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Smart Metering, Water Pricing and Social Media to Stimulate Residential Water Efficiency: Opportunities for the SmartH2O Project

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Abstract

The SmartH2O project aims to provide water utilities, municipalities and citizens with an ICT enabled platform to design, develop and implement better water management policies using innovative metering, social media and pricing mechanisms. This project has as a working hypothesis that high data quality obtained from smart meters and communicable through social media and other forms of interaction could be used to design and implement innovative and effective water pricing policies. Planned case studies in the UK and Switzerland are introduced. We anticipate that SmartH20 research outcomes will be of use to those interested in linking smart metering, social media and smart pricing approaches to achieve more sustainable water management outcomes.

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1. Introduction

"Europe 2020" strategy (education, knowledge and innovation) aims to deliver a sustainable (resource-efficient, competitive economy offering well-paid less carbon-intensive jobs) and inclusive (new skills and jobs, European platform against poverty and social exclusion) growth [1]. One of the seven flagships of the "Europe 2020" strategy is a resource-efficient Europe, i.e., efficient and sustainable use of water and energy resources, climate change, research and innovation, environmental policy. Closely related to the EU 2020 Strategy is a recent publication by the European Commission (EC) [2] "*A Blueprint to Safeguard Europe's Water Resources*" whose purpose was to review the EU water policies since the adoption of the Water Framework Directive (WFD) in 2000 and to recommend further actions for the sustainable use of water resources. One of its key recommendations is the adoption of water efficiency measures such as pricing policies, which can result in saving water consumption as well as energy, in line therefore with the objectives of the resource-efficient Europe 2020. More specifically, [2] highlights that pricing is a powerful awareness-raising tool for consumers and combines environmental with economic benefits, while stimulating innovation. Metering is a pre-condition for any incentive pricing policy.

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 reuse and recycle) disseminate and promote the uptake of innovations by the market and society for major water-related challenges (see for instance SPADIS – AG for pricing policies and RTWQM – AG for sensor technologies for water quality monitoring). Integrated approaches for sustainable water, energy and irrigated management are also stimulated.

The SmartH20 project fits in and meets the above EU water challenges and objectives as it delivers an Information Communications Technology (ICT) platform (see Fig. 1) to support water utilities in determining optimal water pricing and consumers in chancing their water consumption habits, thus dually contributing to the target of a more efficient use of water. This is achieved by integrating smart metering, social computation, dynamic water pricing, and advanced consumer behavioral models. Furthermore, the SmartH20 project highlights the importance of innovation in the water sector by coupling smart meter technologies with innovative end-user services which can reach better water management through the means of rewards, automation and information.

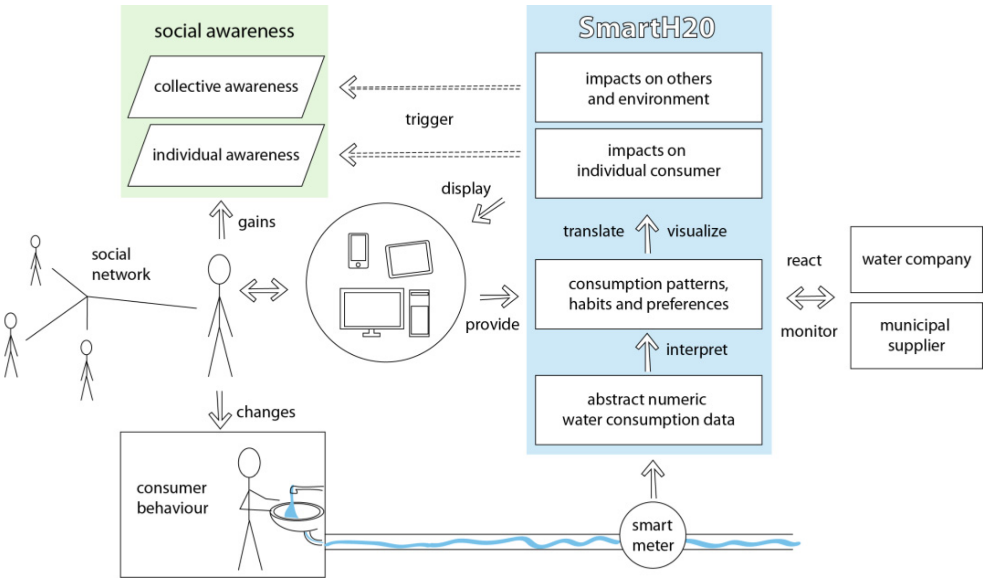

Fig.1. The flow of information and control in the SmartH20 system (Source: [3] Rizzoli et al. 2014).

Overall, the main objective of the SmartH20 project is to develop an innovative ICT solution that will make it possible to study, understand and modify consumer behaviour in order to achieve quantifiable water savings by raising consumer awareness and by the design and implementation of dynamic pricing schemes thus also improving the efficiency and business operations of water companies.

2. Water demand management: the potential of smart metering to increase water efficiency

Traditionally, increasing demand for water has been met with supply-side policies, such as new storage infrastructure, desalinization and recycling leading to increasing environmental and financial costs [4]. Therefore, decision making interest has increasingly shifted to water demand management (WDM) [5]. The five categories of WDM include: (1) engineering, i.e. installing efficient showerheads or washing machines; (2) economics, i.e. water pricing; (3) enforcement, i.e. water restrictions; (4) encouragement, i.e. rebate programs for water efficient clothes washers; (5) and education, i.e. promoting water saving practices such as shorter showers [6].

To evaluate the effectiveness of WDM policies a high quality of data is needed. The key attributes of such data are that they are more accurately resolved in terms of end-use and are available in near-real time, allowing the detection of behaviours which are more difficult to identify through meter readings occurring a few times per year [7]. Data resulting from smart metering applications allows water managers to investigate the effectiveness of WDM strategies and household water consumption patterns amongst different socio-demographic groups ([8], [9], [6]). For instance, a study [8] in the city of Gold Coast in Australia examined the potential savings derived from efficient appliances, the socio- demographic clusters having higher water consumption across end uses as well as the payback period associated with upgrading appliances. The findings were very encouraging (e.g. reported water savings levels were higher than other research studies) and the authors concluded that savings achieved from WDM policies can have a flow-on benefit to the entire water and wastewater system (as well as the water heating and electricity supply system [8]. Another study [10] examined how attitudes e.g. *concern for the environment* and *water conservation awareness and practice* of end users influence water consumption levels, while [11] investigated shower behaviour response before and after the introduction of an alarming visual display monitor. The authors concluded that smart meters may not be effective unless instilled habits or attitudes can be also changed. Finally, [12] analyzed disaggregated (e.g.. hour, day, month) residential (e.g. washing machines, showers etc.) and irrigation peak water demand suggesting that such information can be used to design WDM strategies such as water tariffs.

Yet, several research questions remain to be explored. For instance, how data obtained by smart meters can be effectively managed to fulfil its potential benefits and at the same time what questions need to be asked and answered to ensure privacy issues do not derail the wider implementation of the technology [7]. Moreover, it is apparent that behaviourally influenced water consumption is essentially complicated and will not occur by technology alone [11], therefore further research is needed to understand user behaviour, social norms and beliefs and water consumption. Finally, we will research and assess the feasibility and potential structure of time of use tariffs (e.g. dynamic water pricing policies) using hourly, day, monthly consumption information sources which can promote efficient residential water use as explored next.

3. Water demand modelling, user behaviour and pricing policies

Water pricing is often suggested as a promising mechanism to reduce water demands [13]. Urban residential water pricing usually takes one of three forms: (1) a uniform marginal price (UPs); (2) Increasing Block Prices (IBPs); or (3) Decreasing Block Prices (DBPs) and each of these price structures is typically accompanied by a fixed water service fee [14]. Properly designed IBPs can provide a better incentive for water conservation than UPs ([14], [31]), though the estimation of price elasticity under IBPs raises a few challenges for model specification and data sampling ([14], [34]). Residential water demand in the presence of block tariff structures has been of a subject of research by several authors by using panel data, cross-section and time series econometric techniques (see for instance [15], [16], [17], [18], [19], [20], [21], [13], [14]). Past research suggests that residential water demand is inelastic but not perfectly inelastic, especially in the long run ([30], [31]). Price elasticity is determined by several factors such as the size and the income of households [32], weather conditions and season [32], and the fact that water is seen as necessity good [4]. Price information was found to strengthen consumers' response to price ([4],

[33]). Finally, fixed-sum rebates can be transferred to low-income consumers to cope with possible adverse equity effects of price policies ([32]).

However, as it is pointed out by [19] pricing alone to control demand is a blunt tool because the consumers' perception of rate structures and price schedules can be low and there is a lag observed in the effect of price changes on demand reductions. Moreover, design of pricing schemes requires taking into account components such as institutional framework, transaction costs, policy implement ability and uncertainty (see [22] for an overview). For instance the implementation of increasing block tariffs in California, although it is considered as a successful policy in terms of its economic, environmental and distributional outcomes, suffered from high transactional costs ([23], [24]). Additionally, water planning and pricing policies are affected by user attitudes and behaviors towards water consumption ([9], [25]).

Smart meters and In-Home Displays (IHD) or mobile media 'apps' have the potential to reduce water consumption by changing attitudes away from 'non-negotiable practices' towards proactively responsible water use by consumers [26].

Tests of smart meters as a tool to alter consumer behaviour have shown significant water savings, but these effects are somewhat short-lived, with consumption returning to pre-intervention levels in the long term [27]. This suggests that the use of such tools should be used in conjunction with price mechanisms and dissemination of information to maximize likelihood of changing consumer attitudes and behaviors [28]. A parallel sector, electricity, offers several insights on the joint effects of smart metering and dynamic pricing and the design of experiments, though caution is needed when transferring results, due to sector-specific characteristics, notably the opportunity for retail electricity prices to reflect a proper wholesale price. Electricity consumers are found to respond to the introduction of critical-peak prices and, to a smaller extent, to time-of-use rates ([35], [36], [37]). An even stronger demand reduction has been obtained by the means of higher peak prices, though returns are decreasing.

The SmartH20 project will reassess traditional pricing models and develop new ones such as time of use, critical peak pricing, differential tariffs for essential (e.g. indoor) and non-essential use (e.g. outdoor) or even for potable and non-potable use (e.g. water recycling for gardening purposes) that could take advantage of new opportunities. Given smart meters and new forms of interaction with consumers through social media, new possibilities in dynamic (time-varying) and customised pricing are emerging. Real-time data from smart water meters and historical data on households' socio-demographic characteristics can be used to propose an increasing block tariff that achieves the goals of equity, water conservation and full cost recovery. Additionally, household surveys across various seasons can be a useful tool to capture attitudes and behaviours towards water consumption and conservation. Combining real time data with information about the socio-demographic and psycho-social profile of the consumers can be the basis to stimulate target water policy approaches such as flexible and accurate pricing schemes, educating citizens on their water,

Short-term information on consumption and increased consumer communication potentially enable price being linked to short and/or long-term water scarcity. The goal is to encourage discretionary consumption during off-peak times (e.g. washing machine outside of peak showering times) and during wetter seasons (e.g. filling the pool during a rainy period rather than in a drought). We will consider how up-to-date prices, recent consumption and resulting charges could be communicated in an informative and rapid way to consumers. Data on day-to-day water consumption will allow consumers to have more accurate information about their water use profile and how it measures against other consumers' profile. As a result, consumers can change attitudes towards water consumption for instance by investing in new appliances or even trade water with neighbours as water becomes more valuable.

Other innovative pricing mechanisms will be considered such as schemes where smart meters estimate household occupancy to implement customised rates. Moreover, in England where retail competition in water industry will be introduced in 2017 and prices are reviewed every five years by the economic regulator, the Water Services Authority (Ofwat), real-time data from smart meters can be a valuable source of information for consumers, utilities and regulators. Consumers can ask for more information about "retail" products, utilities can improve their asset management (e.g. water leakage, see for instance [29]) which can then be reflected in more favourable prices (e.g. awards) by the regulator. Therefore, improvements in the level of service and affordable bills can be achieved.

To learn about the effectiveness and social acceptability of dynamic and other pricing schemes, several activities will be undertaken. Historical data (i.e. individual profiles and consumer patterns, pricing policies) will be used to estimate a micro-econometric model of water demand that can be applied to assess new pricing policies. This model will be used to inform the design and calibration of the agent model of water consumption which will simulate whole districts of water users, thus extrapolating the users' model at a larger scale. Assessing social acceptability and validation of econometric and project 'agent' models of water consumption will be done by conducting workshops with stakeholders in an experimental setting to test their reactions to different pricing mechanisms that involve the use of smart meters and social media.

4. Case studies

The SmartH2O platform will be deployed in two case studies, by the two water utilities, Thames Water (UK), and Società Elettrica Sopracenerina (CH), which are partners of the project.

Since 2011 Thames Water, the largest UK water utility, has been running a trial on smart metering technology (Fixed Network Trials - FNT) with the objective of understanding the benefits for customers and the operational benefits of deploying a smart metering infrastructure covering full District Metered Areas (DMAs). Advanced Meter Infrastructure (AMI) equipment has been installed to collect frequent meter readings (15 min intervals) from all connections within the DMA. The main objectives are to obtain an accurate water balance as well as confirming business case benefits of a large scale roll out. Two different fixed network technologies: advanced fixed network supplied by Arqiva/Sensus and a conventional fixed network supplied by Vennsys/HomeRider. This experiment covers 5 DMAs: 2 in London, 2 in Reading and 1 in Swindon with a total number of properties of 5,000. Total number of meters that have been installed are around 2,500.

Società Elettrica Sopracenerina (SES) is a power utility based in Locarno, which has already run a test on multi-utility (water, gas and electricity) smart metering in Gambarogno, on the shores of Lake Maggiore. SES is exploring innovative metering techniques for electricity, gas and water, and the vision is to make the customer an active and self-aware actor in the rational use of water and energy. In the SmartH2O project SES will install 400 smart meters in selected locations in the Locarno region. A first batch (200) is expected to be installed during the 4^{th} Quarter 2014, and a second batch (200) during the 1^{st} Quarter 2015.

In both case studies the SmartH2O project will measure a set of key performance indicators, in order to measure the degree of success in the achievement of the project main economic objectives: a) save water by dynamic water pricing and b) efficiency of business operations of water companies. With regard to the first objective, the key performance indicator to be measured by accounting for amount of water saved per capita per period. As water saving could be the consequence of increased awareness, we will also evaluate the combined effect of dynamic water pricing and user awareness, to verify if the interactions of these two signals can be cooperative or competitive.

Regarding the second objective related to the efficiency of business operations of water companies, the key performance indicators will be: a) peak-period reduction of water consumption: measured by comparing the historical data of peak water consumption in the two case studies with the data monitored after the introduction of SmartH2O; b) energy required for pumping water: another indicator that can indicate considerable savings in costs for the water utility; c) reduction in CO2 emissions: an indicator strictly connected to energy savings, and finally d) investments avoided: it is the total amount of money that has not been spent over a given period thanks to reduction in water consumption. This last indicator helps to assess how reduced water consumptions prevented the building of new infrastructures (e.g. new wastewater treatment plants).

4. Conclusions

The SmartH20 project (2014-2017) is still at its initial stage. In this paper, we briefly discussed the general concept and project structure and provide a review on the benefits from using smart metering infrastructure for water management and public water supply efficiency. We also highlighted how high quality data from smart meters and communicable through social media and other forms of interaction could be employed to design and implement innovative and effective water pricing schemes, which could eventually lead to more accurate and affordable bills. Moreover, we showed how real-time data could be a valuable source of information for water utilities to improve their asset management, which could then lead to more favorable prices by regulators. We anticipate that SmartH20 research outcomes will be of use to those interested in linking smart metering, social media and smart pricing approaches to achieve more sustainable water management outcomes.

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