gas sectors. [Boyle2013] provides a snapshot of the projects undertaken in recent years all over the world. Smart meters deployments in the water sector have occurred mostly in Europe and North America, which account for 89% of the global smart water metering market in terms of module shipments.

Most of the projects are targeted at residential customers, although they are often small-scale pilot initiatives entailing roll-outs ranging from few dozens to few hundreds households involved [Boyle2013]. Moreover, many deployment projects promote AMR technology rather than truly smart meters (AMI).

In this context, some large-scale deployment initiatives deserve special mention. For instance, New York has 834,000 AMR installed, which allow treated customers to create an account on the Department of Environmental Protection (DEP) portal and track water usage, water meter reading history, and payment and billing history.

The City of Chicago Department of Water Management offers a program named MeterSave to voluntarily install water meters (up to 162,000 AMR). Householders participating in MeterSave receive a 7-year guarantee that the home water bill will be no higher than it would have if the meter had not been installed. In addition, they receive an outdoor water conservation kit (a hose timer, a rain gauge, a water restricting hose nozzle, etc), and an indoor water conservation kit (a low flow shower head, a leak detection tablets, etc).

The City of Toronto is engaged in the Toronto Water Meter Program, a mandatory program promoting free water AMR city-wide installation. The new smart metering system will integrate all water meter reading, data storage and billing across the City of Toronto into one seamless system. Once installed, each water meter across the city will send data, four times a day, to a series of collection units. The data is then sent to a central server, which allows for fast, secure access and storage of all information.

Other North American cities currently engaged in smart water metering deployment programs are Detroit (large-scale roll-out), San Marcos (AMI city-wide installation), Spanish Fork (16,000 water meters combined with 10,000 electricity meters), Tampa (trial involving 26 households) and Ottawa (210,000 AMI water meters).

In Europe, Malta has become the first country in the world to sponsor a nation-wide smart water metering roll-out (120,000 smart water meters installed). In UK, Bristol Water has been among the first water utilities to promote free water meters deployment for residential customers. Thames Water, which serves the London area and surroundings, aims to have metered 100% of its customers by 2030. They plan to start work in 2015 on a borough-by-borough basis, focusing on London first as this is where water resources are most stretched, before starting work in the Thames Valley from 2020. In Scotland, a program aimed at equipping 18,000 public sector buildings (hospitals, schools, prisons, etc) with water AMRs has been launched in 2011.

Recently, the Italian Energy and Water Regulatory Authority (AEEGSI) has launched an initiative aimed at trialing multiservice smart meters targeted at electricity, gas, water and district-heating sectors. The project involves approximately 60,000 customers in 9 large and medium-sized cities (Turin, Reggio-Emilia, Parma, Modena, Genoa, Verona, Bari, Salerno and Catania). The initiative is funded by a 10 cents *una tantum* contribution charged to all Italian natural gas customers. As a result, the involved customers will be able to check their energy, gas and water consumption by connecting to a single web portal and, depending on the city, they will enjoy trials of other related services (noise sensors, garbage bin sensors to detect and forecast fill-levels, leakages sensors on the water pipelines, etc)[SmartH2O2015].

Smart water meters roll-out programs in Australia have been very diverse in scale. The larger-scale deployments have occurred in Kalgoorlie-Boulder, Western Australia (13,800 meters installed), in Wide Bay Water, Queensland (20,000 AMRs installed) and in Mackay, Queensland (30,000 meters installed).

5.1.3 Smart water meters: customers' feedback

Customers' feedback on the use of smart water meters is still scant. [Boyle2013] review the results of some trials conducted in Australia, involving several hundred households in Melbourne, Sydney and the Mid North Coast of New South Wales. Sydney Water's 18 month trial involving 468 AMR fitted properties, 161 of which were equipped with a simple in-home display (IHD) providing customers with near real-time data about their water consumption, found an average decrease of 7–10% in water usage. Another trial conducted in Melbourne resulted in water savings ranging between 10% and 29%.

A general concern arising when customers' feedback to smart water metering has to be measured is the complex relationship between the feedback itself and reduced water consumption. Firstly, it is often difficult to disentangle water savings truly ascribable to customers' efforts and water savings due to more effective leak management. Secondly, in many circumstances, the smart water meters roll-out is combined with the introduction of a bundle of additional water conservation policies, which can have an impact in itself. Thirdly, the current embryonic stage of smart water meters deployment makes it difficult to draw a conclusion on their effectiveness in reducing water consumption. Short-run effects can be over- or under-estimated if compared with long-run effects, depending on the context, the selection of trial participants, the level of commitment exhibit by the policy makers.

More robust results can be retrieved by referring to the energy sector. [Faruqui2010] review a dozen utility pilot programs in North America and abroad that focus on the energy conservation impact of in-home displays (IHDs) and report also on customer opinions and attitudes towards IHDs. Their evidence indicates that the direct feedback provided by IHDs encourages consumers to make more efficient use of energy by reducing their consumption of electricity on average by about 7%. In addition, they find that the impact of time-of-use rates is augmented by IHDs. .

5.1.4 Smart water meters: opportunities and challenges

The most prominent lesson from the demand management literature is that programs to encourage DSM activities do not guarantee that the customers' commitment will actually take place or be maintained. Water saving measures are not easily implementable on a large-scale, since customers' attitudes towards water usage differ substantially. A shift in behavior patterns is difficult irrespective of the level of education, wealth or size of the domestic unit. Therefore the probability of success is a very important consideration in determining the cost effectiveness of large-scale smart water meters roll-outs. Considerations of customer behavior and bounce back are necessary to make an informed decision.

Another key challenge is ensuring that there is benefit for both the utility and the customer.

During the historical introduction of smart metering, both utility and customer clearly benefited. For most customers in the energy markets, the result was a reduced bill through a shift in energy use from *peak* to *off-peak* periods. For the utilities much more information becomes available for understanding energy use and devise innovative pricing mechanisms.

However, it is currently not clear what the benefit to customers is with the introduction of smart water metering. Unless tariff structures change, the bill may stay the same (or perhaps even rise to cover the cost of the technology). But the introduction of innovative pricing mechanisms is contingent upon the institutional and regulatory framework characterizing each national context. Therefore, technology evolution leading up to smart water metering systems have to be coupled to institutional evolution in order to foster sustainable water efficiency efforts.

5.2 Innovative pricing schemes for water conservation

This section is aimed at reviewing innovative pricing schemes for water conservation, with particular emphasis on dynamic pricing (DP). In order to show the potential and pitfalls of DP as a price measure for water conservation, some general ideas on price measures are summarized, and different DP types together with an alternative measure, i.e. Increasing block rates (IBRs), are illustrated (Section 4.2.1). Despite its strength points, DP is a highly debated option in the water sector. Concerns about its consistency, feasibility, acceptance, equity are discussed (Section 4.2.2).

5.2.1 Dynamic pricing

Utilities or local governments implement price measures to incentivize water conservation. Existing empirical studies converge to show that on average users respond to price increases albeit to a limited degree. In order to keep a figure in mind, one can refer to a widely cited and mainly US-oriented reference [Dalhuisen2003], which summarizes more than 60 studies and finds that a 20% demand reduction may require a 50% increase in price (in the short run; in the long run a 30% increase may be sufficient).

Price impact is still debated also because the magnitude of users' response and feasibility / acceptance vary across contexts. More generally, the design of price measures for water conservation should reflect a number of local variables, such as (i) the cost of water supply and operation, (ii) price elasticity of local users and (iii) price regulation (e.g. constraints on utilities' profitability or social tariffs for low-income users).

Price measures for water conservation are commonly seen as:

- an instance of economic regulation, i.e. they are implemented to encourage users to undertake conservation efforts in their own interests;
- a water demand management (WDM) strategy in the face of scarce water supplies, e.g. in the short run they can preserve service continuity and reduce operating costs and in the long run they can avoid new investment in capacity development;
- a policy that is substitutive for or complementary to the so called non-price measures, e.g. information campaigns, mandatory restrictions on outdoor uses.

Baseline: Traditional two-parts tariffs

For the sake of exposition, we may term "traditional" those tariffs that include a fixed access fee (for instance, [€/month]) and a usage unitary rate (for instance, [c€/cubic meter]). The usage rate is uniform and it does not change over time but for regulatory reviews. An increase of the uniform usage rate may well drive households to reduce consumption, but there are pricing schemes that are recognized to be more suitable as a WDM policy.

"Real time" dynamic pricing (DP): Critical-peak pricing (CPP) or Critical-peak rebates

(CPR)

Pricing schemes can be defined dynamic when usage unitary rates are changed in the presence of certain adverse supply or demand conditions, e.g. scarce water supplies related to seasons, droughts or excess concurrent demand (e.g. from irrigation).

Various options belong to this class of water pricing schemes. For the sake of exposition DP options can be divided into two main types, "real-time" DP and "mild" DP. Terms are in part taken from the electricity sector that is experiencing advanced forms of DP.

"Real time" DP makes rates highly contingent to exogenous critical events. In coincidence of critical events usage tariffs are modified, on a temporary basis.

- Under CPP water usage is priced higher than standard rates. Users are informed about the event occurrence and rate changes ahead of time yet not instantaneously (e.g. one day-ahead basis).
- Under CPR in coincidence of critical events water usage is priced at the standard rates, but users are granted a rebate / temporarily discount if they reduce consumption during the critical period. Users are informed ahead of time.
- In principle Real-Time Pricing (RTP) is another DP option, even though its implementation seems to be unlikely in the water sector. Users are informed about increases of retail rates almost instantaneously, e.g. one hour ahead.

"Mild" dynamic pricing (DP): Seasonal pricing (SP) and Peak load pricing (PLP)

The so called Time-of-Use prices are a well-known case of DP. Usage tariffs are increased at given times, i.e. rates are predetermined to be higher in given seasons, days or hours. The two most notable examples are Seasonal pricing (SP) and Peak load pricing (PLP).

- Under SP, usage tariffs are set regularly higher in summer and arid months. The typical update frequency is one year or even slower.
- Under PLP, usage tariffs are set regularly higher in high-demand hours of the day or days of the week. The typical update frequency is one year or even slower.

Other price measures: Increasing block rates (IBRs)

Increasing-Block Rates (IBRs) is another innovative price measure. A relatively low usage tariff is charged up to some consumption threshold, while higher consumption is priced at a higher rate; more than two tiers can be used.

In order to protect weaker users, i.e. to cope with equity / distributional concerns, IBRs can take benefit from some design details.

The first ''block'' is designed to cover basic, non-discretionary needs (e.g. drinking and bathing), while the application of higher-tier rates can be reserved to higher-income consumers who are more likely to have discretionary and outdoor uses.

If the utility returns are regulated (e.g. rate of return regulation), profits that are generated by the implementation of IBRs can be returned to low-income consumers through a rebate policy. The rebates should take the form of a lower access fee or a fixed-sum discount, in order to retain incentives to conservation.

There are several good empirical studies on the effect of IBRs in water. Nowadays IBRs are more diffuse than DP. It is well established in the US, and has been experienced in Europe.

5.2.2 Dynamic pricing (DP): Open questions

The main strength of DP as a price measure lies in its potential as a time-varying signal of water scarcity for users. If properly designed, it fully reflects current supply and demand conditions and conveys the full costs of water supply and operations to users. The main difference between DP and IBRs lies in the intrinsic dependence of DP from exogenous supply and demand conditions. By contrast IBRs rates switch to higher tiers whenever households' water consumption exceeds a given threshold, whether supplies are scarcer or not.

Nonetheless DP, and overall CPP or CPR pricing, is highly debated in the water industry and is still not fully understood in its design and implications for users. Some cases and trials of seasonal pricing are documented, while virtually no cases of CPP or CPR are reported. In recent years some trials have been run with electricity distribution and retail markets (see Section 4.3). Empirical studies of dynamic pricing in electricity offer some insights, but there are important structural differences between the two industries.

More generally, there are a few open questions about DP and "real-time" DP more particularly, such as the following ones.

- There are situations, e.g. the UK, where users' acceptance toward DP seems to be quite poor and, in any case, needs to be well understood.
- Even milder DP forms and the IBRs have met objections in the UK. The same concept that the water company charges users higher rates during daily peak hours or summer arises criticisms. Till now UK tariff trials have shown that seasonal tariffs were not accepted, whereas IBRs were difficult for the customers to understand.
- Possible equity effects of DP are a cause of concerns. Its impacts on low-income users and non-discretionary uses and possible remedies are still to be researched in-depth.
- Metering, new billing techniques and other enabling technologies are recognized to be critical for DP implementation.
- DP design in water sector should lean on supply and demand parameters, whereas DP design in the electricity sector takes advantage of a well-developed wholesale market, i.e. retail rates can follow the wholesale energy price over time. Wholesale water markets are less developed, or non-existing at all in some countries.
- WDM is seen as more significant on a seasonal basis than on an infra-day or infra-week horizon.

5.3 Response to dynamic pricing schemes and rewards

Bearing in mind the open questions arisen in the previous section, the present one will provide some insights on the effects of innovative pricing schemes measured through experiments and trials conducted on sampled customers in the last decades. Since the application of dynamic pricing mechanisms in the water sector has been so far very scarce, we will exploit evidence coming from the energy sector, and particularly from the electricity supply.

To the best of our knowledge, the most comprehensive reviews of experimental studies dealing with the relationship between dynamic pricing and energy conservation are [Faruqui2010] and [Newsham2010]. The first one is a detailed survey of 15 experiments conducted in US in a period spanning from 1996 to 2007. The second one is a review on 42 published trials from 1996 to 2008 occurred in North America.

The 15 experiments analyzed by [Faruqui2010] reveal that the conservation behavior impacts from different pilot programs vary widely due to the difference in the pricing mechanisms tested, use of enabling technologies (in the case of energy consumption, a thermostat that can be programmed to automatically increase set-point temperature during peak hours in response to a CPP event signal from a pager can serve as example), ownership of central air conditioning and more generally, due to the variations in sample and experiment design.

The pricing schemes vary both with respect to the baseline pricing structures and the rate tested. Basically, three pricing mechanisms are tested: time-of-use tariffs (TOU), where customers are charged a peak and an off-peak price, with the first one higher than the second one; critical-peak pricing (CPP), where customers are charged an higher peak price in critical-days; critical-peak rebate (CPR), where customers can enjoy a rate discount for each KWh reduction below the reference level peak-period consumption on non-critical-days.

TOU programs are associated with a mean reduction ranging from 3 to 6% in peak usage. The figure can reach even the 30% if the program is supported with enabling technologies. CPP programs reduce peak energy consumption by an amount ranging from 13 to 20%. Moreover, if CPP programs are supported with enabling technologies the peak usage reduction further increases ranging from 27 to 44%. CPR rates are associated with reduction in peak energy use in a range between 8 and 18%. It is worthy to emphasize that these pricing experiments are extremely heterogeneous in their designs and the variation in their experimental quality limits the derivation of a consistent perspective.

[Newsham2010] confirms that CPP is generally more effective than TOU at reducing peak loads. The reason may be twofold. Firstly, the on-peak/off-peak price ratio in CPP is generally much higher than in TOU, typically by a factor of about three. Secondly, householders may be more willing to respond to a CPP program with a relatively small number of critical events, especially in the absence of enabling technology. The frequency of occurrence is found to be very relevant in explaining the customers' response: with TOU pricing they are asked to change their behaviour every single day, which may be much more difficult to sustain. The same source confirms that CPR is less effective than CPP, suggesting that people respond less well to carrots than sticks in this context.

As far as the effects of rewards are concerned, the evidence are even scanter. Given the impossibility to refer to studies coming from the water sector, we have to take advantage of limited evidence produced in the energy sector for an account of the effect of pecuniary rewards on customers' resource saving efforts.

Among the issues arising when estimating the treatment effect of monetary rewards is related to the smallness of potential savings from conservation the treated customers are exposed to. In most experiments they are insignificant in order to bear some relation to the actual price of electricity. [Delmas2013] observe that "pecuniary strategies might not be effective if the monetary incentives are negligible". For instance, [Hayes1977] exposed energy users to a $3 weekly rebate payments for up to a 20% reduction in energy use. The literature is therefore not unanimous about the effectiveness of pecuniary strategies in the current context.

Moreover, other analyses indicate that monetary incentives may be self-defeating for resource conservation because they might crowd-out more altruistic or pro-social motivations [Bénabou2005; Bowles2008].

5.4 Online communities and applications

Over the past decade, researchers as well as utilities, governments, and policy makers have come to realize that more than just economic incentives and information availability drive citizens' behavior. Social and psychological factors also play a significant role in shaping consumers' decisions and behaviors around environmentally sensitive habits and resource use.

People are profoundly influenced by those around them, i.e. they are driven in their judgments and beliefs by social influence and social norms. They are eager to match the judgments shared by the majority of their counterparts in a social environment and even mimic behaviors without any apparent reason to do so. Moreover, they are led to conform with social standards, hinged on beliefs about what other people are doing, and what they approve or disapprove.

Recently, utilities and governments are starting to exploit more and more the power made available by social norms and the chance to scale up social norms by leveraging on social influence. This section is aimed at providing selected examples of community-driven applications in the environmental fields and more particularly in resource conservation efforts.

5.4.1 Community-driven application in the environmental field

Probably, the most famous and successful application of social influence in the resource use field is represented by **Opower**, a company that partners with energy utilities around the world to reduce residential customers' energy use. Opower sends *home energy reports* that provide customers with feedback about their monthly usage, the monthly usage of their average and efficient neighbors, and tips on how to reduce energy consumption. Independent analyses indicate that Opower's strategy reduces energy consumption by an average of 2%.

The success of Opower and similar initiatives comes from a refined understanding of the variety of psychological factors taken into account in the intervention. Indeed, the effectiveness of social norms programs is significantly dependent on the extent to which these factors are interacted to produce meaningful behavioral changes. Firstly, *data credibility* is crucial to achieve intended outcomes: to this aim, comprehensive information, and statistics of the kind made available by smart water meters are of paramount importance. Secondly, the use of feedback strategies going beyond descriptive statistics but conversely taking advantage of symbols and/or evocative images (smiley or sad faces, emoticons,…) is essential to frame the communication in a way that makes it possible to counteract the *boomerang effect*, i.e. an inadvertent increase in socially undesirable behavior among those individuals who initially perform the intended behavior. Thirdly, the identification of *reference group* of people whose beliefs or behavior an individual is compared to, makes most likely to change an individual's behavior, because of a high degree of perceived similarity or social identification between the individual and the reference group itself.

By exploiting the above summarized stylized facts, many applications have been developing in the environmental field. Many of the following applications integrate the leverage on social influence and social norms with an approach based on gamification, i.e. "the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals" [Gartner2014].

RecycleBank was created to encourage people to recycle more and reduce landfill trash by awarding points for recycling, saving energy, and answering sustainability quizzes and pledges. Points are redeemable for actual goods at WalMart, BestBuy and more places, as city government pays RecycleBank for reducing landfill waste. The project is backed by Al Gore and has won numerous awards in innovation, sustainability, and business. It currently has more than 3 Million members and over 180 employees.

m.Paani aims at solving clean-water issue in third world countries. It has implemented a very innovative loyalty program, where by purchasing mobile credits from sponsoring companies, individuals earn points towards sanitization products or water-related infrastructure for the entire village.

The **Gaming for Good** initiative, a partnership between Al Gore's Climate Reality Project and PSFK, where people designed innovative gaming applications to address sustainability and climate change challenges, generating more than 60 entries from around the world.

British Gas's **EnCon CITY©** educational initiative, which illustrates the benefits of conservation by teaching players how energy is consumed and where it might be wasted.

Danish energy firm Vestforbrænding and advertising agency Anew created a pizzeria whose output depended on the amount of energy being saved by local residents. Consumers were first sent information on steps they could take to reduce energy usage, and energy consumption was then measured over a period of time. The less energy consumers used, the more free pizzas were available at the pizzeria.

San Diego Gas and Electric and Simple Energy launched the **San Diego Energy Challenge** in which consumers could compete against each other to reduce their energy consumption during the summer months, when air conditioners, pool pumps and other seasonal devices can put significant strain on the energy system.

Perhaps one of the best-known applications of social norms in the water sector has been by

WaterSmart Software. WaterSmart’s strategy is similar to the one developed and implemented by Opower in the energy sector.

WaterSmart partners with water utilities to help them achieve water conservation goals in their served area. Similarly to the case of Opower, water residential customers receive personalized *home water reports* that motivate and enable water-use efficiency. The report contains: a personalized home WaterScore every billing period; social norm-based, apples-to-apples comparison of water use with similar households; data insights to improve understanding of water use; customized, water-saving recommendations; targeted communications regarding investments, incentives, or other important utility messages.

6. Conclusions

The document has been directed to provide a review of economic policy instruments aimed at achieving water conservation in European countries. It focuses on pricing measures (both currently adopted and not) and in particular on innovative pricing mechanisms that have been experimented around the world (e.g. dynamic pricing).

In addition, the document offers an overview of the role of water innovation (and in particular the diffusion of smart water metering systems) both in sustaining and making viable the exploitation of smarter pricing mechanisms and in fostering *per se* water saving, e.g. through customers' awareness and intrinsic motivation.

The main conclusions drawn by the analyses conducted in the first year of the WP5 activity are:

- Innovative pricing mechanisms (i.e. dynamic pricing) are being experimented more extensively throughout the world. Unfortunately, most of the applications are still limited to the energy sector. In the energy sector, customers' response to innovative pricing measures has been proved to be significant, leading to considerable, although very variable, energy conservation.
- The application of dynamic pricing to the water sector is still debated. Water constitutes a more sensitive application field compared with energy. In many countries, value-for-money principle is not fully acknowledged when applied to water services. Moreover, activities related to water service delivery are natural monopoly and this circumstance limits to a great extent the freedom enjoyed by water utilities to devise complex and more efficient pricing structures.
- Water demand studies published so far show customers are sensitive to increases in water prices. However, the price elasticity varies a lot, depending on the pricing structure in place, the presence of enabling technology, location and household characteristics. In addition, price elasticity estimates are very sensitive to the design characterizing each study (sample, follow-up period, disaggregation level of the data, estimation method,…)
- The introduction of smart water metering systems is a prerequisite for the adoption of more innovative approaches to water conservation. After all, measuring is the first step towards the better understanding of any phenomenon.

The next expected steps within WP5 activity will be:

- The online survey administered among Ticino water users to test the response to economic incentives devised to promote water saving actions.
- The meta-analysis of water demand estimation studies to provide first-hand statistics on price elasticities of water demand.

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