LIFE SWSS

"Smart Water Supply System"

LIFE14 ENV/PT/000508

Document Title:	Guidelines to Implement the SWSS Platform on Water Supply Systems
Deliverable no:	DC4
Issue Date:	31st December 2018
Level of Dissemination (PU/CO):	PU
Author(s):	IST
Contributor(s)	AdTA, Hidromod, ISQ

Table of Contents

Executive Summary

This report describes the assessment of the replication potential of the SWSS platform to other national and international water utilities. The report presents an overview of the water services sector, the description of the proposed replication methodology and the identification of the main barriers to its implementation in other water systems.

1 – Introduction

This report describes the procedure to the replication of the developed SWSS platform to other water utilities. This procedure reflects the lessons learnt from the application to the three case studies belonging to water utilities from the AdP group but with different realities and data management systems.

The main expected difficulties of application at the different stages of implementation are discussed and explained the potential means to overcome them.

The report is organized in five main parts. After this introductory section, an overview of the sector is presented focusing on the characterization of the water services in Europe in general terms and in relation to water losses levels and electric energy consumption. The third part presents details of the methodology proposed for the replication of the platform addressing the main requirements as well as details concerning the five modules to be implemented, namely the modelling module, the predictive module, the optimization model, the leak location module and the assessment module. The expected main difficulties and barriers are described. Finally, the final conclusions and recommendations are presented.

2 – Sector Analysis / Potential improvement

An analysis of the drinking water sector has been carried out in order to identify the main characteristics of the water supply systems in Europe. This analysis is mostly focused on the water losses and electric energy consumption, in order to identify the potential for water-use and the energy efficiency improvement in these services and, hence, the potential benefits expected from the SWSS platform implementation in Europe.

Public water supply, urban wastewater management and municipal waste management are public services essential to the well-being, public health and collective security of the populations and economic activities, as well as to environment protection. In some countries, like Portugal, these are regulated activities. The regulator is the Portuguese Water and Waste Services Regulation Authority (ERSAR) whose aims are (i) to ensure the protection of the water and waste sector users, always trying to avoid abuses resultant from the exclusive rights, focusing on the control of the quality of the services provided and supervising the tariffs charged to the end-users; and (ii) to ensure equal and clear conditions in the access to the water and waste services and the operation of these services; and (iii) to reinforce the right to general information about the sector and about each operator.

Following the later objective, many data regarding the water and wastewater services are made publicly available by the regulator through the web-platform or through official publications. In the case of Portugal, these information is available in http://www.ersar.pt. This is carried out in a standardized way, using a benchmark system composed of selected key performance indicators (KPI), allowing for a general overview of the water sector in the country and the comparison with other countries. However, this is not the case for most European countries. Water data, in many countries, are not accessible to the general public or simply not existent, which hampers a detailed sector analysis.

In this context, the water and wastewater sector analysis is mostly based on data provided by the European federation of national water services (EurEau) who represents national drinking and wastewater service providers from 29 countries, from both the private and the public sectors. Energy data were obtained from the European

Benchmarking Co-operation, a not-for-profit benchmarking initiative that facilitates water and wastewater utilities in improving their services through benchmarking.

2.1. The water services in Europe

2.1.1 Overall characterization

On the 1st January 2018, the European Union population was of 512 647 966 inhabitants (Eurostat), most of which supplied with safe drinking water on a 24h/day basis. However, not all countries present the same level of development and the percentage of population connected to public water supply networks varies from 64% in Romania (in 2015, Eurostat) to nearly 100% in Belgium, The Netherlands, Luxembourg and Spain. The average percentage of population connected to public water supply systems is 92%, although such numbers are not available for five out of 28 countries.

Water services in Europe are managed and organised in very different ways, according to their history, cultural heritage and national or local traditions (EurEau, 2018). While some services are managed by local government departments, others are managed by publicly owned companies, by private operators or by public-private joint ventures. Diversity is also found in size and in complexity of the infrastructures, as the supply of safe drinking water must be adapted to specific local circumstances, such as population density, local topography, the type and amount of available water, required treatment levels, among others.

2.1.2 Water losses

The estimated length of the drinking water network in Europe is of 4 225 527 km, which is about eleven times the distance from the Earth to the Moon (EurEau, 2017). This vital infrastructure for the social and economic prosperity of the European countries requires adequate maintenance and necessary investments to continue guaranteeing, or improving (in some cases), the required and the expected level of service, that is to keep supplying safe water in sufficient quantity and with the required pressure to all citizens all the time. If not well-maintained and wisely operated, water pipes tend to break and water losses in leaks and ruptures tend to become more frequent and to increase, and, consequently, the associated consumed electric energy used for treating and transporting the water increases as well. In systems where the assets are continuously renewed and the operations are closely monitored, it is possible to reduce leakage up to a certain level at which it is economically feasible. However, leakage is invariably present in pressurized pipe systems, thus, the longer the pipe systems, the higher are the chances of leakage.

In EurEau countries, composed of EU28 members except Latvia and Lithuania, plus Norway, Switzerland and Serbia, the average water losses levels, described in terms of water input volume, vary from values below 10% in Germany, Denmark and the Netherlands to over values higher than 40% in Ireland. The average percentage of water losses in these European countries is about 23% (EurEau, 2018) (Figure 1), although there are no available data for 7 out of 29 countries. Such losses include all non-revenue water that is the unbilled authorized consumption (e.g., for maintenance or firefighting), real and apparent losses. The apparent losses account for all types of inaccuracies associated with metering, plus unauthorised consumption (illegal use). Real losses are the physical water losses (leaks and bursts) from the pressurized system.

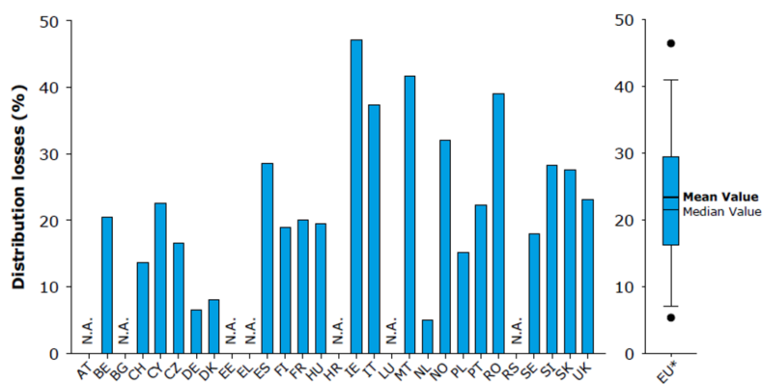

Figure 1. Water losses in European distribution systems as percentage of input water (EurEau, 2018)

The assessment of water losses by making use of the percentage of non-revenue water is very common and often helpful in a preliminary evaluation of the performance of water distribution systems. However, this key performance indicator should not be used for comparing different systems, but only for the performance assessment of a given system through time. Another commonly used indicator for assessing water losses, typically in pipes with very few service connections, is the volume of water lost per length of pipe and per time unit (Figure 2).

The results for this indicator are not known for eight out of the 29 EurEau countries. For the remaining 21 countries, it ranges from approximately 700 m^3/(km.year) (Denmark) to close to 6000 m^3/(km.year). The average value in Europe is 2171 m^3/(km.year) or 5.9 m^3/(km.day).

In Portugal, water losses over than 5.0 m^3/(km.day) represent an unsatisfactory performance level according to the regulator classification system (ERSAR, 2017). A good quality of service associated to losses lower than 3 m^3/(km.day) in water distribution systems.

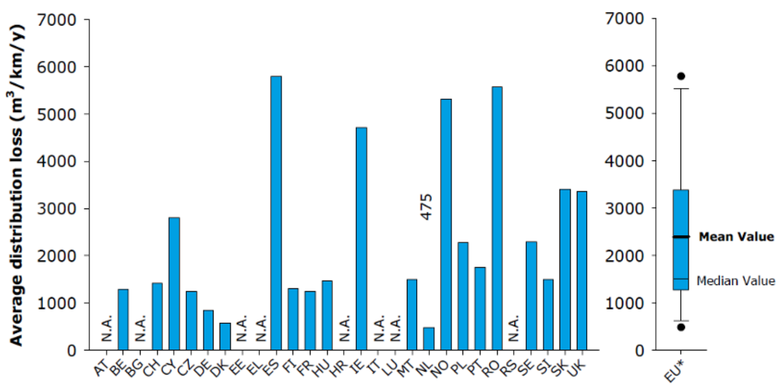

Figure 2. Water losses in European distribution systems in m^3/(km.year) (EurEau, 2018)

2.1.3 Electric energy consumption

Drinking water supply, from surface and groundwater sources, including water treatment, transport and distribution, requires significant amounts of energy (IEA, 2016). The total energy needs vary from system to system depending on the topography, the distance between the abstraction and the consumer tap, the water losses' levels, equipment inefficiencies and the necessary level of treatment. In the European Union, water supply and distribution systems account for c.a. 40% of the total electrical energy consumed in the water sector (Figure 3).

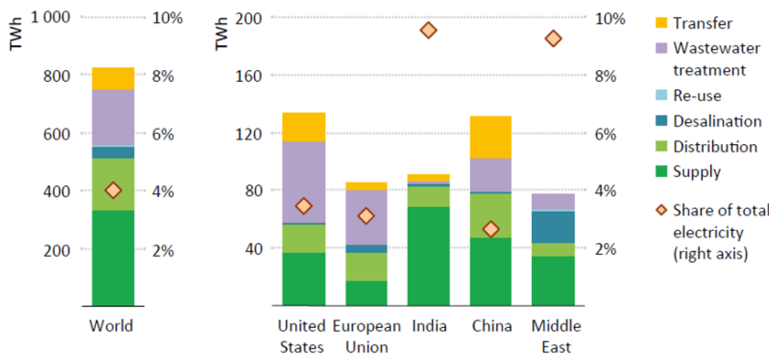

Figure 3. Electricity consumption in the water sector by process and region (IEA, 2016)

In water supply systems, pumps are the most relevant consumers of electricity, which makes their efficiency an important factor in the reduction of electricity use. Other causes for inefficient use of energy are the inadequate layout of the systems, the lack of recovery of the excess energy and, of course, real water losses.

A study carried out in 2017 with data from 47 water utilities from 20 countries (17 European countries and 3 countries from outside Europe, namely Oman, Singapore and the USA) showed that the energy use per cubic metre of water ranges from 0 to 1 kWh/m^3 (Figure 4). An abnormal value of 3.4 kWh/m^3 is associated to a utility that relies on desalination for drinking water production. The average electricity use for the treatment and distribution of water is of 0.49 kWh/m^3. These values are only associated to the electric component of energy consumed, though there is also another part that is obtained from gravity and that should also be considered in the assessment of water-use energy.

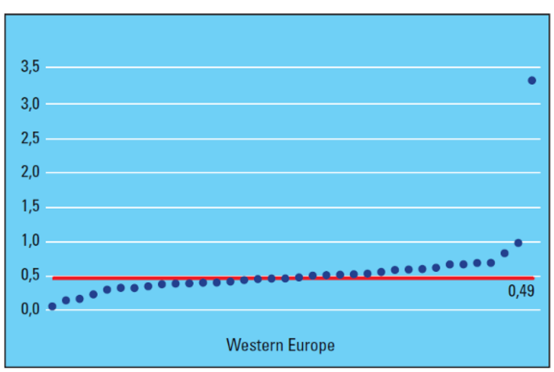

Figure 4. Electricity use for production and distribution per m^3 water produced (kWh/m^3) (EBC, 2017).

The purchased electricity by the utilities for pumping and transporting drinking water is produced from various sources and, thus, the associated CO_2 emissions, also, vary significantly (Figure 5). In EBC study, each cubic metre of water has associated –0.1 to 0.33 kg CO_2 eq. An average value of 0.1 kg CO_2 eq. was obtained.

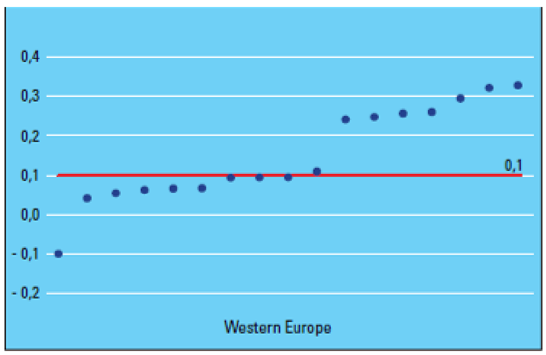

Figure 5. Emissions from the generation of purchased energy in kg CO_2 eq/m^3 (EBC, 2017).

2.2. Water and energy efficiency improvement potential

The results presented show that the water and energy efficiency of the European water utilities have a high potential of improvement and, thus, significant benefits can come from the implementation of the SWSS.

SWSS platform implementation can help utilities in improving their performance, although its impact will vary depending on:

- the utility present and future situation regarding water losses and energy efficiency;
- the utility ability to take advantage of the platforms' full potential and on local constraints (existing infrastructure size and complexity, population, water resources, etc.);
- the utility human resources and technological resources available.

The potential savings in water and energy by implementing SWSS platform is grounded on the assumption that the percentage of water losses in the country will decrease by 5%. Additionally, for countries for which the present water loss value is not available, an average value of 23% is considered as a reference for the calculation of the water losses in the current situation. For the countries in which water losses are already of 15% or less, no potential for water losses improvement is considered.

For energy consumption, the approach is based on electricity consumption per cubic metre of abstracted water. It is assumed that all countries currently consume 0.49 kWh/m^3 and that the implementation of the SWSS platform would decrease this mean value to 0.45 kWh/m^3. While the efficiency improvement can be much higher in some utilities, depending on the topography and the current status of the pumps, in other systems the local conditions might hamper the energy consumption decrease, for which a conservative value of 0.45 kWh/m^3 is considered in this analysis.

The results of this analysis, presented in Table 1, show that water losses can potentially decrease from 13 738 to 9 887 Mm^3 and, consequently, a potential saving of 3 851 Mm^3 per year can be achieved. Regarding electrical energy consumption, it can decrease from 25 983 to 23 862 GWh/year, if a relatively small improvement in the energy efficiency indicator is achieved.

Table 1. Estimated water losses and energy consumption in water utilities in Europe at the present and if platform SWSS is implemented

	Water abstraction for public water supply (Mm^3) (Eurostat)	year	Annual Water Losses (Mm^3)		Annual Electricity Consumption (GWh)	
			Present (%)	If SWSS platform is implemented	Present	If SWSS platform is implemented
Belgium	721	2014	144 (20%)	108	353	324
Bulgaria	869	2015	200	156	426	391
Czechia	613	2015	98 (16%)	67	300	276
Denmark	360	2012	83 (<10%)		177	162
Germany	5 081	2010	1169 (<10%)		2490	2286
Estonia	61	2013	14	11	30	27
Ireland	627	2015	288 (46%)	257	307	282
Greece	1 418	2015	326	255	695	638
Spain	4 552	2014	1275 (28%)	1047	2230	2048
France	5 481	2012	1096 (20%)	822	2686	2466
Croatia	473	2015	109	85	232	213
Italy	9 451	2012	3686 (39%)	3213	4631	4253
Cyprus	61	2015	13 (22%)	10	30	28
Latvia	102	2013	23	18	50	46
Lithuania	130	2015	30	23	64	58
Luxembourg	42	2015	10	8	21	19
Hungary	605	2015	121 (20%)	91	296	272
Malta	13	2015	6 (42%)	5	7	6
Netherlands	1 224	2014	282 (<10%)		600	551
Austria	685	2010	158	123	336	308
Poland	2 047	2015	307 (15%)	205	1003	921
Portugal	883	2012	203 (23%)	159	433	397
Romania	1 019	2015	408 (40%)	357	499	459
Slovenia	164	2015	48 (29%)	39	81	74
Slovakia	289	2015	81 (28%)	66	141	130
Finland	415	2013	79 (19%)	58	203	187
Sweden	908	2010	163 (18%)	118	445	409
United Kingdom	5 222	2014	1149 (22%)	888	2559	2350
Iceland	739	2014	170	133	362	333
Norway	863	2014	285 (33%)	242	423	388
Switzerland	933	2015	112 (12%)	65	457	420
Macedonia	147	2013	34	27	72	66
Albania	437	2015	101	79	214	197
Serbia	645	2015	148	116	316	290
Turkey	5 424	2014	1248	976	2658	2441
Bosnia and Herzegovina	321	2015	74	58	157	144
Total			**13738**	**9887**	**25983**	**23862**

3 – Replication Methodology

3.1 Introduction

The replication of SWSS platform to other systems in Europe or abroad entails many technical requirements. In this chapter, a comprehensive description of the requirements for each module that comprises SWSS platform is provided namely the modelling module, the predictive module, the optimization model, the leak location module and the assessment module. For the successful replication of the platform, care must be taken in attending all the requirements.

3.2 Overall requirements for SWSS platform implementation

3.2.1 Technical requirements

Supervisory Control and Data Acquisition (SCADA) data needs to be available as a SQL or PostgreSQL database with full access in order to be integrated in SWSS platform. SWSS platform access to this database is carried out via SQL authentication. Alternatively, the import of SCADA data can be made via FTP service.

Each record in the database needs to include the date, the time, the local and the associated monitored parameter. Ideally, this should be carried out with a sampling frequency of 1 minute; in some cases, lower sampling rates may be acceptable, such as every 5 minutes. Additionally, it is necessary to provide the database structure, including the variables and their description.

The LIFE SWSS platform is available to all users through a desktop application. Therefore, the internal APN domain where the LIFE SWSS platform server will be installed must be connected to the APN of the operation, maintenance and engineering departments.

Requirements for the server are the following:

i. Processor: Intel Core i7-3930 or Intel Xeon E5-1650V2;
ii. Hard drive: 2x HDD 3,0 TB SATA;
iii. Memory: 4x RAM 8192 MB DDR3.

The server can be installed in an internal network or in the cloud. If installed in an internal network, it can communicate with SCADA via OPC or through an indirect connection via database or files. If installed in an external network, it is necessary to set a VPN or to export the data via FTP to the machine where the server is. All communications with the server are carried out via *Hyper Text Transfer Protocol Secure* – https.

3.2.2 Data requirements

All available data regarding operation of the supply system in which SWSS platform are to be implemented can and should be integrated in the database. The parameters than must be connected to SWSS platform are:

i. Water flow rates.
ii. Storage tank levels.
iii. Pressure head values
iv. Pumps in operation per pumping station.
v. Pumps operating frequency per pumping station.
vi. Pump operating times per pumping station.
vii. Active and reactive power and energy per pumping station.
viii. Control valve status (and respective setting)

Other parameters, such as those regarding water quality, like chlorine, pH, conductivity, turbidity and temperature, can also be incorporated in SWSS platform. In that case, the platform will only be used for real time visualization of results. Such data are not necessary for running the standard SWSS modules.

3.3 Modelling Module

The modelling module is the basis for the pump operation optimization, the leak location and the energy efficiency assessment modules. For that reason, this module must be developed before all the others. It includes the development and validation of the hydraulic model of the system. The model accuracy will condition the results of the other modules and, hence, the hydraulic model has to be carefully built and validated.

For the hydraulic model development, the water utility must have specially trained engineers. Alternatively, the utility can hire the hydraulic modelling services to a specialized consultancy or software company. Because nowadays the hydraulic models are a very powerful tool for the water utilities, with applications in many areas, it is highly recommended that the water utility aiming to implement SWSS platform has, at least, one person with the adequate training and experience in hydraulic modelling to use and to update it whenever necessary.

In LIFE SWSS, the models are built using a free software EPANET 2.0 (Rossman, 2000) developed by the United States Environmental Protection Agency (USEPA) and utilized all over the world for almost 20 years. The platform is prepared to accommodate models in EPANET native format (.inp).

For the hydraulic model assembly, it is firstly necessary to gather GIS and/or CAD information of the system, including characteristics of all its elements, such as pumps, pipes, tanks and valves. After import to EPANET, it is necessary to create demand patterns by making use of historical data of flow at the consumption nodes, as well as operational rules and pump curves. The time-frame of the data must be enough to include the variations of weekday, weekend, vacation, dry weather, wet weather. Additional measurements of some parameters might have to be performed to calibrate the model. The model such be calibrated validated with real data.

3.4 Predictive Module

The predictive model aims is to forecast water consumption at each delivery point, based on historical time records. This model allows to predict future water consumptions, that is, to develop the water consumption patterns for each tank in the following 24 h. It has been developed on the basis of optimal scheduling and, thus, it must be carried out before the optimization.

In order to run the predictive module, data must be pre-processed, that is the outliers must be identified and removed and missing data must be filled. Then, ARIMA predictive models are computed for each delivery point by running a software code in R. The platform is prepared to incorporate models built in R. It is recommended that offline tests with actual data of each delivery point are firstly carried out outside the platform, for the validation of results. The predictive models are then integrated into the platform and should be run on the platform for each delivery point.

The consumption prediction on the LIFE SWSS platform is calculated based on ARIMA models for each delivery point for the next 24 hours with values every 15 minutes. It is necessary to calculate the ARIMA models of each delivery point of system, in order to replicate this module for different systems. To compute the ARIMA models, it is ideally necessary to have one year of historical data of water consumption with time interval of 15 minutes or less. If there is no historical data of delivery point water consumption, but it is possible to calculate it indirectly through other records, consumption can be calculated for a period never less than one year. In the calculation of the ARIMA models the data cannot have missing values or outliers, so it is necessary to apply outlier detection and missing data filling methods.

3.5 Optimization Module

The optimization module requires that the hydraulic modelling of the system as well as the predictive modules have been previously developed. The model allows to evaluate scenarios and test the feasibility of different solutions. The model must contain accurate information on the physical characteristics and system components, embodied hydraulic constraints, and should be able to read the demands (e.g. water demands) in order to evaluate a specific operational scenario. Optimization is based on a water consumption prediction model developed in predictive module. The water demand prediction is based on historic data collected by the water company with the time step of 1h.

In addition to system physical characteristics, the module requires initial conditions such as tank levels, constraints, such as specific operation rules, and the electricity tariff, i.e., the electricity price per period (€/hour).

3.6 Leak location module

The leak location module goal is the real time detection and location of burst and leaks. Thus, for this module, it is necessary that the data acquisition and communication systems are working properly without data acquisition failures.

For the leak location, the hydraulic module is necessary. It is particularly important for this module that the pipes roughness are accurate in the hydraulic model, for a more precise leak location.

The module can only be implemented if water flow and pressure data are monitored in locations upstream and downstream of the leak. It can detect leak with flow rates higher than 5% of the total inlet flow rate.

3.7 Assessment module

The assessment module establishes the water and energy balance on a monthly basis. It requires accurate flow measurements at all points were water enters or leaves the system. It is preferable that the measurement uncertainties associated with the flowmeters are known for a more precise calculation of apparent losses. If those are not available, the platform will assume that the measurement error is of 0.5% of the input volume.

For the energy balance, the hydraulic model is necessary if a complete assessment of the energy efficiency is to be obtained. Though, the energy balance can also be computed in a simplified way, not requiring the hydraulic model. In systems where water losses are low, the simplified approach can provide a reasonably good estimate of the most important components of the energy balance.

4 – Identification of main barriers

Throughout the development and validation of SWSS platform, several barriers to its implementation and use were identified, mostly at the technical and management level. The most important aspects that may hamper SWSS implementation in other systems were identified and explained as follows.

Qualified people

The effective use of the platform on a daily basis requires adequate training of the staff as well as time for the people to gain on-the-job experience. The customization of the platform and the achievement of its full potential requires qualified people, who can understand the platform architecture, how the data are handled and how data can be transformed into information and presented in the platform. It is recommended that, at least, one person from the water utility can master the use of the platform, using it on a daily basis and helping others on to use it.

Data loss

Too often, the data acquisition and transmission systems fail in providing real time information of the system. This happens in every systems, due to power failures, communication failures or measurement equipment failures. As a result, the time series of the measured parameters are often incomplete, which can compromise, up to a certain point, the calculations made with these series, such as KPIs. Efforts must be made to guarantee that there is no missing data and that the platform will receive all measurements from SCADA system.

Security

Common issues that frequently arise are data protection and cybersecurity. The water utilities want to be sure that linking their SCADA systems to servers outside the utility will not provide a way into their systems operation and control for people outside the company. In addition, managers need to be sure that sensitive information will not be made available to public, for security reasons. SWSS platform is a safe application and the demonstration utilities in Portugal did not experienced any problems regarding security.

Competition

Other software applications for water systems management, including leakage management and energy optimization have been developed and are already in the market, such as:

- Baseform's Monitor (https://baseform.com/np4/papps1.html);
- Scubic (https://scubic.tech/),
- FP7 Project Effinet (http://effinet.eu/)
- FP7 project Smart Water for Europe (https://sw4eu.com/).

SWSS platform implementation might be hampered by the existence of similar, older and publicized software.

5 – Conclusions

The implementation of the SWSS platform can bring significant advantages to water utilities, by decreasing water losses and optimizing energy consumption, thus reducing the operational costs. In addition, the implementation of SWSS platform in water systems across Europe would benefit the citizens, by allowing water tariffs decrease. Less water losses also mean that less water is abstracted from groundwater and surface water sources, thus enabling the better management of the natural resource. The decrease in electrical energy consumption also promotes a better environment, as most of electricity is still produced from non-renewable sources, with the associated CO_2 emissions.

The technical requirements for SWSS platform implementation and use are identified, as well as the main barriers for its implementation. The SWSS platform is likely to be successful in many other water utilities as it has been demonstrated in the Portuguese utilities.

References

[1] ERSAR (2017) Guia de avaliação da qualidade dos serviços de águas e resíduos prestados aos utilizadores, 3ª geração do sistema de avaliação. Série Guias Técnicos 22.

[2] EBC (2017) Learning from International Best Practices. 2017 Water and Wastewater Benchmark. European Benchmarking Co-operation. Available at https://www.waterbenchmark.org/documents/Public-documents

[3] EurEau (2017) Europe's water in figures - An overview of the European drinking water and waste water sectors. Available at http://www.eureau.org/resources/publications/1460-eureau-data-report-2017-1/file

[4] EurEau (2018) The governance of water services in Europe. Available at http://www.eureau.org/resources/publications/150-report-on-the-governance-of-water-services-in-europe/file

[5] Eurostat - https://ec.europa.eu/eurostat accessed at 18th December 2018

[6] IEA (2016) The Water Energy Nexus, Excerpt from the World Energy Outlook 2016. The Organisation for Economic Co-operation and Development & International Energy Agency.

[7] Rossman, L. (2000) EPANET User's manual. United States Environmental Protection Agency.