ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 89 (2014) 1105 – 1112
Procedia Engineering
www.elsevier.com/locate/procedia

16th Conference on Water Distribution System Analysis, WDSA 2014

Smart Meters, Smart Water, Smart Societies: The iWIDGET Project

D. Savić[a,*], L. Vamvakeridou-Lyroudia[a], Z. Kapelan[a]

[a]*Centre for Water Systems, College of Engineering, Mathematics and Physical Sciences, University of Exeter, North Park Road, Exeter EX4 4QF, UK*

Abstract

Population growth and economic development are main causes for increases in the demand for freshwater throughout the world. The likely impacts of climate change and increased urbanisation will result in the increase of the share of global water use to satisfy urban demand and will make water security for urban population even more difficult and costly to achieve. iWIDGET is an EU FP7 funded project (2012-2015), aiming to advance knowledge and understanding about smart metering technologies in order to develop novel, robust, practical and cost-effective methodologies and tools to manage urban water demand in households across Europe. The main scientific challenges for iWIDGET are the management and extraction of useful information from vast amounts of high-resolution consumption data, the development of customised intervention and awareness campaigns to influence behavioural change, and the integration of iWIDGET concepts into a set of decision-support tools ('widgets') for water utilities and consumers, applicable in differing local conditions, in three case studies in the UK, Portugal and Greece.

Peer-review under responsibility of the Organizing Committee of WDSA 2014
Keywords: smart meters, water efficiency, ICT, water distribution systems, water demand, water and energy nexus.

1. Introduction

With population growth and economic development, the demand for freshwater are increasing throughout the world. According to the OECD Environmental Outlook to 2050, global water demand is expected to increase by 55% (taking 2000 as a baseline) and more than 40% of the global population may be under severe water stress by 2050 [1]. The likely impacts of climate change and increased urbanisation will result in the increase of the share of global water use to satisfy urban demand and will make water security for urban population even more difficult and costly to achieve.

* Corresponding author. Tel.: +44-1392-723637.
E-mail address: d.savic@exeter.ac.uk

Peer-review under responsibility of the Organizing Committee of WDSA 2014
doi:10.1016/j.proeng.2014.11.231

In urban areas worldwide, utilities spend $184 billion each year supplying clean water [2], but they lose $9.5 billion each year from leaked water alone. It is, therefore, obvious that we need new smarter approaches to manage water in cities. Water use in households is also linked to energy use, given that 50-60% of domestic water consumption occurs in energy consuming appliances (washing machines, shower, bathtubs, dishwater)[3]. The supply of clean water and disposal of wastewater are energy intensive processes. A change of water use behaviour therefore not only has the potential to reduce the cost of lost water but also to extend the life of our present water resource and wastewater systems and to reduce the demand for energy with its consequent environmental benefits. According to Sensus [2], "a smart water network is an integrated set of products, solutions and systems that enable utilities to remotely and continuously monitor and diagnose problems, prioritize and manage maintenance issues and use data to optimize all aspects of the water distribution network". However, the definition is narrowly focusing on the utility alone as smart monitoring (involving devices that allow continuous electronic reading, transmittal and display of the water consumption) has in the past focused on the supply side, i.e., at major facilities and input points to the system with the main aim of monitoring leakage in the distribution system or billing bulk customers, rather than on the demand side, at the user's premises. The EU funded project iWIDGET (Improved Water efficiency through ICT technologies for integrated supply-Demand side manaGEmenT), aims to investigate the use of smart water network technologies for better management of urban water distribution systems considering both the supply side (i.e., utility) and demand side (i.e., customers) [4]. The project, which is funded under the EU 7th Framework Programme, started in November 2012 and will run for 3 years. The partnership assembled to deliver the project is a combination of all the key players in the field, leading ICT companies, business leaders, technology developers, standardisation organisations, water companies and top scientists in the field of water management, information and systems analysis and the social sciences. The following sections will introduce the iWIDGET project and its achievements during the first year and a half.

2. Project Objectives, Partnerships and Structure

The objective of the project is to deliver novel Information and Communication Technology (ICT) solutions that will support the integrated management of water by drastically improving the efficiency of water use and reducing waste by householders and by enabling utilities to manage better the domestic demand for water. These objectives will be achieved by researching, developing, testing and evaluating a new intelligent ICT solution, **the iWIDGET system**. This new system will support decisions at both the household and utility levels. It will analyse the usage pattern of individual households and present data, analytical results, comparisons and feedback. iWIDGET will provide households, for example, with information about both their behaviour and the behaviour of others and offer customised suggestions on how to reduce use and take advantage of current pricing schemes. It will raise alarms if local leakage is suspected. For the utilities, the system will provide information to help with the development of water pricing, demand forecasting and demand management. It will assist with the design of intervention options and awareness campaigns customised to the requirements of householders and utilities, taking advantage of state-of-the-art thinking on behavioural change processes in the social sciences. Based on current evidence [5] the overall potential of smart-meter technology in curbing domestic water use is clear, but more research is required to establish the most effective type of feedback in terms of information content and granularity, delivery frequency and medium. Further, extraneous factors, such as water pricing and user demographics, also need to be explored further, and these aspects are part of the scientific challenges for iWIDGET [5].

The key outcome of the project will be a working prototype of the iWIDGET system which will be tested on three real-life operational case studies. To validate iWIDGET, off-line simulations will be run for a number of full scale scenarios to optimise the performance of the system under different conditions not experienced during the historical data collection period (year 2 of the project). One year of "live" testing (year 3 of the project) will be undertaken to validate the iWIDGET system in the three case studies in close collaboration with water utilities and their customers (Fig. 1).

The project is structured around seven work packages, WPs (Fig. 1 indicates the focus of each WP):

- WP1-Requirements analysis aims at identifying the requirements of householders and suppliers;
- WP2-Reserach and Development of iWIDGET Systems;
- WP3-Implementation and validation of the iWIDGET Systems;

- WP4-Review and evaluation of the iWIDGET Systems (starting in Year 2);
- WP5-Exploitation, Planning and Partnership building;
- WP6-Dissemination and e-learning platform; and
- WP7-Management.

The partnership assembled to deliver the iWIDGET project, research, prototype and business approach is a combination of all the key players in the field: leading ICT companies (IBM, Ireland), business leaders (SAP, Switzerland), technology developers (UPL, UK), standardisation organisations (HR Wallinford - OpenMI Association, UK), water companies (AGS/Águas de Barcelos, Portugal; Waterwise working with Southern Water, UK) and top scientists in water management, information and systems analysis (University of Exeter, UK, LNEC, Portugal; and National Technical University Athens, Greece) and the social sciences (University of Exeter, Waterwise, UK; and LNEC). Together the iWIDGET consortium brings to the table a clear understanding of the market, the technological state-of–the-art with respect to hardware and software, new research and development in data mining, analytics, decision support, data management, visualisation, water conservation modelling and social simulation. The project also obtains input from householders through the three case studies and input from the broader water industry through its Advisory Panel.

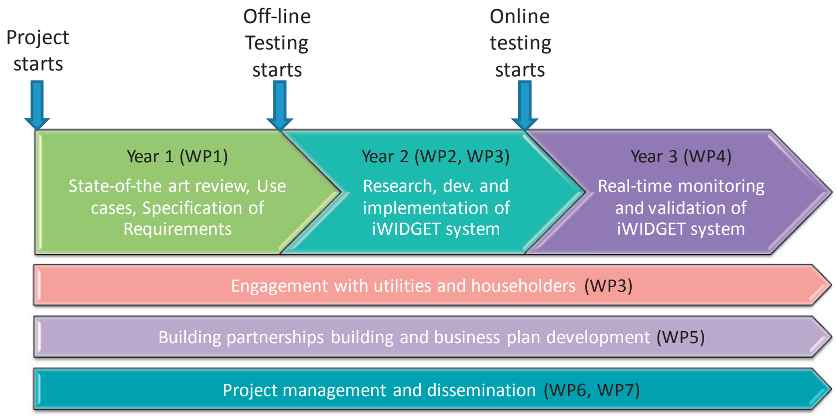

Fig. 1. iWIDGET project structure and timing.

Table 1. Main characteristics of the Case Studies.

Location	Barcelos, PT	South East UK	Athens, GR
Overall approach for sampling	DMA based	Along special van routes	Volunteers
Water utility involved	Aguas de Barcelos	Southern Water	None
Partner responsible (overall)	AGS	Waterwise	NTUA
Initial number of households to be contacted	400	3,000	25-30
Active expected sample size for responses/log-in to the iWIDGET system	100-150	>1000 survey and 500-600 to log-in	20
System of approach for participation	opt-in	opt-out	personal contact
Control group-out of people who were contacted and opted out (or did not opt in)	yes - around 200-250	yes-around 1,000	no - all the participants are volunteers

The project originally intended to use two case studies for the demonstration and validation of the iWIDGET system. These are the case study of in Barcelos (Portugal) and in Southern Water (UK). However, due to initial delays with the latter, another case study has been commissioned in Athens (Greece). All three studies are now well under way and their summary characteristics are given in Table 1.

3. Project Achievements

3.1. Requirement Analysis

The project started with the development of 'use cases' and requirements for the iWIDGET system (WP1), which precedes the development of the new system. This was a specific objective for the 1st year, and it has been achieved as use cases and Requirements have been defined. The use cases cover a range of possible usages that can be built upon the exploitation of high-resolution data related to water and energy use collected from water distribution network flow meters and water meters installed at the households.

In order to obtain a comprehensive and feasible list of possible use cases, the following methodology was used. Firstly, a list of high-level use cases was compiled, described and harmonized. High-level use cases were used to describe the main process in supply systems and are largely business-oriented and in line with of the iWIDGET project. Harmonization aimed at balancing the level of detail between use cases, finding equivalent or overlapping use cases and identifying conflicting objectives or use cases. For each high-level use case, a list of detailed-level use cases was subsequently derived, described and harmonized. Detailed-level use cases exhaustively describe the sub-processes within a given high-level case and were used for deriving system requirements.

This work was developed for two domains: consumer and water utility. In total, for the consumer domain, 6 high-level and 18 detailed-level use cases were described, whereas for the water utility domain, 7 high-level and 20 detailed-level use cases were described. For the consumer domain, the goals of the high-level use cases were to promote easier, faster and more flexible access to detailed water consumption data and related energy consumption in the household; to enable consumers to understand their water consumption patterns and related energy consumption patterns; to assist consumers in changing wasteful behaviors and appliances, through customized suggestions (practices, tips, interventions, technologies); and to promote an effective control of water uses and appliances at the household level. For the water utility domain, the goals of the high-level use cases were to promote easier, faster and more flexible access to accurate data; to improve understanding of metered water consumption and related energy consumption and water losses; to optimize real-time operation in terms of water-energy efficiency; to enable the water utilities to improve the quality of service provided to the consumers; to improve domestic demand management; and to improve operational planning and long term asset management [6]. All the use cases are presented in Table 2.

At a second stage, the proposed high-level use cases were validated and ranked, based on the contributions of two different target audiences - the project partners and a group of stakeholders that attended three workshops held in Portugal, the UK and Athens, Greece. A detailed discussion about the findings, similarities and differences between the workshops in the UK and Portugal are presented in [7]. The group of stakeholders included experts from water utilities, consumer's organizations, technology providers, water services regulators, professional associations, government organizations, research institutions and associations for environment protection, as well as end-users (volunteers) in Athens.

Although the groups of stakeholders were similar in Portugal and the UK, their attitudes were different. For instance, in the consumer domain, the use case related with energy-water consumption was more relevant to UK stakeholders, while Portuguese stakeholders consider control water use as more significant. On the other hand, in the water utility domain, understanding water consumption and energy associated with water consumption are the most relevant use cases for the Portuguese stakeholders, whereas UK stakeholders considerer that getting support to increase quality of service and to improve efficient water use are the most relevant use cases [7].

3.2. Research and Development of the iWIDGET system

The development of the iWIDGET system requires the conceptual design and high-level architecture to be defined based on the business case and technical requirements gathered in WP1. The architecture is based on a system that extracts useful information from high-resolution water consumption data and provides this information to individual consumers and utilities. In the proposed system, each analytic component reads and writes to the central database so that individual components do not have to communicate directly, though direct communication is not prohibited by the system (Fig. 2). Results will be displayed through a user interface built on 'portlets'.

Table 2: Consumer and water utility domain 'widgets' derived out of the use cases, grouped and classified according to subject

	CONSUMER DOMAIN
1	**Obtain water consumption data**
1.1	Obtain total water consumption and costs using real-time data from smart meters
1.2	Obtain per appliance water consumption and costs (total water consumption breakdown) using real-time data from smart meters
2	**Obtain energy data associated with water consumption**
2.1	Obtain total energy consumption and costs associated with water consumption using real-time data from smart meters
2.2	Obtain per appliance energy consumption and costs associated with water consumption using real-time data from smart meters and display carbon emissions related to water consumption (carbon footprint of water)
3	**Understand water consumption**
3.1	Compare current water use pattern with historical consumption data of the same household
3.2	Compare water consumption with other consumers (e.g., neighbour in the same building or street)
3.3	Compare water consumption with standard profiles (consumers with the same socio-demographic factors)
3.4	Compare household water consumption with most efficient users
3.5	Obtain information on inefficient water uses
3.6	Receive warnings about faults (leakages, bursts) and unusual water consumptions
4	**Understand energy associated with water consumption**
4.1	Compare energy pattern associated with water use in the same household
5	**Assistance to increase water use efficiency**
5.1	Receive customised suggestions (practices and interventions) on how to reduce water consumption
5.2	Receive information on specific and alternatives pricing schemes
5.3	Forecast the next water bill
5.4	Forecast the component of next energy bill associated with water consumption
6	**Control water use**
6.1	Direct control of water consumption-scheduling of appliances use in order to optimize water/energy bill (indoors-outdoors activities)

	WATER UTILITY DOMAIN
1	**Obtain water consumption and related energy consumption data**
1.1	Obtain inflow (and associated energy consumption) and total water consumption per network sector using real-time data
1.2	Obtain water consumption data per category of consumer using real-time data
2	**Understand water consumption**
2.1	Obtain real-time water balance data
2.2	Benchmark water losses against reference values
2.3	Obtain information on consumption profiling
2.4	Obtain detailed information on operational inefficiency
3	**Understand energy associated with water consumption**
3.1	Obtain information on energy consumption associated with pumping
4	**Get support to increasing operational efficiency**
4.1	Receive warnings about faults (leakages, bursts) and unusual water consumptions in the network
4.2	Receive warnings about the status and sizing adequacy of water meters
4.3	Obtain information on the effect of pressure control on leakage components and consumption.
4.4	Receive customized suggestions about pressure reducing valve (PRVs) settings
4.5	Receive customized suggestions about pumping scheduling
5	**Get support to increasing the quality of service**
5.1	Receive information to make billing more accurate and flexible
5.2	Receive information to improve the management of complaints
5.3	Receive information to provide warnings to consumers
6	**Get support to influence consumers to modify their behaviour**
6.1	Receive customized suggestions about adaptive pricing schemes
6.2	Receive customized suggestions about awareness campaigns
7	**Get support for system planning and design**
7.1	Obtain water consumption trends regarding "what-if" scenarios
7.2	Get support to decision-making on water network expansions
7.3	Obtain information to support optimal equipment replacement scheduling
7.4	Determine optimal placement of valves and flow meters on pipes in the network

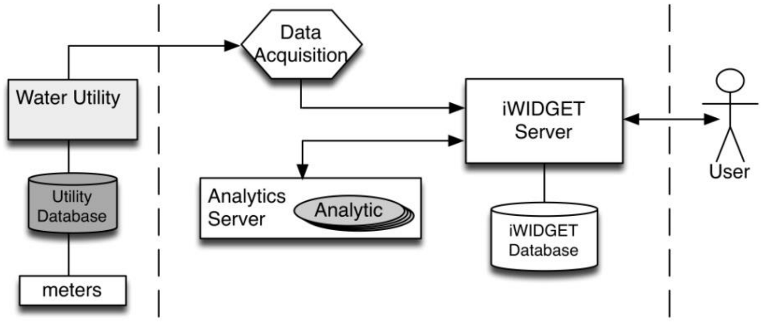

Fig. 2: iWIDGET system architecture.

The iWIDGET central system is composed of a database, a web application server, and FTP client. There will be a different iWIDGET central database for each utility so that data from different utilities is kept separate. Project Partners access the user interface through the webserver on the central system. Householders and individual consumers can login through the utility or another project partner and access required data through a secure tunnel to the central system. This arrangement relies on the utility or most likely project partner UPL, to support credential authentication of customers. Details about the conceptual model and the architecture of the iWIDGET system are presented in [8].

In addition to the basic iWIDGET system architecture, the project is developing a number of analytics components based on consumer and utility side use cases identified in WP1. The analytic components will support the processing and presentation of data collected from smart water meters at both individual households and utility level. Consequently, these analytics components, which are named 'widgets', are divided into household (consumer) and water utility domain components, as shown in Table 2. A detailed description of the 'widgets' is given in [9], while the water utility widgets are described in [8]. An example of a consumer domain widget is presented in Fig. 3.

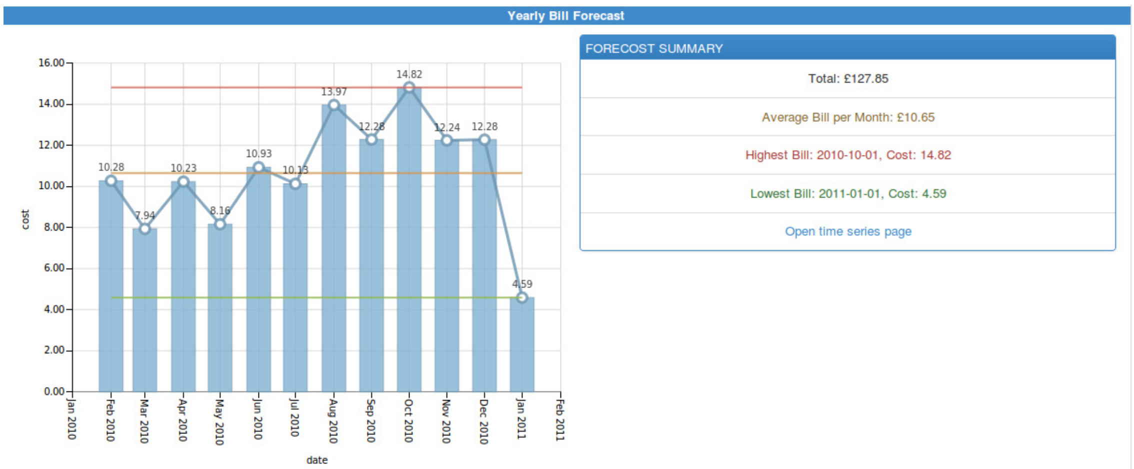

Fig.3. Forecast of consumer water bill for the next 12 months using Artificial Neural Network modeling-Use Case 5.3- Consumer domain.

3.3. Engagement with Householders and Utilities

From the start of the project iWIDGET has been actively involved with stakeholders, water utilities and end-users (consumers). The first action involving stakeholders in the Case Studies was the initial stakeholder workshops, for the definition of the Use Cases. The same type of workshop, with stakeholders from the water industry, public organisations and selected consumers was organised in the three case studies, in exactly the same way. The only difference was that for Athens, the stakeholder workshop comprised only the group of volunteers. During these workshops the main scope of iWIDGET was presented to the participating stakeholders, while their views on potential use cases and priorities (hierarchical rankings) was expressed through specifically designed questionnaires. The methodology and approach for the workshops is detailed in [7].

During the second year an online survey investigating attitudes towards smart meters has been distributed to over 3,000 consumers in the UK case study, resulting in over 1,000 responses. The same procedure will be followed for the other two Case Studies, although the sample there will be smaller (around 300 in Portugal and the group of volunteers in Athens). Based on the online survey responses a number of focus groups will be organised in each case study, in order to further investigate the response of end users to feedback from smart meters and the iWIDGET system, before and during the online testing (3rd year).

Meetings and discussions with water utilities across Europe represent a different type of engagement employed in the project. These utilities are not involved in the project, but their views are sought and reflected in the development of the ‘widgets’, in order to develop the business case and the business model of the iWIDGET system. iWIDGET is expected to drastically change business-as-usual in terms of water demand management and water efficiency. It will facilitate cooperation and awareness raising among water users and between them and the utilities and will revisit social (information and behaviour), economic (water pricing, business plan and business networks) and also environmental (leakage control and energy reduction) assumptions and practices. The project will build one or more partnerships to roll out the iWIDGET system, as part of its research outcome.

3.4. E -learning platform

Further to obvious and standard dissemination actions, iWIDGET aims to motivate and support users to improve their domestic water and energy efficiency. Towards this direction, the consumer domain ‘widgets’ are integrated with an on-line *e-Learning facility* developed around Moodle environment[10] during the first year of the project [11].

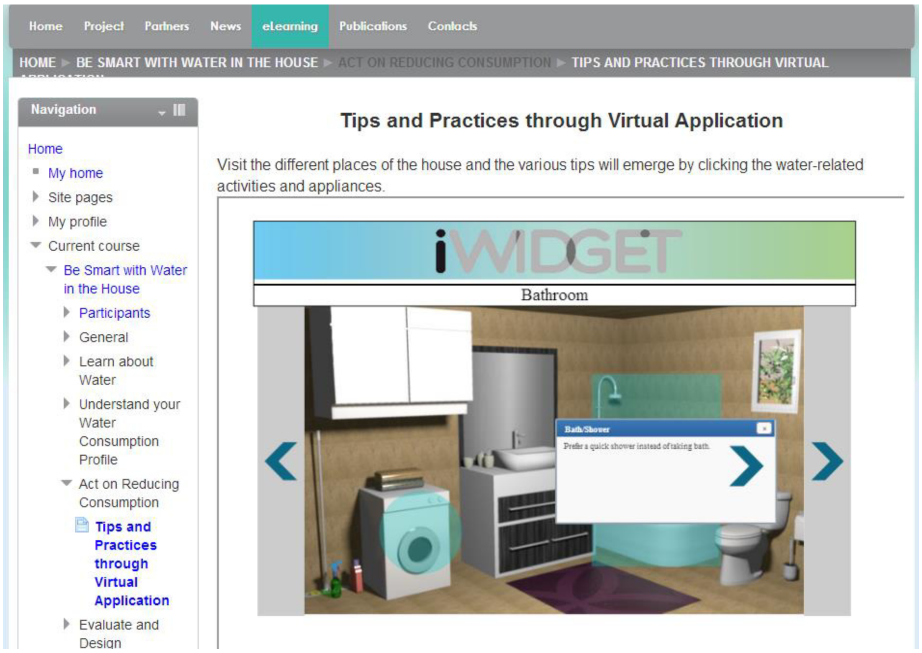

Fig. 4. Example webpage of the e-learning platform facility, showing the drop down navigation list on the left and water effiviency suggestions for the bathroom.

The e-Learning platform comprises several facilities and applications, such as educational questions and answers, quizzes, tips, water calculator, design and modelling tools, that support end-users from the one hand to understand their water consumption profile and its components, and on the other hand to identify alternative and affordable interventions (either technical or behavioural) which could contribute to the improvement of domestic water efficiency. Details about the e-learning platform are presented in [11]. Fig. 4 shows a characteristic webpage from the e-learning platform.

4. Conclusions

In this paper an overview of the iWIDGET project has been presented. This project is an EU FP7 funded project (2012-2015), aiming to advance knowledge and understanding about smart metering technologies in order to develop novel, robust, practical and cost-effective methodologies and tools to manage urban water demand in households across Europe. The project develops a set of decision support-tools ('widgets') for consumers and water utilities, aiming at providing useful information about water and energy-related water consumption. Data are being collected through water and electricity meters, which are partially pre-existing in the sampling area and partially installed during the project. The main scientific challenges for iWIDGET are the management and extraction of useful information from vast amounts of high-resolution consumption data, the development of customised intervention and awareness campaigns to influence behavioural change, and the integration of iWIDGET concepts into a set of decision-support tools ('widgets') for water utilities and consumers, applicable in differing local conditions. The paper has presented the general structure and approach to the problem, the list of the use cases ('widgets') and the progress achieved during the first year, including the interaction with stakeholders and the workshops for establishing the use cases, an example of a 'widget' and a webpage from the e-learning platform supporting awareness and tips for behavioural change in domestic water use for the consumer.

5. Acknowledgments

The research presented in this paper is being funded from the European Union Seventh Framework Programme (FP7/2007-2013), through the **iWIDGET** Project (2012-2015), under grant agreement no. 318272.

References

[1] OECD (The Organisation for Economic Co-operation and Development), OECD Environmental Outlook to 2050: The Consequences of Inaction, OECD Publishing, http://dx.doi.org/10.1787/9789264122246-en, 2012.

[2] SENSUS, Water 20/20 – Bringing Smart Water Networks Into Focus, Report by Sensus, 2012. Available at: http://sensus.com/documents/10287/3906954/Sensus_Water2020-USweb.pdf,

[3] D.P., Giurco, S.B. White and R.A. Stewart, Smart Metering and Water End-Use Data: Conservation Benefits and Privacy Risks, Water, 2 (2010) 461-467.

[4] iWIDGET, Improved Water efficiency through ICT technologies for integrated supply-Demand side management, EU FP7 project (grant agreement no 318272), Available at http://www.i-widget.eu/.

[5] Sønderlund, A.L., Smith, J.R., Hutton, C. and Kapelan, Z., Using smart meters for household water consumption feedback: knowns and unknowns, Proc. of Water Distribution System Analysis Conference (WDSA2014), 14-18 July 2014, Bari, Italy, 2014.

[6] D. Loureiro, P. Vieira, C. Makropoulos, P. Kossieris, R. Ribeiro, J. Barateiro, and E. Katsiri, Smart metering use cases to increase water and energy efficiency in water supply systems. Water Science & Technology: Water Supply, 2014.

[7] M. Rebelo, J.R. Smith, and M. Menezes, Prioritizing use cases for water smart technology development: Similarities and differences from Portugal and UK case studies, in: Proc. of Water Distribution System Analysis Conference (WDSA2014), 14-18 July 2014, Bari, Italy, 2014

[8] M.G. Barry, M.E. Purcell, B.J. Eck, J. Hayes, and E. Arandia, Web Services for Water Systems: the iWIDGET REST API, in: Proc. WDSA2014, 14-18 July 2014, Bari, Italy, 2014.

[9] P. Kossieris, S. Kozanis, A. Hashmi, E. Katsiri, P. Gerakopoulou, L.S. Vamvakeridou-Lyroudia, R. Farmani, C. Makropoulos, and D. Savic, A web-based platform for water efficient households, in: Proc. of Water Distribution System Analysis Conference (WDSA2014), 14-18 July 2014, Bari, Italy, 2014.

[10] C. Makropoulos, A. Katsiri, D. Assimacopoulos and M. Mimikou, E-learning: roles in distance and traditional postgraduate engineering courses, Journal on Education, Informatics, and Cybernetics (JEIC), , 1(2) (2009) 45-50.

[11] P. Kossieris, A. Panayiotakis, K. Tzouka, P. Gerakopoulou, E. Rozos, and C. Makropoulos, An eLearning approach for improving household water efficiency, in Proc. of Water Distribution System Analysis Conference (WDSA2014), 14-18 July 2014, Bari, Italy, 2014.