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A Web-Based Platform for Water Efficient Households

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Abstract

The advent of ICT services on water sector offers new perspective towards sustainable water management. This paper presents an innovative web-based platform, targeting primarily the household end-users. The platform enables consumers to monitor and control, on real-time basis, the water and energy consumption of their household providing valuable information and feedback. At the same time, the platform further supports end-users to modify and improve their consumption profile via an interactive educational process that comprises a variety of on-line tools and applications. This paper discusses the rationale, structure and technologies upon which the platform has been developed and presents an early prototype of the various tools, applications and facilities.

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Keywords: smart metering; web applications; ICT; urban water management; water-energy nexus; analytics; end-user

1. Introduction

The advent of new smart metering technologies along with innovative methods of data management, storage and communication, offers greater opportunities for sustainable urban water management [1]. However, despite several ICT services already deployed on the utilities side aiming at improving the management and planning of water infrastructures (including for example, real time control of water networks, dynamic pump scheduling etc.), little work

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has been done to date targeting the consumer side. In principle, however, it is now possible to provide detailed, accurate and real-time measurement of water consumption at the household level, through for instance Advanced Metering Infrastructures (AMI). This would enable the integrated monitoring and management of both the supply and demand sides of the potable water equation [2]. Utilities can process this new high-resolution data from smart meters to develop insights on user attitudes and consumption behaviours, especially in combination with feedback from socio-demographic surveys ([3], [4]). The household on the other hand, can better understand its consumption, identify wasteful (and potentially costly) behaviours and make informed water saving choices.

This paper brings the consumer at the center of this discussion and presents prototypes of web-based applications and services that exploit high-resolution water consumption data from smart meters at the household level. This will deliver valuable information to the end user, with the ultimate goal of improving domestic water and energy efficiency.

2. The on-line platform for water efficient households

2.1. Facilities of the platform

The design of the web-based platform and its system architecture was implemented following a systematic process based on the concept of *use cases* that considers the possible interactions between the user and the system [5]. This step-by-step process enables the efficient derivation of functional and non-functional system requirements, facilitating at the same time the determination of technological solutions, tools and methodologies to be implemented during development.

Following the use case formalism, a list of the system functionalities was compiled, with special focus on improving domestic water and energy efficiency using available consumption data from smart meters at the household level. The main processes of the iWIDGET system are briefly outlined in the following six high-level use cases [6]:

- **Obtain feedback on water demand:** This system functionality is devoted to real-time monitoring of consumption at the household level, using data from smart water meters. The platform displays detailed information on the progress of total domestic water demand and how the latter is allocated to various uses and appliances (group 1 in Table 1).
- **Obtain feedback on energy consumption related to water demand:** This high-level use case comprises the processes for the real-time monitoring of energy consumption associated with water demand. Using high-resolution energy data from smart meters along with the corresponding from water meters, the platform provides information on the domestic water-energy nexus. The feedback concerns not only the total energy consumption and the corresponding cost, but also the breakdown into appliances that consume water and energy simultaneously, adding up to the carbon footprint of the household (group 2 in Table 1).
- **Understand water consumption:** This high-level use case comprises all functionalities, which support householders to better understand the water consumption profile of their household. Aiming to motivate users to alter potentially wasteful attitude towards water, the system enables users to compare their current consumption with: (i) other neighboring consumers; (ii) consumers of similar characteristics; (iii) other efficient households; (iv) past consumptions of the same household. Through these comparisons, possible wasteful and inefficient uses are identified and presented in the form of notifications and messages. In the same framework, the system detects various faults, such as bursts and leakages. Furthermore, the analysis of long-term water consumption trends enables the detection of abnormal situations, which could be linked to other factors, such as health (group 3 in Table 1).
- **Understand energy associated with water consumption:** Similarly to the previous use case, the platform enables householders to monitor and understand better their energy consumption profiles, associated with water demand. The system provides comparative statistics about past energy consumption and the breakdown of total energy consumption into various uses (group 4 in Table 1).
- **Get assistance to increase water use efficiency:** The function of this high-level use case aims at supporting householders to improve the water efficiency of their household. The system provides customised and alternative suggestions that include practices, tips and interventions. The system, based on the specific needs and characteristics of the household, is also able to compose and perform different hypothetical but realistic scenarios,

using combinations of innovative technologies, such as water-efficient appliances, rainwater harvesting systems, greywater treatment systems, advanced gardening systems etc. These scenarios enable users to see what types of savings they could achieve if they installed advanced water demand management measures in their houses. Also past water consumption enables the consumer to forecast the next water bill (group 5 in Table 1)

- **Control water use:** This use case is devoted to more advanced (and potentially less realistic in the short run) functions that support users to optimize their water/energy bills by optimally scheduling water and energy related activities according to, for example, tariff structures, weather conditions and other specific needs of the household (group 6 in Table 1).

Each of above high-level use cases was further broken down into a set of more detailed, lower level use cases that provide additional information on specific system functionalities, as shown in Table 1.

Table 1: List of the higher and lower level use cases and functionalities provided by the platform

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)

2.2. Methodology and tools

The development of system architecture and platform analytic components was based on a series of state-of-the-art, flexible and advanced programming tools and technologies. The core of the platform is a system that can acquire and handle raw data from household smart meters, as well as process and visualize those data for the user, as meaningful information by applying suitably designed analytics. For that purpose the "*Enhydris*" database system for storage and management of hydrological and meteorological data was extended in order to support the specific needs of the web-based platform [7]. Enhydris is an open source system developed in the National Technical University of Athens and is written in Python/Django with some parts implemented in C. The system uses PostgreSQL RDMS as its database engine while its extensible RESTful API can be used for communication with external machines and databases, allowing the direct incorporation and integration of the platform with other systems, such as remote Utility databases etc.

2.3. An early prototype of the web platform

The platform is accessible via a web portal using secure password and username credentials. The homepage (Fig. 1) hosts overview information that presents and summarize the "bigger picture" of consumption profile of the household. Feedback includes, among others, daily/monthly/annual statistics and comparison with the previous year as well as water cost information. Additionally, water consumption is compared to indicative target consumption (120 litres per person per day) and signs are displayed aiming to motivate user towards water efficiency.

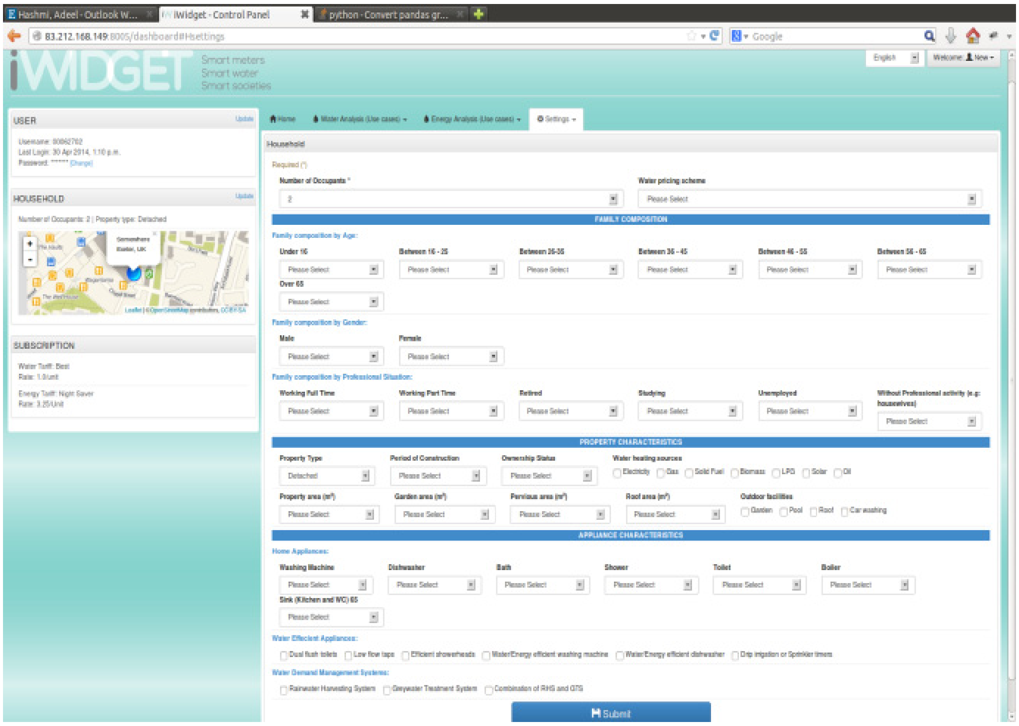

Fig. 1. Information on family, property and water appliances characteristics on the web-based platform

The system is able to acquire and store not only raw and processed high-resolution water and energy data from smart meters but also several important additional information including, inter alia, instrument characteristics, geospatial data, household characteristics as well as information essential for the operation of analytic components. Some information is static, i.e. geospatial data, while other information changes dynamically. Household characteristics fall into this latter category. The platform enables end-users to set up and/or modify their personal profile providing the system with specific information on family, property and water appliances characteristics. Fig. 2 presents the form through which the users can update their profile.

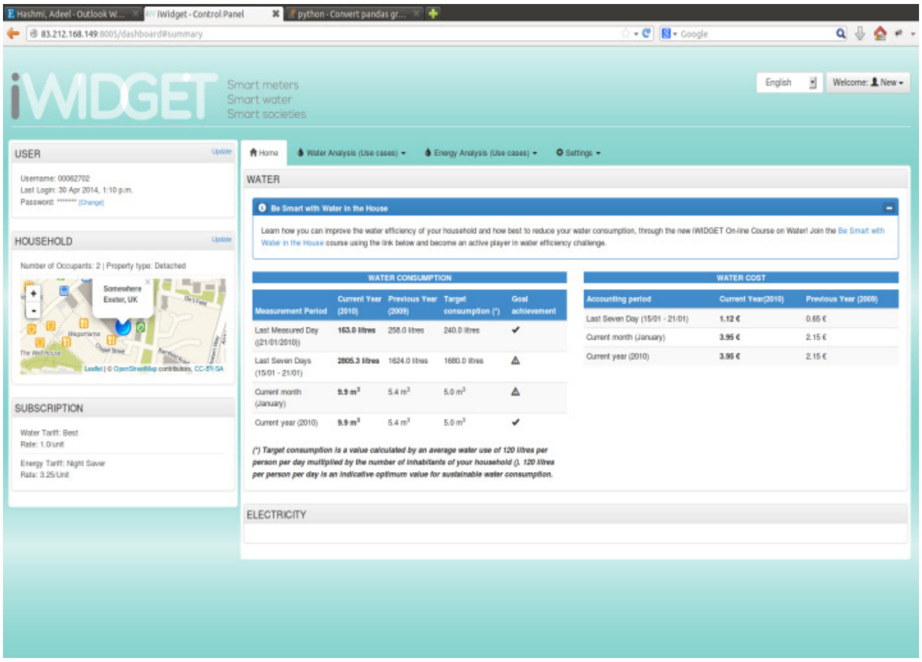

Fig. 2. Presentation of overview information on water consumption through the web-based platform.

The water consumption data are presented in the form of dynamic time series charts. Charts are refreshed automatically on a regular basis to enhance the "real time" impression. The level of presented information is determined via options that control the time-resolution of time series graphs, i.e. 15-minutes, hourly, daily, weekly, monthly and annually, as well as the units, i.e. litres, cost, per capita litres etc., enabling a more detailed or a more coarser aggregation of water consumption – as the user desires – in real time. At the most detailed level of information, the system gives access to full time series, downloadable for further external processing by the user.

Along with time series charts, some pie charts are also displayed, presenting nightly/daily water consumption breakdown for hourly data and summer/winter breakdown for monthly data. Pie charts are also dynamic and give the opportunity to the householder to monitor the water consumption trend within a day or a year. Fig. 3 presents the time series charts at different time scales as they are displayed via the web-platform.

In order to further help the consumers to understand their water usage and billing, in another chart the historical water consumption data is used to forecast the future water bills. Calculations are performed on a monthly basis, by applying dynamically an Artificial Neural Network (ANN), which is updated on request, according to the most recent historical monthly data. The user may define the scale of water bill forecasting, i.e., for the next 3 months, 6 months or 12 months. Every time the user requires this functionality the ANN model is being re-trained and updated on the fly. Fig. 4 shows the forecast of consumer water bill for the next 12 months. Similar graphs show the forecast for the next 3 or 6 months at request.

The Figures and functionalities included in this paper are only an indication of the full functionalities of the platform, because it is not possible to present all of them in the limited space of this paper.

Special attention has been paid to the colours, the captions and the structure of the information shown to the consumer. This process is still under way, in order to make all the messages and captions free of technical jargon. Also special information/ training material, as a leaflet and online, has been developed, in order to facilitate the use of the platform by the general public [8].

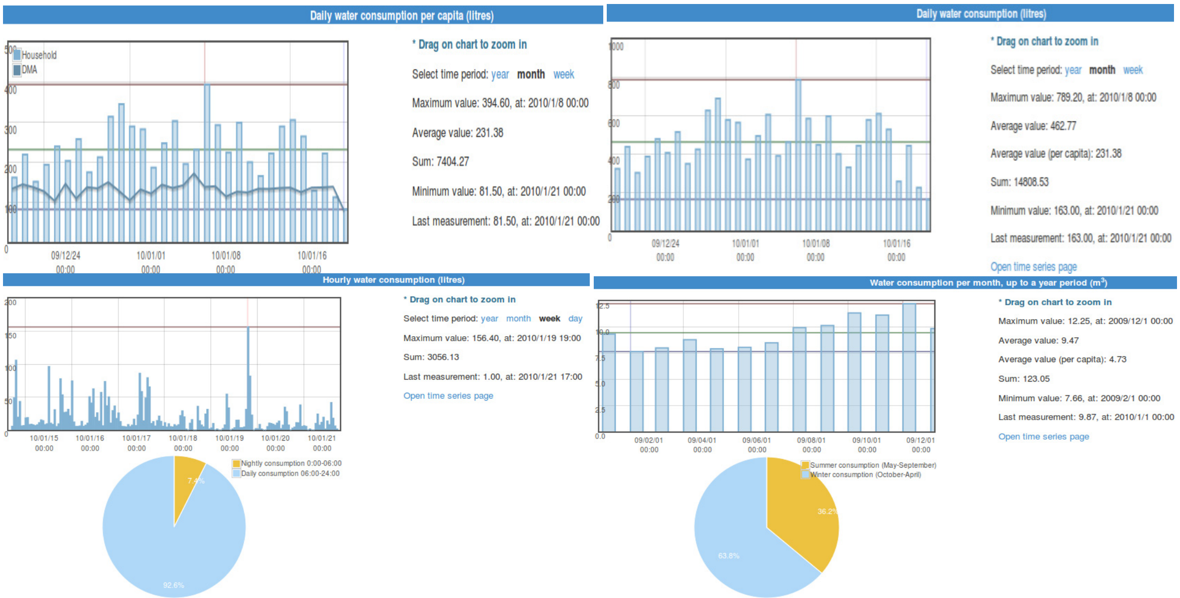

Fig. 3. Presentation of real-time water consumption data through the web-based platform

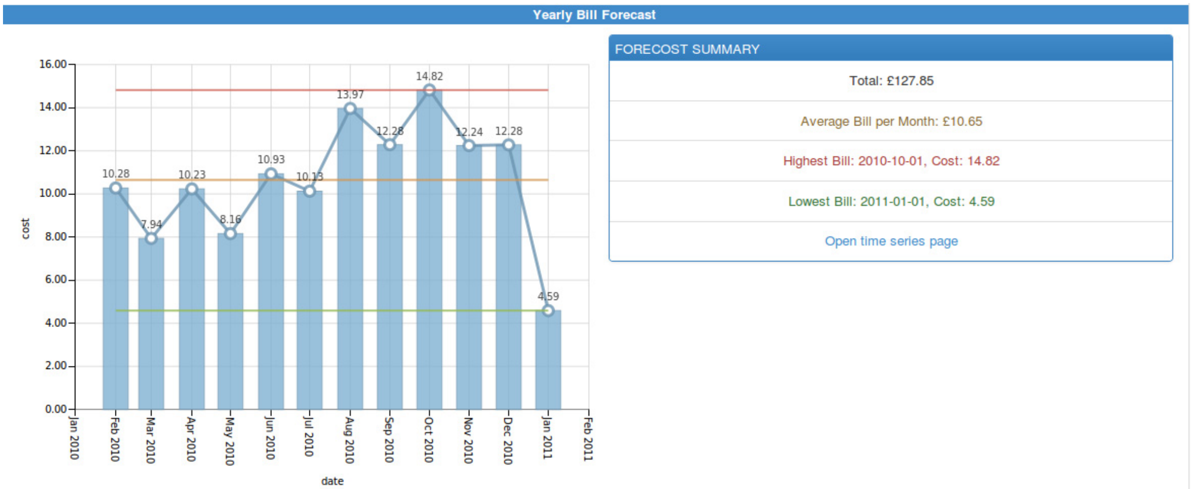

Fig. 4. Forecast of consumer water bill for the next 12 months using Artificial Neural Network modelling.

Further to data acquisition and visualization, the platform aims to motivate and support users to improve their domestic water and energy efficiency. Towards this direction, the household analytics platform is integrated with an on-line *e-Learning facility* developed around Moodle environment [9], which is presented in detail in a separate paper [10]. An example page, offering advice on water saving options in the kitchen is shown in Fig. 5.

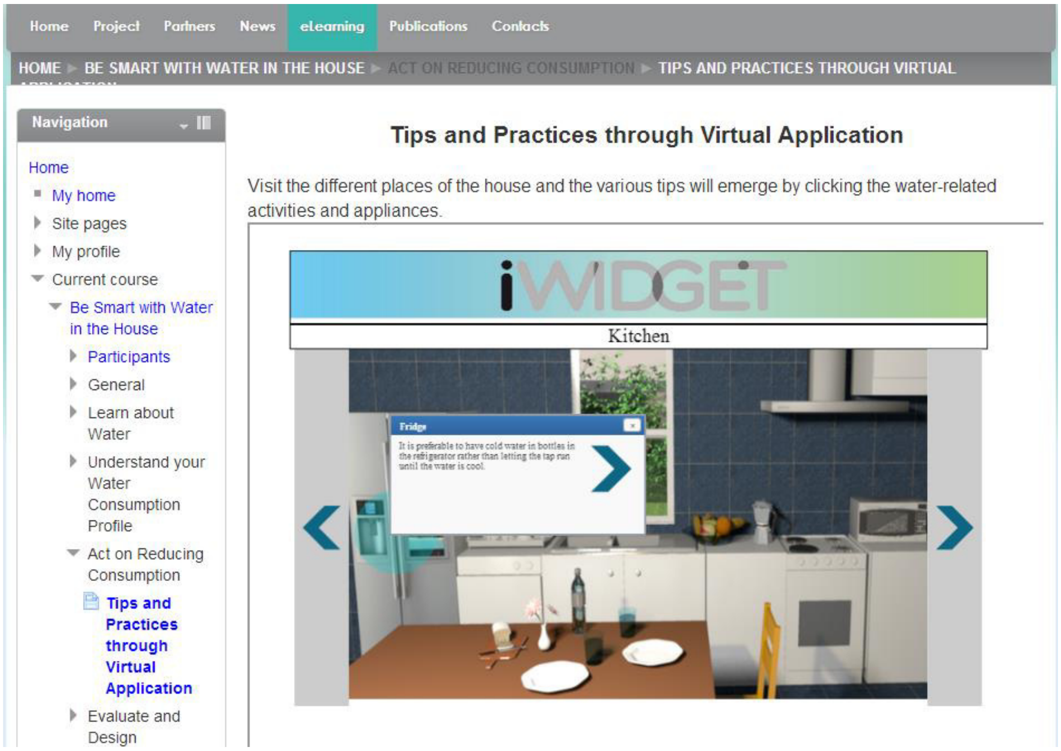

Fig. 5. Example webpage of the e-learning platform facility, showing the drop down navigation list on the left and water efficiency suggestions for the kitchen .

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.

3. Conclusions and next steps

This paper presented a series of on-line tools and applications integrated in a web-based platform that targets primarily householders. The system aims to support customers to monitor, control and improve their domestic water and energy consumption exploiting the great opportunities derived from the advent of new metering and communication technologies, such as smart metering. Initially, the different possible uses and facilities of the platform were identified while an early prototype of the developed tools was presented.

The household analytics platform is an innovative and integrated on-line service that enables end-users to monitor, on real-time basis, the progress of their water and energy consumption profile through different visualization forms (dynamic bar charts and pie charts, comparative tables and statistics, overview tables, reports etc.). Additionally, the platform provides a variety of options that controls the level of detail of presented information (units, time-resolution, time-framework etc.). At the same time, the e-Learning platform supports further end-users to better understand and modify their possible wasteful through a multistage educational process that comprises various tools and applications.

This paper sets the groundwork for the further design and development of integrated solutions and services that exploit the potentialities of smart metering and ICT technologies and target mainly customer side. It is expected that such initiatives will bring end-user closer to the center of discussion for sustainable urban water management, providing support towards the wiser use of natural resources in daily life.

Acknowledgements

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References

[1] R.A. Stewart, R. Willis, D. Giurco, K. Panuwatwanich, G. Capati, Web-based knowledge management system: linking smart metering to the future of urban water planning, Aust. Plan., 47 (2010) 66-74.
[2] B. Neenan, R.C. Hemphill, Societal Benefits of Smart Metering Investments, Electricity J. 21 (2008) 32-45.
[3] R.M. Willis, R.A. Stewart, K. Panuwatwanich, P.R. Williams, A.L. Hollingsworth, Quantifying the influence of environmental and water conservation attitudes on household end use water consumption, Journal of Environmental Management, 92 (2011) 1996-2009.
[4] R. Willis, R. Stewart, K. Panuwatwanich, Jones, S. Kyriakides, Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households, Resources, Conservation and Recycling, 54 (2010) 1117-1127.
[5] OMG Object Management Group, Unified Modelling Language, Superstructure – Version 2.4.1, August, 2011.
[6] D. Loureiro, P. Vieira, R. Ribeiro, C. Makropoulos, P. Kossieris, E. Katsiri, J. Barateiro, O. Goerkem, C. Grimm, L.S. Vamvakeridou-Lyroudia, J. Smith, C. Hutton, Use Case Description, Internal report – MS12, Project iWIDGET, April 2013.
[7] A. Christofides, S. Kozanis, G. Karavokiros, Y. Markonis, A. Efstratiadis, Enhydris: A free database system for the storage and management of hydrological and meteorological data, European Geosciences Union General Assembly 2011, Geophysical Research Abstracts, 13, Vienna, 8760, European Geosciences Union, 2011.
[8] J. Smith, L.S. Vamvakeridou-Lyroudia, L. Dant, Z. Kapelan, How to use the iWIDGET system and how to interpret the data: A training manual for consumer users, Internal report – MS32, March 2014.
[9] C. Makropoulos, A. Katsiri, D. Assimacopoulos, M. Mimikou, E-learning: roles in distance and traditional postgraduate engineering courses, Journal on Education, Informatics, and Cybernetics (JEIC), 1 (2009) 45-50
[10] P. Kossieris, A. Panayiotakis, K. Tzouka, P. Gerakopoulou, E. Rozos, C. Makropoulos, An eLearning approach for improving household water efficiency, Proceedings WDSA2014, 14-18 July 2014, Bari, Italy, 2014.