Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 153 (2018) 408–413

Energy Procedia

www.elsevier.com/locate/procedia

5th International Conference on Energy and Environment Research, ICEER 2018

Water consumption monitoring system for public bathing facilities

Carlos Felgueiras[a,*], Luís Kuski[a], Pedro Moura[a], Nídia Caetano[a,b]

[a]CIETI/ISEP R. Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[b]LEPABE/FEUP, R. Dr. Roberto Frias S/N, 4200-465 Porto, Portugal

Abstract

The European Commission has been developing efforts resulting in directives and programs to stimulate water saving. The lack of information about water usage in public bathing facilities is an obstacle to achieve an adequate management. This work proposes a monitoring system able to observe individual water consumption in public bathing facilities. Gathered information will be used to characterize user behaviour, or even to drive changes in their attitudes.

Keywords: Bathing facilities; resources management; sustainability; water consumption; water consumption monitoring

1. Introduction

Sustainability has been one of the main challenges of the scientific and industrial community in the last decades. Our Common Future, also known as Brundtland Report [1], defined sustainable development as the development that meet the need of the present without compromising the ability of the future generations of meeting their own needs and demonstrate the need to improve the management of resources: "So-called free goods like air and water are also resources (…) Sustainable development requires that the adverse impacts of air, water and other natural elements are minimized so as to sustain the ecosystem's overall integrity". To prevent the lack of any resource there's a need to manage carefully the inputs and outputs in the ecosystem. A technological point of view goes further as "the basis of

* Corresponding author. Tel.: +351 228340500; fax: +351 228321159.
E-mail address: mcf@isep.ipp.pt

10.1016/j.egypro.2018.10.016

development and application in systems which are intended to be increasingly sustainable, i.e., having such resource-consuming functionality as is precisely necessary to achieve a given effect" [2]. One of the most important resources is precisely water but many nations worldwide as experienced the problematic lack of this resource specially in latest decades. This resource has been a focus in sustainability on the way to assure its quality and availability for all world population. This subject has become so important that the United Nations declared water as a human right in 2010 [3]. In Europe, this issue started to focus in 1980 with the publication of the first legal proposals to assure quality of water on all members' states, being this the starting point of incoming years of a demand for quality and better managing of this resource. In 2000, the European Commission introduced the Water Framework Directive (WFD), amended later in 2008. In this directive the European Commission established some resolutions, strategies and goals relative to water conservation [4]. More recently, in 2012, the European Commission present the Blueprint of Safeguard Europe's Water Resource. This program objective is to assure the implementation of the Water Framework Directive and improve the previous directives with a more recent framework and suggest some ways to address domestic water consumptions. With these directives, each member must address attending their own framework [5].

In Portugal, the Portuguese Environment Agency (*Agência Portuguesa do Ambiente, APAMBIENTE*), is the responsible entity to assure the implementation of the European directives regarding the environment. In 2000 was created the National Program to Efficient Water Use (*Plano National para o Uso Eficiente de Água – PNUEA*). Based on studies conducted until 2005, this program launched a report with strategies and goals to be implemented in 10 years. Amended later in 2012 with new developments and the objective to accomplish until 2020. These new goals intent to reduce the inefficiency in the main areas of water consumptions, as presented in Fig. 1 [6].

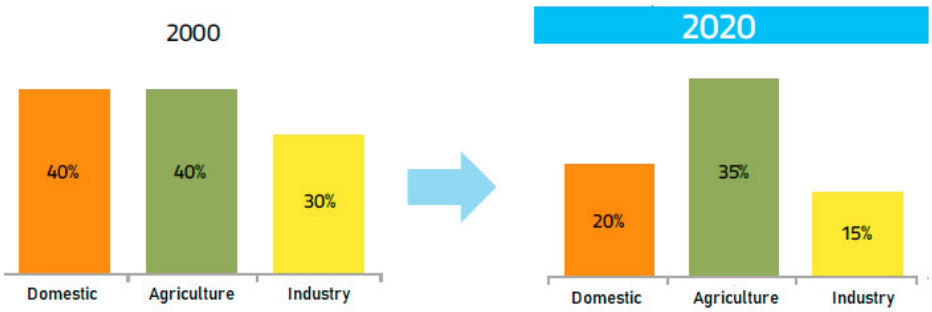

Fig. 1 - Water wasted in 2000 and the goal for 2020 [6].

As we can see in Fig. 1, this response intents to reduce 20% on domestic water waste, 5% on agriculture water waste and 15% on industry water waste. PNUEA also considers some strategies to reduce water consumptions in public non-domestic systems like gymnasiums, pool and hotels. Some of these objectives includes the application of the water real cost (this situation brings both advantages and disadvantages. By one hand water with a low price is good because people with less income can affordable easier, in another hand with water at low price people does not see the need to save water) and a change of behaviour in bathing time [5]. According a Tulsa University study, hotels buildings significantly contribute to the increase water consumption in the world. The same study also refers that most hotels does not monitor individual guest water usage. The scenario is essentially the same in gyms and pools. As result, users often use large quantities of water that are not charged individually by use [7].

There other projects that try to address the behaviours in water consumptions such as the European FP7 project DAIAD, which is a group project that are developing a real time water consumption monitor system [8]. There exist companies as well that focus in this issue such Flo Technologies [9] and also FLUID Labs [10]. Both companies developed systems able to monitor water consumptions. The disadvantages of these systems are that they are design to household consumptions, so they can't identify individual consumptions, which is needed in public bathing facilities.

Note that usually resource infrastructures for water or energy are typically designed just to supply a service, and not to quantify it. Consequently, the consumers don't have the information needed to be able to optimize their establishments and so it's difficult to address the strategies proposed by APA and EU.

2. Materials and methodology

The water consumptions monitoring system was developed to address the lack of information in public bathing facilities such as gymnasiums, pools, hotels, etc. The system described is a low cost, small size and accurate device designed to monitor for a limited time, sufficient to monitor bathing behaviours of the customers of the services. The information collected needs to be analysed later and will offer to the manager of the service the number of baths in his establishment as well as the time, water and energy spend in every bath.

The objective is to offer the manager the information he needs to be able to optimize his establishment in the way he sees fit, in order, to secure a more sustainable facility as well as reducing water and heating water energy related bills. The system is design to be a discreet solution that monitor water consumptions of the users without them changing behaviours during the monitoring time.

3. Development

The system can be divided in hardware which are the boxes, and the software which is installed in the microcontroller. The hardware is composed by several parts:

- Box A – Sensors box: contains the sensors which are responsible for measure water and temperature as well as knowing how much clients used the showers;
- Box B – Controllers box: contains the microcontroller which is responsible to control all the sensors and the datashield which save the information safely;
- Box C – Power box – contains the power regulation circuit.

As can been seen in Fig. 2-A only the Box A interacts with the user. It is positioned directly in the pipping system just before the head shower. The installation can be fast and easy because of the connections in both sides of Box A that attach directly to the pipes and shower.

In Fig. 2-B it is represented the connections between all the Boxes. Every block can control up to six Boxes A, due to restrictions of the microcontroller utilized.

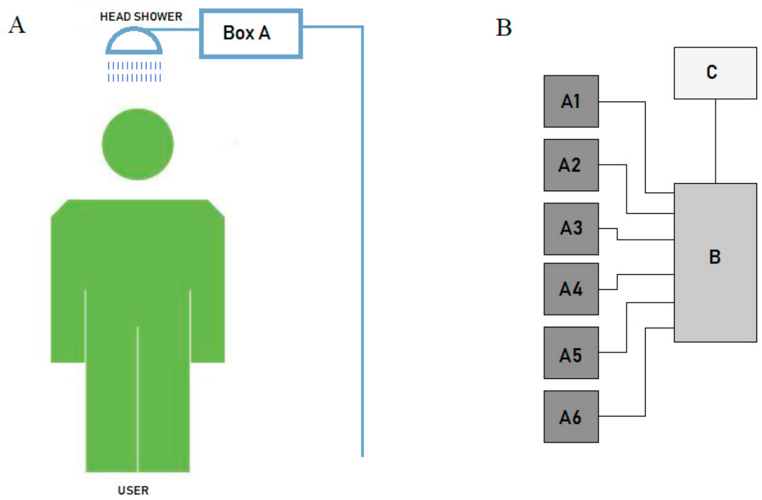

Fig. 2 – Interaction between the user and the system (A) and a representation of the connection between the boxes of the system (B).

Fig. 3 represents the block diagram with the contents of all block types (A, B and C).

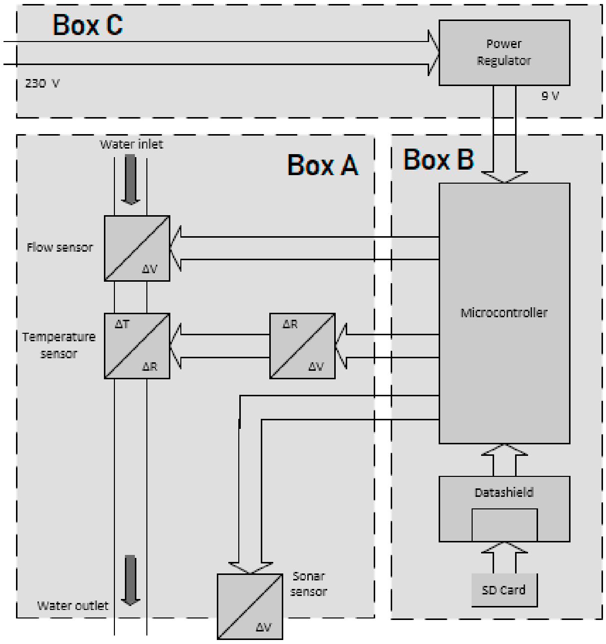

Fig. 3 - Block diagram of the global system.

Box A description

Box A is a small rectangular box which contains all the sensors responsible for obtaining the information need, namely: a flow sensor, a temperature sensor and a sonar. In Fig. 4 it is shown the system installed in pipes in laboratory.

- **Flow sensor** – responsible for measuring the amount of water that flows through the piping. This information allows knowing exactly how much water is consumed.
- **Temperature sensor** – responsible for measuring the temperature of the water in the interior of the pipes allowing to know the temperature of water used by the consumers to be possible to calculate the amount of energy spent.
- **Sonar sensor** – used to check when a person stands in the shower zone. In order to be able to distinguish utilizations by different user it was need a sensor that detects the presence of a user. The sensor is set to have a maximum range of 1 meter, so if the ultrasound wave does not reach an obstacle in that range it means that the shower is not being used.

Fig. 4 - Representation of Box A installed.

Box B description

Box B is located in the closest position to the shower as possible, in order to reduce the length of cables in the bathing room. This box contains: a microcontroller (iv) and a datashield (v).

The system is controlled by the microcontroller Arduino MEGA 2560 (iv). This component can control up to six Boxes A due to the restrictions of interruption ports of the water flow sensor. These ports emit an electric signal that interrupts an action of the controller to execute another action. It is an essential function to read the pulses generated by the flow sensor.

A Datalogger Shield (v) is connected to the controller. This component is necessary because it gives the microcontroller the capability of storing the information obtained in a SD card and registers the exact time of each data entry.

Box C description

The voltage need to supply the microcontroller is low, 9 V, and the microcontroller supplies energy for all the sensors and the datashield board. The power supply is obtained outside the bathing room directly from the grid in the electric general panel, with a power regulator circuit that converts 230 Vac to 9 Vdc. This means that all voltages involved in the control and monitoring system of the bathing room are completely harmless to users.

4. Validation

The developed program will print in a text file (.txt) the information system every second. After ending the time of the study, all the material is uninstalled and the SD Card, where the information is stored, is retracted of the Box B to be possible to have access to the data. To organize the information measured, the text file need to be exported to an excel file. The information displayed is represented in Table 1.

Table 1 - Information of one Box A between 10 seconds.

Date	Hour	Flow 1	Temp 1	Sonar 1
08/03/2018	13:26:11	0	19.54	-1
08/03/2018	13:26:12	236	27.51	20
08/03/2018	13:26:13	469	36.65	21
08/03/2018	13:26:14	720	37.22	20
08/03/2018	13:26:15	719	37.96	18
08/03/2018	13:26:16	721	38.02	30
08/03/2018	13:26:17	720	38.05	20
08/03/2018	13:26:18	722	38.10	23
08/03/2018	13:26:19	157	24.19	-1
08/03/2018	13:26:20	0	20.62	-1

The first two rows are common to all sensors' box and present the exact time and data of the measured information. The column three represents the flow (litres per hour) of the water being consumed. Column four presents the temperature of the water inside the pipping. Finally, column five represents the distance between the sonar installed in the sensor's box and the user. In Table 1, it is presented one example of 10 seconds of use of the bathing zone, with entrance at 13:26:11, and exit at 13:26:19. Change of values in column "Sonar 1" from a certain distance to the value -1 and again to a distance signifies a change of the shower user.

Note that the system is only a data acquisition solution, after having the information in a spreadsheet, it is possible to identify manually, how many users utilized the shower, the individual water and energy related consumptions, and an average water and energy related consumptions of the facility.

One future improvement could be the development of a program that treats the information automatically, as well as an interface mechanism to interact with the customers. Treating this information, real detailed data can be compared with the European and National standards and directives. So, the owners of bathing facilities can analyse and study their own facilities and search for solution to become more sustainable.

5. Conclusion

After numerous studies and discussions, the European Commission proposed directives with strategies and goals to accomplish on resources management, including water. The inexistence of information represents a real problem in order to water managing to be possible.

The present work offers a solution capable of monitoring public non-domestic bathing facilities. This solution can improve the information available of water and energy related consumptions in this sector as well as help make people aware to better manage this resource.

A disadvantage of this system is that it does not offer a real time solution, as it is designed to monitor a limited period of time. A system able to do real time continuous monitoring of water consumptions with interaction with the customers is currently under development. Information like average, maximum and minimum time of bathing could help make customers aware to change their own behavior towards water and energy consumption.

Acknowledgements

Authors thank Research Project UID/EQU/00305/2013 and Project POCI-01-0145-FEDER-006939 (Laboratory for Process Engineering, Environment, Biotechnology and Energy – LEPABE) funded by FEDER through COMPETE2020 - Programa Operacional Competitividade e Internacionalização (POCI) and by national funds through FCT.

References

[1] World Commission on Environment and Development. "Our Common Future". 1987.
[2] Felgueiras, Carlos, André Fidalgo, Ricardo Costa, Gustavo Alves, Clovis Pertry, Luís Schlichting. "A demonstration circuit to support (e-) learning on control systems engineering" 4th Experiment@ International Conference 2017.
[3] United Nations. The human right to water and sanitation, resolution A/RES/64/292. 28 July 2010.
[4] European Commission. Water Directive Framework. November 2010.
[5] European Commission. A water blueprint for Europe. ISBN 978-92-79-30543-6. 2013.
[6] PNEUA. Programa Nacional para o Uso Eficiente de Água. June 2012. (in Portuguese)
[7] Hawrylak, Peter J., Will Nichols, Xiang Li, Ty Johannes, Ryan DeCook, Kameron Mongold, Clarie Cornell, LeRoy Albert Flint, Anshuman Singh. "HydroSense: A Self-Powered Wireless Device for Monitoring Water Usage in Hotel Showers." *2015 IEEE Global Humanitarian Technology Conference (GHTC),* Seattle, WA, 2015, pp. 314-320. doi: 10.1109/GHTC.2015.7343990.
[8] Athanasiou, S., T. Staake, T. Stiefmeier, C. Sartorius, J. Tompkins, E. Lytras "DAIAD: Open Water Monitoring" 16th Conference on Water Distribution System Analysis 2014.
[9] Flo technologies Inc. "Meetflo" 2018. [Online]. Available: https://meetflo.com/how-it-works/. [Accessed at 12 01 2018].
[10] FLUID LABS Inc. "Fluidmeter". 2017. [Online]. Available: http://www.fluidwatermeter.com/. [Accessed at 12 01 2018].