

The role of communication in the deployment of water loss and energy management strategies: the experience of collaborative research with water utilities

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ABSTRACT

Water utilities (WU) have to deal with different challenges including ageing infrastructures, demand variability, climate change and increased societal expectations. This paper aims at outlining potential synergies between communication promotion and the implementation of a structured approach to enhance water loss and energy management in WU. The use of a structured approach in the decision-making process leverages knowledge production from various stakeholders, enabling them to propose solutions for the challenges faced by the WU. Collaboration is essential to achieve improvements in the long-term by breaking down information silos and boundaries resulting from functional specialism. In the scope of the iPerdas 2014 project, 17 Portuguese WU followed a joint training and capacity-building approach to work strategically with water loss and energy efficiency issues. The benefits of implementing a comprehensive communication framework are presented, highlighting the interconnected nature of barriers to energy and water efficiency and the need to address these barriers in a holistic manner. The paper concludes with the presentation of some lessons learned regarding the promotion of communication in collaborative projects.

Key words | collaborative projects, communication, energy efficiency, self-assessment, water loss management, water utilities

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INTRODUCTION

Developing feasible and implementable strategies to address sustainability objectives within water utilities (WU) is a challenging task. In water supply systems, the driving factors for improving efficiency in water and energy use can be a combination of economic issues, environmental goals, self-image and public demand, among others (Walsh *et al.* 2015).

Despite important advances in the service levels provided, the values of non-revenue water (water losses, unbilled authorized consumption and apparent losses) are still unacceptable in many utilities. Generally, losses in distribution systems (5% to 50%) exceed the production losses (2% to 10%). Therefore, water distribution networks should be the initial focus in water loss reducing efforts (EEA 2014). The first step towards reducing water losses

should be the calculation of the water balance in network sectors (IWA 2000), followed by the evaluation of minimum night consumption (Puust *et al.* 2010).

The energy used in the treatment and distribution of water is reflected in the energy footprint of the water (Walsh *et al.* 2015). Any wastage of water has direct implications for energy wastage, and improvements made in water systems have a direct impact on energy utilization. Since energy may represent 30% to 40% of operational costs in drinking water and wastewater services, WU are focused on improving the energy efficiency of their operations (WWAP 2014). Besides the decrease of embedded energy due to water loss reduction, improved energy efficiency can be achieved through upgrading to more

efficient equipment and improving system layout. However, barriers such as capital costs and reluctance to change practices or implement new technologies delay the process towards improved energy efficiency (Copeland 2014).

An interesting aspect of the water–energy nexus is the opportunity to align the water loss and energy management systems. In this context, the implementation of the world-wide standards ISO 50001:2011 (for energy management) and ISO 55001:2014 (for asset management, with an impact in water loss management) may boost coordination for both energy and water efficiency in WU. These standards are based on the ISO management system model, following the Plan-Do-Check-Act (PDCA) process for continuous improvement. It is important to recognize possible difficulties in the implementation of this model which may go beyond the technological barriers (Thollander & Palm 2015). Success in the implementation of referred management systems depends on having top management support and the involvement of different departments of WU, among other factors.

Research results indicate that an energy management gap is often associated with the existence of barriers that inhibit the adoption of cost-effective measures (Backlund *et al.* 2012). Chai & Yeo (2012) proposed the MCIR framework (Figure 1), inspired in the systems thinking process, aiming to highlight the interconnected nature of barriers to energy efficiency in industry and the need to address these barriers in a holistic manner. For each stage, questions are posed in order to capture factors affecting energy efficiency adoption and reflect the interests and objectives of stakeholders.

The main objective of this paper is to illustrate the advantages of addressing water loss and energy management in WU with a focus on practitioners' capacity-building. Herein, collaborative projects are presented as an

enabling factor for management systems implementation, focusing on the communication role.

METHODOLOGY

iPerdas 2014 project

Collaboration is an effective tool to support the organizations' change processes. The success of a collaborative project depends on aspects such as clear and shared objectives, team alignment, effective leadership, clear duties and obligations between the project lead and each participant, self-assessment and continual improvement practices, effective communication and trust (Bosch-Sijtsema & Postma 2009). Another advantage of collaboration is the fact that it entails the process of learning, reflected in the construction and transformation of knowledge by the participants (Coughlan & Coughlan 2002).

The iPerdas 2014 is a collaborative project launched by LNEC (National Civil Engineering Laboratory, Portugal) in partnership with IST (University of Lisbon, Portugal), ITA (Polytechnic University of Valencia, Spain), Addition (a software development company, Portugal) and 17 Portuguese WU (www.iperdas.org). This project was structured into three main stages and a preparatory phase, from November 2013 to December 2014. The final dissemination forum happened in April 2015. Examples of comparable collaborative research are the study of barriers that can affect the implementation of energy management systems in the Norwegian shipping sector, led by Johnson *et al.* (2014), and the study performed by Westling *et al.* (2014) together with UK WU technicians aiming at the development of adaptive management capacity for climate change.



Figure 1 | MCIR framework (Chai & Yeo 2012).

If adequately integrated into corporate strategies and implemented into operational plans and concrete actions, the management of water loss and energy efficiency can be addressed mainly at the tactical decision level (corresponding to a medium-term planning horizon of up to 3 to 5 years), which is one of the planning decision levels of the infrastructure asset management approach. The search for synergies with infrastructure asset management can facilitate the implementation of a water loss management and energy efficiency system, by formalizing a link with organizational objectives regarding the efficient use of resources. For that reason, the iPerdas project followed the AWARE-P methodology, a structured process for decision-making in infrastructure asset management (Alegre *et al.* 2013). The iPerdas methodology uses a systematic and novel approach for water–energy auditing and performance assessment. First, a preliminary characterization of the system is set in terms of water audit, energy audit and water meter analysis. This characterization of the whole system and its functional areas (e.g., district meter areas, subsystems) aims at helping the definition of objectives and the respective assessment system, by identifying the main water–energy inefficiencies and data gaps (Loureiro *et al.* 2016). Next, the diagnosis of the whole water system and its functional areas is conducted using the AWARE-P tool, for identifying priority areas for intervention (Alegre *et al.* 2013). For each selected priority area, a set of alternatives (comprised of infrastructural and non-infrastructural interventions) is identified by addressing risk, cost and performance dimensions. Finally, the overall diagnosis and the best alternative analyses provide a set of tactics that need to be implemented at the operational level (Loureiro *et al.* 2016).

The participating WU corresponded to 14% of the supplied drinking water in Portugal and presented different sizes and different capability levels in terms of available technology and competences. These differences did not present a direct link with the size of the WU or the respective governance system (i.e. public management or private concession). Some WU presented significant experience with water loss management and were focused on improving the energy efficiency of the water distribution system. Others were primarily interested in managing water losses. Nevertheless, all participating teams were equally

committed to the iPerdas project independently of their starting point.

Non-revenue water in the participating utilities represented 25.6% of the total water input – lower than the national average (Loureiro *et al.* 2015). On the energy side, the average standardized energy consumption (note: this is the IWA Ph5 indicator and expresses the average amount of energy consumed per m³ at a pump head of 100 m) was 0.47 kWh/m³·year – an acceptable service level according to the Portuguese regulator (Loureiro *et al.* 2015). A new metric that establishes the ratio between energy supplied and minimum energy required has been calculated (Mamade *et al.* 2015). Globally, the iPerdas WU supplied 2.3 times the minimum energy required (Loureiro *et al.* 2015).

iPerdas communication framework

‘Project management and communication’ was one of the four axes of activity of the iPerdas 2014 project, reflecting the importance given to communication as a tool for effective capacity building. The other axes were ‘Data and information’, ‘Technical and technological’ and ‘Plan development’.

The iPerdas communication framework comprises oral and written communication and its structure is presented in Figure 2. The oral communication comprises two subgroups: ‘Network’ and ‘Train’. The networking activities were mainly composed by the plenary meetings and the final dissemination forum, in parallel with the promotion of a contact group within each utility. Training was performed via classroom and webinar sessions, constituting the theoretical background provided to the participating teams for capacity building. Finally, the iPerdas 2014 written communication comprised diverse ‘Document’ types, such as the water loss management and energy efficiency plan template and guidelines; procedural templates to formalize technical aspects (e.g. water audit, energy audit, water meter analysis); progress and final assessment project reports; and the self-assessment questionnaire.

Plan development was the driving force for the capacity-building effort in the iPerdas 2014 project. LNEC proposed a plan template to the participating WU teams in order to facilitate the identification of the main requisites of the water loss management and energy efficiency systems. This

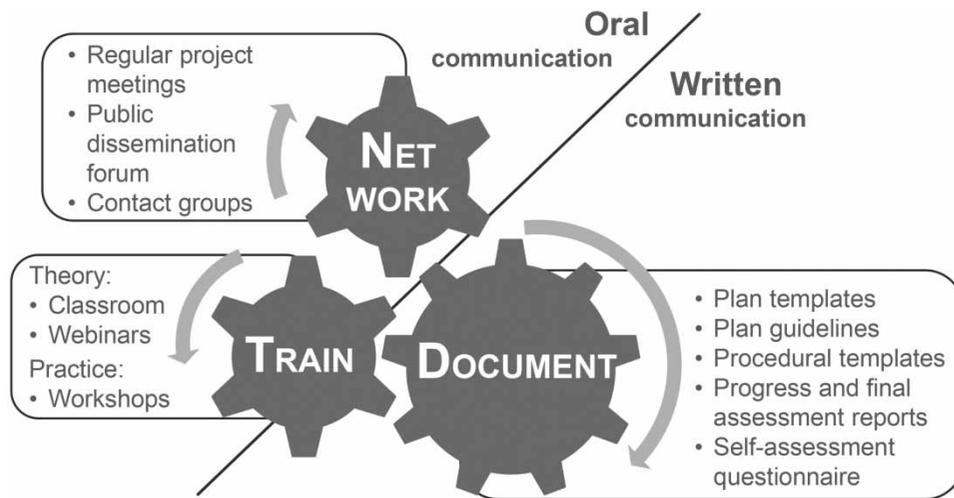


Figure 2 | iPerdas 2014's communication framework.

template includes a table of contents and a comprehensive collection of tables (without values). The template is supported by a guidelines document with some theoretical background and examples for plan development.

iPerdas self-assessment questionnaire

To assess capacity building during the iPerdas 2014 project, a self-assessment questionnaire was prepared with two objectives: (i) assessment of the capacity building of utilities for water loss management and energy efficiency; (ii) setting up goals to be achieved during the project. This questionnaire was inspired by a self-assessment questionnaire prepared for ISO 50001:2011 (BSI n.d.) and it is organized in four areas (relative to PDCA cycle stages) and further systematized in 13 subcategories (Table 1).

The iPerdas questionnaire comprises 43 questions which were applied to water loss management and energy efficiency domains and addressed organizational capacities and aspects required for implementation of these management systems, resulting in 86 questions to 17 WU. The available answers were of closed type with the following options:

- Not applicable – ‘At the moment, our organization considers of limited relevance this capability or aspect’ (corresponding to value 1).
- Incipient – ‘Our organization acknowledges the importance of this capability or aspect but has no plan for developing it’ (value 2).

- Aware – ‘Our organization presents a basic knowledge about this capability or aspect and considers important its future development’ (value 3).
- Under development – ‘Our organization has already started to develop this capability or aspect’ (value 4).
- Competent – ‘Our organization has suitable knowledge and experience for this capability (or aspect) development’ (value 5).
- Excellent – ‘Our organization is a recognized leader in developing this capability or aspect’ (value 6).

RESULTS AND DISCUSSION

Results of the iPerdas self-assessment questionnaire are discussed using median values of the different subcategories. Table 1 presents the results obtained at two moments: December 2013 and December 2014, at the beginning and end of the project respectively. These median values should be understood as a ‘most likely value for a typical case’ for iPerdas WU teams’ perception about organizational positioning regarding water loss management and energy efficiency at distinct points of the capacity-building process. The differences between the two assessment periods were not statistically verified due to the small sample size and the impossibility of excluding a response bias as a result of the questionnaire’s double presentation.

Table 1 | iPerdas self-assessment questionnaire: structure and results (median values)

Areas	Subcategories (number of included questions)	Water loss management		Energy efficiency	
		December 2013	December 2014	December 2013	December 2014
Plan	Organizational commitment and policy (6 questions)	4.0	5.0	3.0	4.5
	Legal, regulatory and other requirements (2 questions)	4.5	5.0	4.0	5.0
	Actions to address risks and opportunities (2 questions)	3.5	5.0	3.0	4.0
	Objectives, metrics, targets and plans (3 questions)	3.0	5.0	3.0	5.0
Do	Resources, roles, responsibilities and authorities (4 questions)	4.0	5.0	4.0	5.0
	Awareness, training and competence (4 questions)	4.0	5.0	4.0	4.5
	Communication (3 questions)	3.0	4.0	3.0	4.0
	Information support systems (3 questions)	4.0	5.0	3.0	4.0
	Control of documents (2 questions)	4.0	4.5	3.0	4.0
	Operational controls (2 questions)	3.5	5.0	3.0	4.0
Check	Monitoring and assessment (5 questions)	4.0	5.0	3.0	4.0
	Non-conformities, corrective actions and preventive actions (3 questions)	3.0	5.0	3.0	4.0
Act	Plan review (4 questions)	3.0	4.0	3.0	4.0
		Water loss management		Energy efficiency	
		December 2013	December 2014	December 2013	December 2014
<i>Global median value</i>		4.0	5.0	3.0	4.0
<i>Global standard deviation value</i>		0.5	0.4	0.4	0.4
<i>Minimum value</i>		3.0	4.0	3.0	4.0
<i>Maximum value</i>		4.5	5.0	4.0	5.0

Another aspect that it is important to refer is the fact that the values presented herein are global, representing 17 WU. However, an analysis of the individual self-assessment results was presented to each participating team in the individual project's final report. In general, a good agreement between the self-assessment evaluation and LNEC's evaluation of the work performed by each team was found.

Finally, reference should be made to the results of the self-assessment questionnaire not presenting a visible link with the starting conditions or dimension of the WU. For instance, there were cases of WU with experience in water loss management that reported a significant increase in capacity in this domain, while others reported limited evolution.

According to [Table 1](#), it is possible to infer a perception of an improved capacity by the participating WU teams in the iPerdas. In the case of water loss management, an evolution is observed from a mostly predominant evaluation of 'under development' (value 4) in December 2013 to 'competent'

(value 5) in December 2014 (in 10 of the 13 subcategories). Similarly, the reported capacity in terms of energy efficiency evolved from an essentially 'aware' level (value 3) in December 2013 to 'under development' (value 4) or 'competent' (value 5) in December 2014 (in 10 and three of the 13 subcategories, respectively). The occurrence of a similar evolution in both domains supports the iPerdas approach, demonstrating that it is possible to work in an integrated manner with water loss management and energy efficiency systems.

Some subcategories presented an identical final result (identified by bold values in [Table 1](#)) in water loss management and energy efficiency domains. The reported improvement in the subcategory 'Objectives, metrics, targets and plans' (an evolution from 'aware' to 'competent' level) is presumably linked to the provision of a framework for the definition of water loss management and energy efficiency objectives and the respective assessment system, as well as the iPerdas template for plan production. Regarding the

'under development' evaluation received by the subcategories 'Communication' and 'Plan review' in water loss management and energy efficiency, it is possible to consider this result to be an indicator of potential fragilities that may affect the completion of the PDCA cycle by the WU, delaying new iterations in the continual improvement process in both domains.

Figure 3 illustrates how communication was used in the iPerdas 2014 project to overcome barriers to water loss management and energy efficiency, by indicating the distribution of the main iPerdas communication outputs through the four stages of the MCIR framework.

The definition of goals for project participation in the initial plenary meeting and in the self-assessment questionnaire responded to in December 2013, simultaneously with the establishment of intra-organizational groups, contributed to the awareness and engagement of different organizational levels of the participating WU (*motivation stage*).

The use of a template and guidelines for plan development, as well other procedural templates, contributed to the production of a water loss management and energy efficiency plan by each participating team. The iPerdas *capability stage* was supported by extensive classroom (21 sessions) and webinar (19 sessions) training, essential for effective capacity building.

The promotion of an open discussion about results and difficulties encountered by the WU teams during the iPerdas

plenary sessions and the use of periodic progress reports, which indicated the project's expected results and corresponding assessment criteria, clearly contributed to the teams' alignment and to efficient project coordination (*implementation stage*).

The *results stage* of the iPerdas project encompassed two main features: a public dissemination forum and the individual project's final report produced for each WU with recommendations for future improvements. Both aspects were important for increasing the visibility of key aspects of water loss management and energy efficiency and were targeted at WU's top management.

CONCLUSIONS

The subject this paper addresses is that improving water loss management and energy efficiency in WU involves improved communication, besides the use of adequate technology. The learning and communication processes can accelerate innovation as a more methodical approach to the design and implementation of effective solutions. Cornell et al. (2013) focused the need of linking knowledge with action for effective societal responses to persistent problems of unsustainability. According to these authors, it is necessary to ensure interface arrangements for translating knowledge to action.

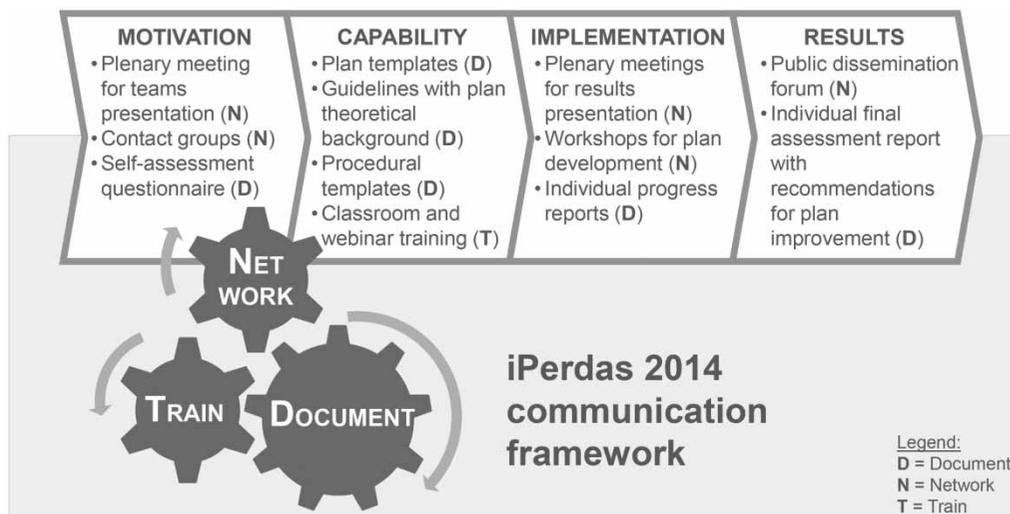


Figure 3 | Integration of iPerdas communication activities and products in the MCIR framework.

In the iPerdas 2014 collaborative project a structured approach to communication was applied, composed of three components: networking and training (oral communication) and documentation (written communication). Numerous communication outputs were produced aiming to support the capacity-building process in the development of a water loss management and energy efficiency plan. The responses given to a self-assessment questionnaire gave additional information about perceived successes and difficulties experienced by the participating 17 WU. Globally, a more significant gain in capacity was reported regarding the objectives' definition and planning process, whereas communication and plan review were perceived as a less consistent capability.

Finally, some lessons learned during the iPerdas 2014 project are shared as they may be useful to other collaborative projects with the water industry, namely:

1. Develop and maintain strong communication between researchers and practitioners to promote a continuous alignment with shared objectives from the project's day one.
2. Do not underestimate the time and effort needed to build a strong relationship within the project's network.
3. Encourage participating teams to adopt this effort in communication in their own organizations to achieve top management and staff commitment.
4. Support a reflective analysis of existing barriers to water loss management and energy efficiency and possible ways to overcome or reduce their impact.

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REFERENCES

Alegre, H., Coelho, S. T., Covas, D., Almeida, M. C. & Cardoso, M. A. 2013 *A utility-tailored methodology for integrated asset*

management of urban water infrastructure. Water Sci. Technol.: Water Supply **13** (6), 1444–1451. doi:10.2166/ws.2013.108.

- Backlund, S., Thollander, P., Palm, J. & Ottosson, M. 2012 *Extending the energy efficiency gap. Energy Policy* **51**, 392–396. doi:10.1016/j.enpol.2012.08.042.
- Bosch-Sijtsema, P. & Postma, T. 2009 *Cooperative innovation projects: capabilities and governance mechanisms. J. Prod. Innovat. Manag.* **26**, 58–70. doi:10.1111/j.1540-5885.2009.00334.x.
- BSI (n.d.) Self-assessment questionnaire: How ready are you for an assessment to the requirements of ISO 50001? <https://www.bsigroup.com/Documents/iso-50001/resources/BSI-ISO50001-Assessment-Checklist-UK-EN.pdf> (accessed 4 July 2016).
- Chai, K.-H. & Yeo, C. 2012 *Overcoming energy efficiency barriers through systems approach – a conceptual framework. Energy Policy* **46**, 460–472.
- Copeland, C. 2014 *Energy-Water Nexus: The Water Sector's Energy Use*. Congressional Research Service 7-5700, R43200, USA.
- Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J. D., Jäger, J., Chabay, I., de Wit, B., Langlais, R., Mills, D., Moll, P., Otto, I. M., Petersen, A., Pohl, C. & van Kerckhoff, L. 2013 *Opening up knowledge systems for better responses to global environmental change. Environ. Sci. Policy* **28**, 60–70.
- Coughlan, P. & Coughlan, D. 2002 *Action research for operations management. Int. J. Oper. Prod. Man.* **22** (2), 220–240. doi:10.1016/j.envsci.2012.11.008.
- EEA 2014 *Performance of Water Utilities beyond Compliance: Sharing Knowledge Bases to Support Environmental and Resource-Efficiency Policies and Technical Improvements*. EEA report 5/2014. doi:10.2800/13253.
- ISO 50001:2011 *Energy management systems: requirements with guidance for use*. ISO.
- ISO 55001:2014 *Asset management: management systems, requirements*. ISO.
- IWA 2000 *Losses from water supply systems: standard terminology and recommended performance measurements* [online], A. Lambert & W. Hirner (eds). IWA, London, UK (accessed 18 October 2011).
- Johnson, H., Johansson, M. & Andersson, K. 2014 *Barriers to improving energy efficiency in short sea shipping: an action research case study. J. Clean. Prod.* **66**, 317–327. doi:10.1016/j.jclepro.2013.10.046.
- Loureiro, D., Alegre, H., Mamade, A., Vieira, P. & Coelho, S. T. 2015 *Implementing water-energy loss management in water supply systems through a collaborative project: the Portuguese national initiative*. In: *The Leading Conference on Water Security for Sustainable Development*, 18–22 October, IWA, Jordan.
- Loureiro, D., Alegre, H., Silva, M. S., Ribeiro, R., Mamade, A. & Poças, A. 2016 *Implementing tactical plans to improve water-energy loss management. Water Sci. Technol.: Water Supply* **17** (2), 381–388. doi:10.2166/ws.2016.092.
- Mamade, A., Sousa, C., Marques, A., Loureiro, D., Alegre, H. & Covas, D. 2015 *Energy auditing as a tool for outlining major*

- inefficiencies: results from a real water supply system. *Procedia Eng.* **119**, 1098–1108. doi:10.1016/j.proeng.2015.08.944.
- Puust, R., Kapelan, Z., Savic, D. A. & Koppel, T. 2010 [A review of methods for leakage management in pipe networks](#). *Urban Water J.* **7** (1), 25–45. doi.org/10.1080/15730621003610878.
- Thollander, P. & Palm, J. 2015 [Industrial energy management decision making for improved energy efficiency: strategic system perspectives and situated action in combination](#). *Energies* **8**, 5694–5703. doi:10.3390/en8065694.
- Walsh, B., Murray, S. & O'Sullivan, D. 2015 [The water energy nexus: an ISO50001 water case study and the need for a water value system](#). *Water Resour. Ind.* **10**, 15–28. doi:10.1016/j.wri.2015.02.001.
- Westling, E. L., Sharp, L., Rychlewski, M. & Carrozza, C. 2014 [Developing adaptive capacity through reflexivity: lessons from collaborative research with a UK water utility](#). *Crit. Policy Stud.* **8** (4), 427–446. doi:10.1080/19460171.2014.957334.
- WWAP 2014 *United Nations World Water Development Report 2014: Water and Energy*. UNESCO, Paris, France.

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