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## Article

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Energy Reports

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Elsevier

*Suggested Citation:* Kuski, L.; Maia, E.; Moura, P.; Caetano, N.; Felgueiras, C. (2020) : Development of a decentralized monitoring system of domestic water consumption, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 1, pp. 856-861, <https://doi.org/10.1016/j.egyr.2019.11.019>

This Version is available at:

<https://hdl.handle.net/10419/243833>

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6th International Conference on Energy and Environment Research, ICEER 2019, 22–25 July,  
University of Aveiro, Portugal

# Development of a decentralized monitoring system of domestic water consumption

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Received 4 November 2019; accepted 9 November 2019

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## Abstract

Inefficient use of water represents a major source of direct cost of water production, but especially of excessive energy use to purify it. Greater efficiency could be achieved if management were supported by objective data in addition to the rules of good practice that have been disseminated. This work aims to contribute directly to the reduction of water consumption and indirectly to the huge amount of energy used to pump water from its reserves and then to treat and make it drinkable through the use of a decentralized consumption monitoring system.

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Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

*Keywords:* Buildings; Monitoring of water consumption; Resources management; Sustainability; Water management

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## 1. Introduction

Water, as a fundamental resource, is one of sustainability main focuses. This resource is vital to life on the planet. However, this resource has been poorly managed, especially in the last century. The poor management of water, allied to the climate changes and the exponential population growth is threatening the availability of potable water, not only for future generations, but also today, as more and more regions of our planet suffer from water scarcity. An analysis in the 2016 World Energy Outlook [1] shows that, in 2014, the water sector, which includes wastewater collection and treatment, accounted for 4% of total global electricity consumption. Considering only the wastewater treatment, it represents approximately one quarter of the electricity consumption of the water sector. In addition, some estimates put the water sector's share of total greenhouse gas emissions at 3% [2]. Therefore, saving water not only contributes to less stress on water reserves, but also contributes to lowering the electric energy consumption

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associated to its production, wastewater treatment, as well as through reduction of energy consumption associated to water heating.

As can be seen in Fig. 1, the amount of wastewater is higher than the water consumption in each of the three basic areas of water usage, which means that the withdrawals are very high comparing to the real needs [3].

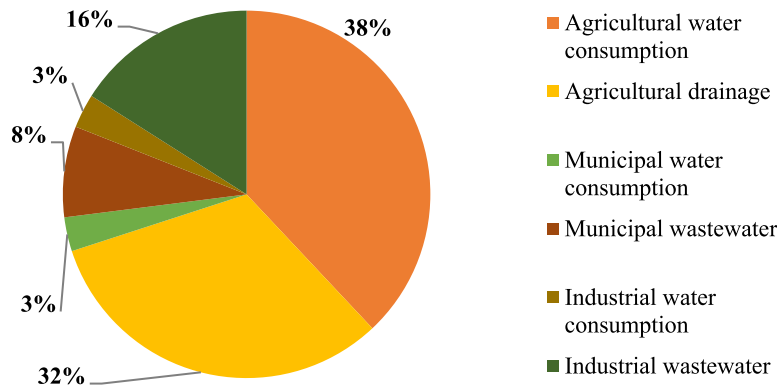


Fig. 1. World's water consumption and wastewater by sector [3].

Huge investment has been made to improve water consumption, especially in the agriculture and industrial areas, which are the sectors where more wastewater is produced. In the last decades, the European Union has been working hard on this problem, and this work resulted in various directives such as the Water Framework Directive (WFD) introduced in 2000, and later reformed in 2008, and the Blueprint of Safeguard Europe's Water Resources. This directive includes strategies especially for municipal water usage [4].

Through the European Directives, the Portuguese Environmental Agency (*Agência Portuguesa do Ambiente - APA*) carried out several studies on water consumption. These studies resulted on the creation of the National Program to Efficient Water Usage (*Plano Nacional para o Uso Eficiente de Água - PNEUA*). The plan for the period 2012–2020 seeks to reduce the lack of efficiency in water consumption, by proposing targets for water wasted in the several sectors, namely 20% for urban usage, 35% in agriculture and 15% in industry, by 2020 [5]. All these measures have been contributing to decrease water wasting. However, it is difficult to save water efficiently without knowing our detailed consumption. Nowadays, the information about water consumption, only represents the water really consumed and is only used for billing purposes. To save water efficiently it is necessary to know the amount of water that we consume in the various activities of the daily life [6].

These efforts are being carried out not only in Europe but also in Asia, namely in China, gathering information and implementing measures to tackle the challenge of water efficiency usage in the several sectors [7–9]. Many methods are being used such as applying geographical information system (GIS) to map water resources for agricultural use [10]. At the industrial level, efficiency in water usage is also being addressed, as shown in some studies to improve the performance for example of some traditional industries such as textile and steel and iron industry [11,12]. There are other projects that are also trying to address the lack of information in Municipal water usage such as the DAIAD (a European FP7 project) [13].

There are companies that developed water monitoring systems for household application. The biggest disadvantage of such solutions is that they are centralized, that is, they have a centralized water measurement system and forecasting technologies. Although they are a cheaper solution relative to a decentralized system, the information is much less accurate.

Based on the need of information regarding water consumption of municipal usage, this work proposes a decentralized water consumption monitoring system that allows the measurement of the quantity of water used for each application in a building, enables to cut off the water supply through a solenoid valve, in case of a leak, and allows the access to all of these information through a graphical user interface.

This is a multidisciplinary work engaging different areas such as Electronics Engineering, Mechanical Engineering, Software Engineering, Product Design allied with project management, and financial management.

## 2. Requirements of the system

Hardware requirements: *The present solution must be a small size accurate device that allows the measurement of water consumption in each water application in a building.*

Software requirements: *The user must be able to interact with the system through an user graphical interface where he can see detailed water consumptions by date, by house division and by application and also cut off the water flow with just a click on a button.*

System goal: *The goal of the system is to inform the consumers of their detailed consumptions. Accurate information about water consumptions will allow to save water more efficiently.*

## 3. Development

The solution is divided in hardware, which comprises the system boxes with components, and software which comprises the programming and graphical user interface. The hardware contains the following parts:

- Box A – Power Supply Box – contains the power circuit responsible to supply the Box B.
- Box B – Monitoring Box – contains a water flow sensor, a solenoid valve, and a microcontroller equipped with Wi-Fi.

Fig. 2 represents the installation of the proposed solution for a house with six water exits, three in the bathroom, two in the kitchen and one in the exterior.

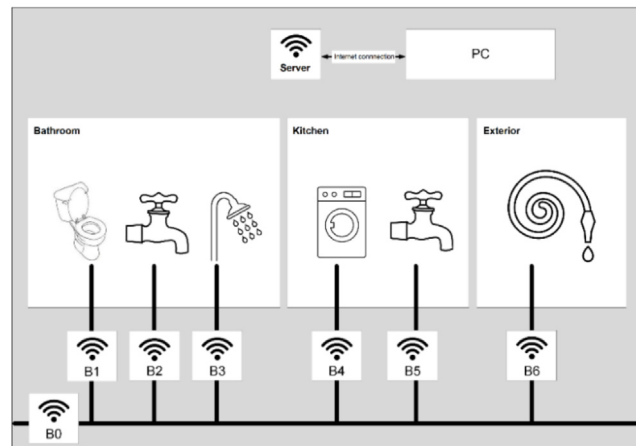


Fig. 2. Schematics of the installation of the decentralized water monitoring system in a house.

The monitoring system is installed in all the water exits, and also at the entrance of water pipes of the house, Box B. The Boxes B, installed in the water exits, are labeled from B1 to B6 as shown in Fig. 2. With such configuration the system can identify potential water leakages.

The blocks diagram of the solution is shown in Fig. 3.

### 3.1. Description of Box A

Box A is a small box containing the power supply for Box B. Box B requires voltages of 9 VDC for supplying the microcontroller and 12 VDC for supplying the solenoid valve. Box A is installed inside the wall for security reasons.

### 3.2. Description of Box B

Box B is directly connected to the water piping system. It contains a flow sensor, responsible for measuring the quantity of water flowing through the pipes, a solenoid valve, responsible for cutting off or allowing the water flow through the pipes, a Wi-Fi Module that communicates with a server and a microcontroller, responsible for controlling all of the components.

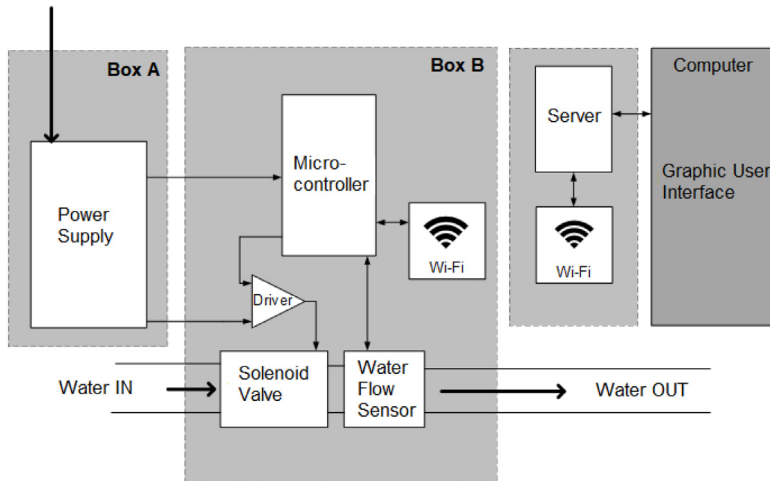


Fig. 3. Block diagram of the system.

### 3.3. Server

The server receives and saves the data collected from Box B, as shown in Fig. 4. Each line contains the information relative to one use of water. Each use has an identification number (ID) in the box, the quantity of water consumed in liters and the duration of the consumption in seconds.

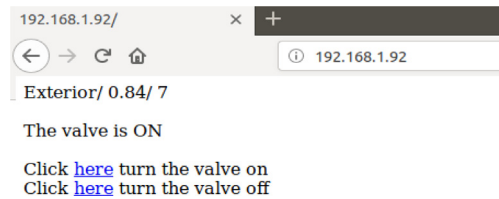


Fig. 4. Position of the data collected in the server.

### 3.4. Graphical user interface

The graphical user interface collects the information from the server through an url link. In addition, through the graphical user interface it is possible to cut off and open the valve with an url link for each action. In Fig. 5 is shown the base page of the graphical user interface.

## 4. Results and discussion

Box B communicates constantly with the server and the graphical user interface, so all information is frequently updated. The graphical user interface collects the data, saves it in a general consumption table, as shown in Fig. 6.

With the information displayed in this table it is possible to identify water consumptions, date and duration of the utilization. In addition, the software can organize the consumptions by their ID, that is, the water exits of the house, such as bathroom shower or faucet, as shown in Fig. 7.

The information displayed in this table allows one to compare the consumptions for each water exit daily, weekly or monthly.

The data collected and stored can be downloaded in excel format for further processing, making it a user friendly tool for water monitoring in domestic application.

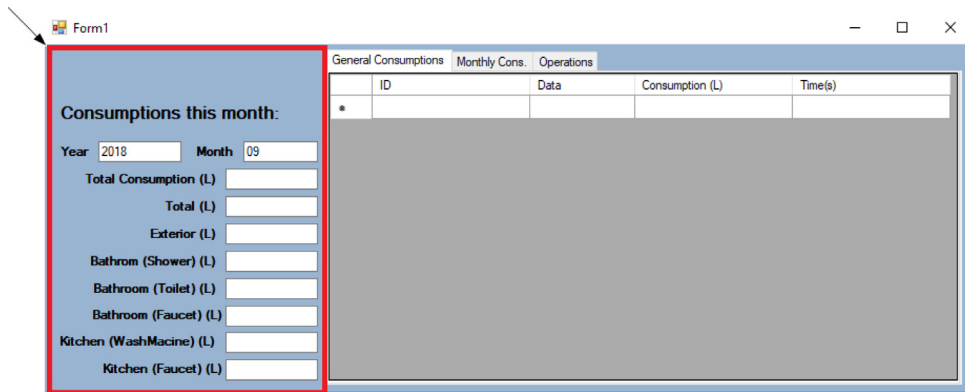


Fig. 5. Main area of the graphical user interface.

General Consumptions		Monthly Cons.	Operations		
ID	Data	Consumption (L)	Time(s)		
Exterior	2018-09-20	1.90	2		
Exterior	2018-09-20	0.95	2		
Exterior	2018-09-20	16.83	24		
BathroomShower	2018-09-20	1.62	2		
BathroomShower	2018-09-20	26.54	34		
*					

Fig. 6. Screen showing the general consumptions area of the graphical user interface.

General Consumptions		Monthly Cons.	Operations			
Year	Month	Total (L)	Exterior (L)	Bathroom (Shower) (L)	Bathroom (Toilet) (L)	
2018	9	47,84	19,68	28,16	0	
*						

Fig. 7. Screen shot of the monthly consumptions area of the graphical user interface.

Furthermore, in future developments of this tool, it will be possible that the user receives alerts in case of detection of a water leak, or in case the water consumption profile of a certain house division changes, or even if it is reached a percentage of the set water consumption (as with internet communications in a mobile phone).

Another interesting development would be to apply such tool to a block of flats, allowing to perform benchmarking of water consumption profiles of different families.

### 5. Conclusion

Water use has had a very significant impact on energy consumption. Reduction of water consumption contributes to the reduction of energy consumption. The lack of information about the consumption represents one of the biggest challenges that prevents efficient water saving, especially in what concerns municipal usage. The solution developed in this work offers a system capable of monitoring, collecting and saving, in a simple application program, detailed information relative to water consumptions of the users. Using this system will allow consumers to better understand their water consumption behavior, what will make them able to find and implement actions to effectively reduce water consumption, contributing to water savings, and indirectly, to energy savings. Other advantage of the system is to detect a water leak faster, since it allows the comparison of water measurements in several points of a building and over time.

A disadvantage of the present solution is the price of the hardware (that for now has not been optimized) and labor needed for installation, because to implement this solution it is necessary to install a Box B at every water exit in a building. A potential disadvantage is the inability of precisely locating a leakage in a particular division, something that can be solved, adding more Boxes B in every division. In the near future other capabilities can be added, such as sending an autonomous alarm by e-mail or text message (SMS), warnings about leakage or an open faucet detection, among others.

## Acknowledgments

Authors thank the financial support of the project UID/EQU/00305/2013 – Center for Innovation in Engineering and Industrial Technology (CIETI), Portugal. This work was financially supported by project UID/EQU/00511/2019 – Laboratory for Process Engineering, Environment, Biotechnology and Energy (LEPABE), Portugal funded by national funds through FCT/MCTES (PIDDAC) and Project LEPABE-2-ECO-INNOVATION” — NORTE-01-0145-FEDER-000005, funded by Norte Portugal Regional Operational Programme (NORTE 2020), under PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

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