

Reducing the Energy Dependency of Water Networks in Irrigation, Public Drinking Water, and Process Industry: REDAWN Project [†]

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Abstract: The EU funded Interreg project REDAWN is presented, setting a new operational framework for efficiently foster micro-hydropower in water distribution.

Keywords: micro-hydropower; water distribution; irrigation; energy recovery; pressure reduction

1. Introduction

The drinking water industry is one of the most energy intensive sectors in industrialized regions. It has been noted to be the 4th most energy intensive in the UK, with considerable contributions to CO₂ emissions as a result. Much of this energy consumption is consumed inefficiently in the distribution of water to end users and in the transport of wastewater to treatment facilities. An example of the inefficiency of the water distribution process is evident in the excess pressure which exists in water networks and is typically dissipated wastefully in pressure reducing valves, break pressure tanks, inlets to reservoirs, and in other elements of the water infrastructure. This inefficient distribution of water and the presence of excess pressure is also known to exist in irrigation networks and water intensive industrial facilities. If it is considered that irrigation and industrial use of water account for 40% and 44% of water use in the EU, whilst drinking water only accounts for only 15%, this greatly increases the extent of the inefficient use of water in distribution networks.

This paper outlines progress in the reduction of the energy consumption in water pipe networks through the use of low-cost micro-hydropower (MHP) turbines as a means to exploit the excess pressure within these networks to produce electricity for local or grid consumption. The paper outlines progress in the selection, design and implementation of three real-world demonstrations of MHP in a pressurized irrigation network: a public drinking water network, and a paper processing

plant. The results give insight into the design of low-cost MHP solutions and demonstrate the impact of MHP on reductions in the net local demand for energy in water distribution. The paper also outlines the program of work being conducted by the EU funded research project REDAWN aimed at fostering greater resource efficiency in water networks in the Atlantic area of Europe.

2. Materials and Methods

A PAT (Pump as Turbine) is a low cost, highly reliable solution for micro-hydropower in water networks. Compared to traditional turbines, the lower cost of PATs arises due to their lower electromechanical complexity, and the absence of any mobile parts at the inflow of the machine. An additional feature is the diffusion of pumps in the water sector, preventing any psychological barrier to their diffusion as energy production devices. These peculiarities are important in the water distribution sector when the small power available for energy production is considered. A residual hydraulic head can be converted at different points of the network in order to grant optimal pressure values to end users. A PAT is the most advanced solution to replace pressure reducing valves, reducing the energy footprint connected to water transportation and the amount of water lost in leakage [1,2].

PAT design and regulation is based on a well-established theory [1]. The complexity of the MHP layout is connected to the necessity of an external piping and/or electronic circuit granting an optimal regulation of the hydropower plant in the presence of the classical variation of flow rate and head observed in any point of a distribution network. Hydraulic and electrical regulation are the commonly suggested solutions. Many scientific papers have recently been published to investigate the various aspects of the mechanical design [3–5], the fluid dynamics [6,7], and the reliability [8–10] of PATs, contributing to an optimal design of the MHP. In addition, the economic viability of MHP has been analyzed based on the different costs of energy, benefits of feed-in tariffs, and on the lower use of water due to the pressure reduction [11–13]. Finally, the impact of the MHP on the network management can be analyzed in a more comprehensive way together with all the factors affecting the circular economy [14–16].

Despite all these advancements, the uptake of PAT and MHP technologies remains low in the real world and only a small number of pioneering plants exist. The experience in PAT design and construction seems too poor to grant the promised plant efficiency. Finally, no guidelines are available for some crucial phases of the design, such as water system recognition, site data acquisition, and pump selection.

3. Resulting Solution

In order to overcome the barriers to the diffusion of PAT technology, and to increase the attraction of the exploitation of PAT technology in different industrial sectors, the authors of this paper are all participants in a new EU-funded research project titled: Reducing Energy Dependency in Atlantic area Water Networks (REDAWN). The aim of REDAWN is to foster greater resource efficiency in water networks in the Atlantic area of Europe. The framework of the REDAWN project is reported in Figure 1. The project focuses on MHP application in four water network sectors: Water supply; Waste water; Irrigation and; Process Industry. It will evaluate the opportunities for energy recovery in each sector, and work with three end users-SMPGA, FERAGUA and RENOVA- to demonstrate the design and installation of three micro-hydro power plants.

An advancement in the traditional operational framework for the assessment of economic viability of PAT technology in MHP at regional/country level will be necessary to effectively foster the adoption of hydropower energy recovery technology, (see Figure 2). Therefore, REDAWN aims to promote a positive institutional, social and technological environment for better resource efficiency in water networks through the:

- Completion of an energy recovery resource assessment in water networks in the AA.
- Completion of an economic/environmental impact assessment of this technology on the region.

- Development of design guidelines and support tools for hydropower energy recovery in drinking water, waste water, irrigation and process industry sectors.
- Development of policy and institutional support tools to increase the implementation of energy recovery projects.
- Quantification of the societal impacts of hydropower energy recovery in water networks.
- Widespread dissemination and promotion of energy efficiency in AA water networks.

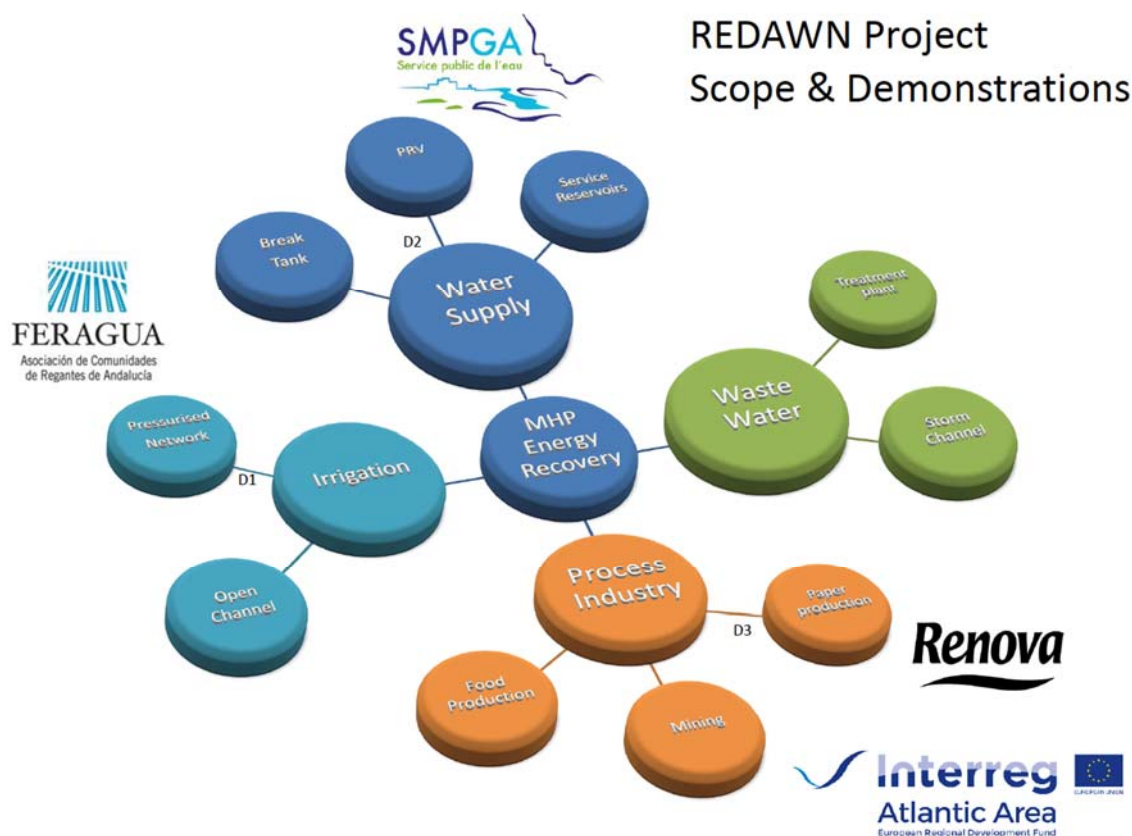


Figure 1. Conceptual scheme of REDAWN project.

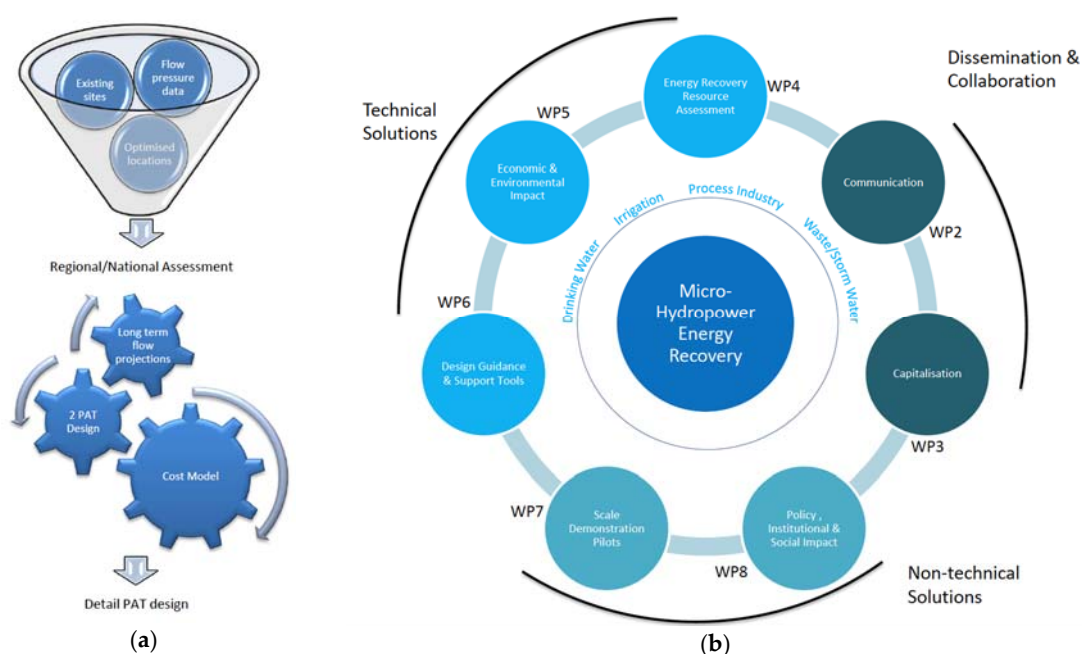


Figure 2. Assessment of economic viability of PAT technology in MHPat regional/country level: (a) Traditional assessment; (b) REDAWN solution.

Each topic is being investigated within a corresponding Work Package. The traditional assessment is extended by a number of actions/procedures that will close the gap between institutional, social and technological environments. In particular, guidelines and support tools will facilitate the more technical phases of the resource assessment and MHP design. Policy and institutional support tools will provide water managers and policy makers with adequate instruments for the implementation of such energy recovery projects. The quantification of societal impact will increase the interest of the public opinion on the energy footprint of water transportation and on the benefit of energy recovery within the water systems. Finally, the professional techniques of dissemination and promotion will increase the impact of the project within AA and EC water networks.

As mentioned, an important aspect of the REDAWN project is to promote the understanding and adoption of MHPs in water networks in the Atlantic Area and Europe as a whole. This task is being administered by the Water Efficiency network, a collaborative network of academics, industry practitioners, policy makers and NGOs. In collaboration with the project partners, the WATEF network will organize events, produce and disseminate knowledge and awareness materials, enhance the visibility of the project in all water-related avenues and using all available tools and, support the dissemination and capitalization of the project outputs. On the latter, a targeted steering committee will be established and a mailing list of relevant stakeholders will be compiled. A review of relevant stakeholders in the AA and EC area has been concluded ahead of the project launch event. Stakeholders identified by the review will be invited to the launch event to be hosted by SMPGA at their headquarters in Saint-Pair-sur-Mer, Normandie, France in March 2018. An interested shortlist of participants at this event, will be subsequently invited to the project's steering committee. Periodic meetings of the steering committee, held in rotation across the AA (streamed live via You-tube and/or webinar), and in conjunction with dissemination activities, will be held throughout the duration of the project. All outputs of the REDAWN project including, presentations and reports of events, will be disseminated via the multi-language project website: www.redawn.eu (Figure 3), twitter feed @REDAWNAA, as well as videos and animations via the REDAWN You-tube channel, which can also accessed via the website. Academic publications such as this are also proposed to be made accessible to academic, industry and policy audiences in Europe and beyond.



Figure 3. REDAWN Website shown in English and French as an example.

The key output of the project will be the demonstration of the potentiality of the REDAWN approach to the end users, represented by SMPGA, FERAGUA and RENOVA. SMPGA is an association of water utilities operating in the French region of Normandie, distributing the drinking water from the springs of Granvillais and Avranchin. FERAGUA, founded in 1994, is a non-profit association which gathers Irrigation Communities and Private Irrigators in Spain. Its goal is the administration and management of irrigation water. FERAGUA represents around 300,000 hectares and it is the most important irrigation association in the region. RENOVA is a multinational company manufacturing several types of paper, and consuming large volumes of water in the process. RENOVA brings to the REDAWN project the perspective of water-intensive process industries in the Atlantic Area, with the potential to recover energy in their internal private water network.

Among the macro-area technical solutions, the main results concern the Energy recovery resource assessment, and the Design Guidelines & Support tools. Two important aspects of these two deliverables have been analyzed so far: the definition of the methodologies used for the energy recovery resource assessment in the different sectors, and the establishment of a data base of PAT performance curves. Figure 4 shows the results of the application of the resource assessment methodology for 16,000 hectares of irrigated land in the region of Andalusia (Spain). Preliminary results show the potential for 43 MHP installations with a total potential to reduce more than 1 GWh of energy per irrigation season.

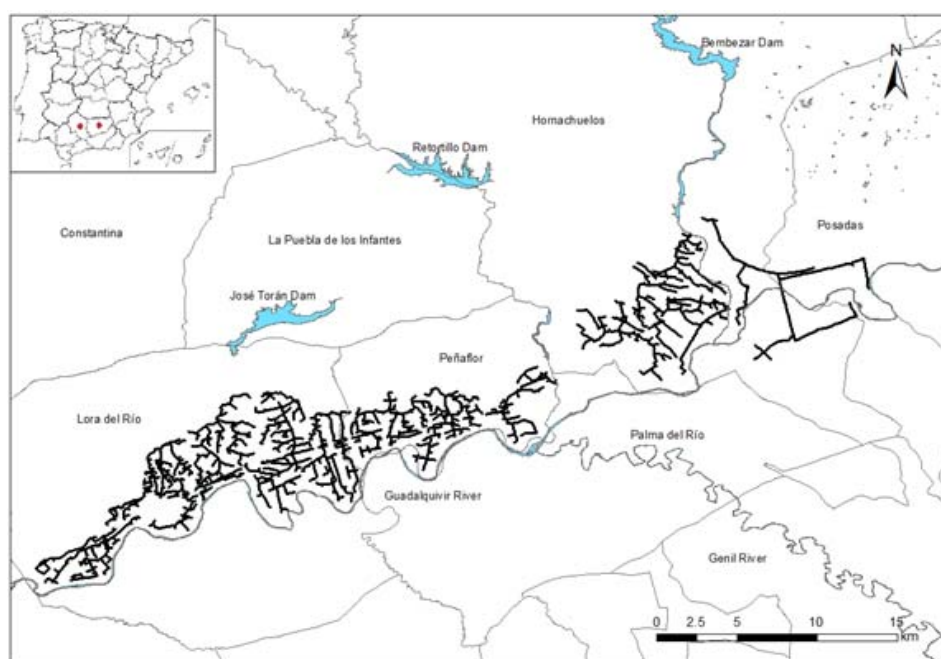


Figure 4. Energy resource assessment in irrigation sector.

Figure 5 shows the results of the application of the resource assessment methodology to parts of the UK and Ireland. Preliminary results show that more than 20 GWh of energy per annum could be saved from public water networks servicing approximately 5 million people. For power plant design it is fundamental to have a full characterization of the technologies available for energy recovery and, in particular, of PATs. One of the obstacles for the full exploitation of hydropower in the water distribution networks is represented by the lack of knowledge of all technical and design parameters. Therefore, an inquiry on all energy production devices on the market has been performed and a request for the characteristic curves of pumps working in inverse mode has been addressed to the main pump manufacturers. In Figure 6, all PATs characteristic found within the project are represented in the (Q, H) plot.

With reference to the macro-area non-technical solutions, demonstration sites will be selected on the basis of the resource assessment. An attempt location has proposed by FERAGUA. The power plant will be installed in the Irrigation District “Margen Izquierda del Genil” of Palma del Río, in

Córdoba and Seville Provinces. The District has a surface of 6000 ha, serving around 600 farmers. The typical crops in the area are orange trees, olives, almonds, cotton, corn and vegetables crops. The MHP will be located close to facilities where the energy can be used, such as a pump station or offices, Figure 7. Based on preliminary studies of flows and excess pressure, there is a great potential for power generation. Two alternative MHP placements are presently under analysis: the first one is near to the main pump station and the main office, and the second, one is near to a booster pumping station. Another possibility to be considered is the direct coupling of the PAT and of the pump for the direct use of the energy excess recovered on a part of the network for pumping water to a different more elevated part [12].

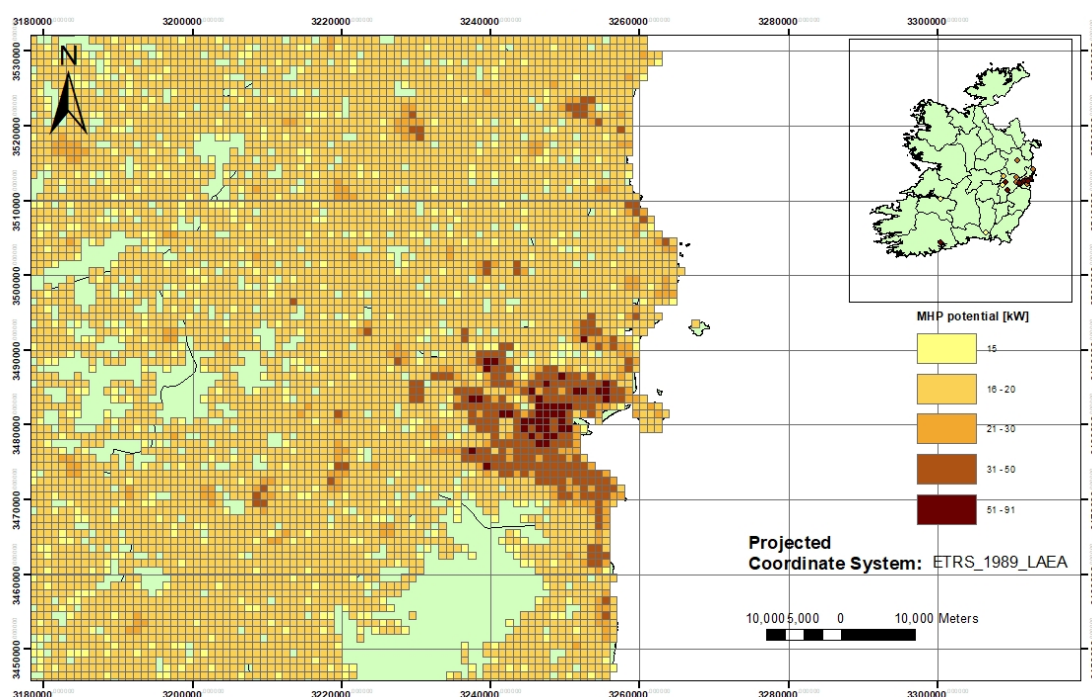


Figure 5. MHP potential in Ireland based on population density.

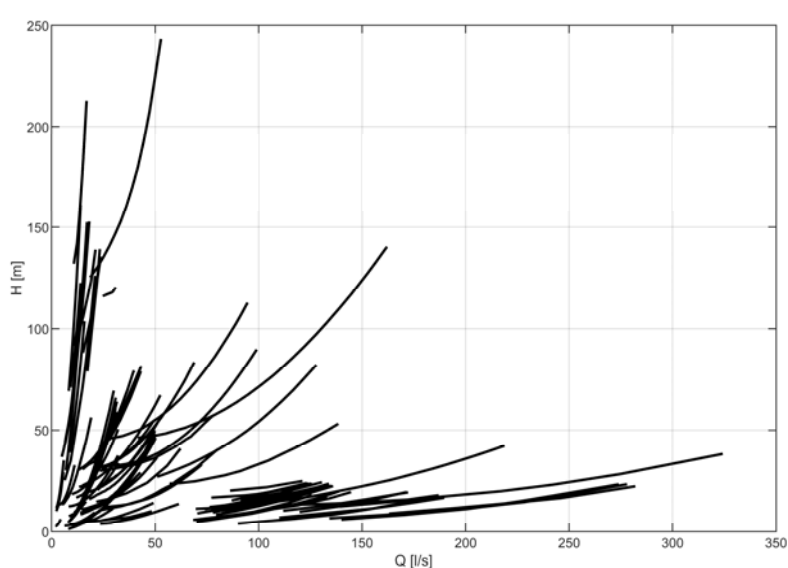


Figure 6. PAT characteristic curves from manufacturers.



Figure 7. Alternative MHP locations in the irrigation sector.

4. Conclusions

The reduction of the energy use in water pipe networks in the water sector and in industry is an important challenge in the Atlantic area and in the whole Europe. The use of micro-hydro power plant to recover the excess pressure in the network is a very promising possibility. The new project REDAWN is applied to the exploitation of the micro hydropower technology by a new multi-sector approach, involving institutional, social and technological aspects. Energy recovery resource assessment, economic/environmental impact assessment, development of design guidelines and support tools for hydropower energy recovery in the different sectors, development of policy and institutional support tools, quantification of the societal impacts of hydropower energy recovery in water networks, and, finally, widespread dissemination and promotion of energy efficiency in AA water networks are the main aspects considered in the project. The first steps of this methodology as outlined within the project are presented in the paper, together with the site selection for the pilot power plant to be installed in drinking water, irrigation and process industry sectors.

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