Asseiceira 0% Energy

Relevance & Objectives of Case Study

Over recent years Portuguese water and waste water utilities have faced an enormous challenge, mainly due to economic crises but also through the transition between a period of significant investment in infrastructure and a most recent period which has been more focused on optimization, resource recovery, the circular economy towards an economy less dependent on fossil energy, developing the potential to produce energy from renewable sources, maximizing processes efficiency and reducing GHG emissions.

Introduction

In Portugal, the water sector is responsible for about 2% of the energy consumed within the country.

With more than 50% of operating costs relating to electricity consumption (150 GWh/year), Empresa Portuguesa das Águas Livres, S.A. (EPAL) has developed an energy management plan based on assumptions to maximize energy utilization of endogenous assets and resources to rationalize consumption and improve overall energy performance.

Asseiceira Water Treatment Plant (WTP) is the largest Portuguese WTP treating up to 625,000m3/day, supplying water to Lisbon and other surrounding municipalities, encompassing more than 3,000 000 inhabitants, around one third of Portuguese population.

Figure 1 - Asseiceira WTP near Tomar - Portugal

The trend towards increasing energy costs and the fact that the urban water cycle sector has increased responsibilities in reducing greenhouse gas emissions have led to implementation of an Energy Management System (EMS) based on NP EN ISO 50001 and subsequent external certification. For Asseiceira WTP, the EMS encompassed an even more ambitious objective: to ensure that this WTP becomes the first Portuguese energy self-sufficient WTP - and one of the first in the world of such a size - thus representing a benchmark for the sector and boosting projects within the AdP – Águas de Portugal holding and in other water and waste water utilities.

Background

EPAL - Empresa Portuguesa das Águas Livres, S.A. is the successor of the century-old CAL - Companhia das Águas de Lisboa, a water supply concession for the city of Lisbon, which began operating in 1868. Over the years, company activity has been extended to other municipalities and most recently, in 2015, has included wastewater and sanitation activities.

Currently, EPAL is as a state-owned enterprise, held100% by AdP - Águas de Portugal, SGPS, S.A., serving 87 municipalities that occupy a coverage area of around 33% of the Portuguese continental territory and around 3,5 million people.

EPAL's supply system includes the production and transport system as well as the distribution system for the city of Lisbon network.

EPAL currently manages and operates a supply system that consists of three main sub-systems: Castelo do Bode reservoir, opened in 1987 and extended in 2007 with a production capacity of around 625,000 m^3 daily; the Tejo, opened in 1940 and extended in 1963 and 1976, with a daily production capacity of 400,000 m^3; and Alviela, which has been operating since 1880.

From these three sub-systems mentioned, the largest and most relevant is Castelo de Bode, representing around 75% of EPAL's production. It composes of an extraction tower, located in the Castelo do Bode reservoir, two pumping stations downstream, a water treatment plant and the transport system between the Asseiceira WTP and Vila Franca de Xira Pumping station.

Figure 2 – Castelo do Bode Reservoir (River Zêzere)

The management board, in order to demonstrate the company commitment to the EMS and to achieving continuous improvement of its energy performance, approved an energy policy, integrating it in the existing corporate responsibility system, based on ISO normative references. In order to operationalize the EMS, the company President, as the board representative, appointed an energy management team responsible for effective implementation of EMS activities and for energy performance improvement. This multidisciplinary team includes elements of operations, maintenance, asset management and sustainability services.

Tomar has a warm and temperate climate, with significantly more rainfall in the winter than the summer. According to Köppen and Geiger, the climate classification is Csa (warm temperate summer in the interior regions of the Douro Valley (part of the Bragança district), as well as the southern regions of the Montejunto-Estrela mountain system except on the west coast of the Alentejo and Algarve). Tomar has an average temperature of 16.4 ° C and average annual rainfall of 773 mm.

Problem description

Under Portuguese law, Asseiceira WTP is covered by the Energy Intensive Consumption Management System, namely for consumption of over 500 Tpe. It is a measure regulated by the central administration that aims to promote energy efficiency and consumption monitoring in intensive energy consumers and industrial installations. This legislation determines implementation of energy efficiency measures, in PDCA cycles of 6 to 8 years, with fiscal gains for the company by complying with energy performance indicators. The obligations resulting from application of this legislation determine a reduction of 6% of the energy specific consumption within 6 years.

Associated with this legal requirement for EMS implementation, an even more demanding challenge was launched; "Asseiceira 0% Energia".

The work developed by this multidisciplinary team began in March 2016, together with staff from different areas of the utility, namely the Operations, Engineering, Maintenance and Communication divisions, leading to the certification of the EMS (ISO 50001) by an external entity in October 2016. Implementation of Energy Management System was the starting point for a pathway that will lead to Asseiceira WTP becoming energy self-sufficient and seeing reduced GHG emissions.

Process description

At present, Asseiceira WTP, has two treatment lines with line 1, composing of 24 double layer filters, producing 500,000 m^3/day and line 2 composed of six single layer filters producing 125,000 m^3/day.

The surface water abstracted at Castelo do Bode dam is treated at Asseiceira WTP. The treatment process comprises of the follow operations: pre-chlorination, remineralization followed by a coagulation/flocculation and then filtration, pH adjustment, final chlorination and storage for further transport. The sludge process comprises of thickening, dewatering and a final solar drying.

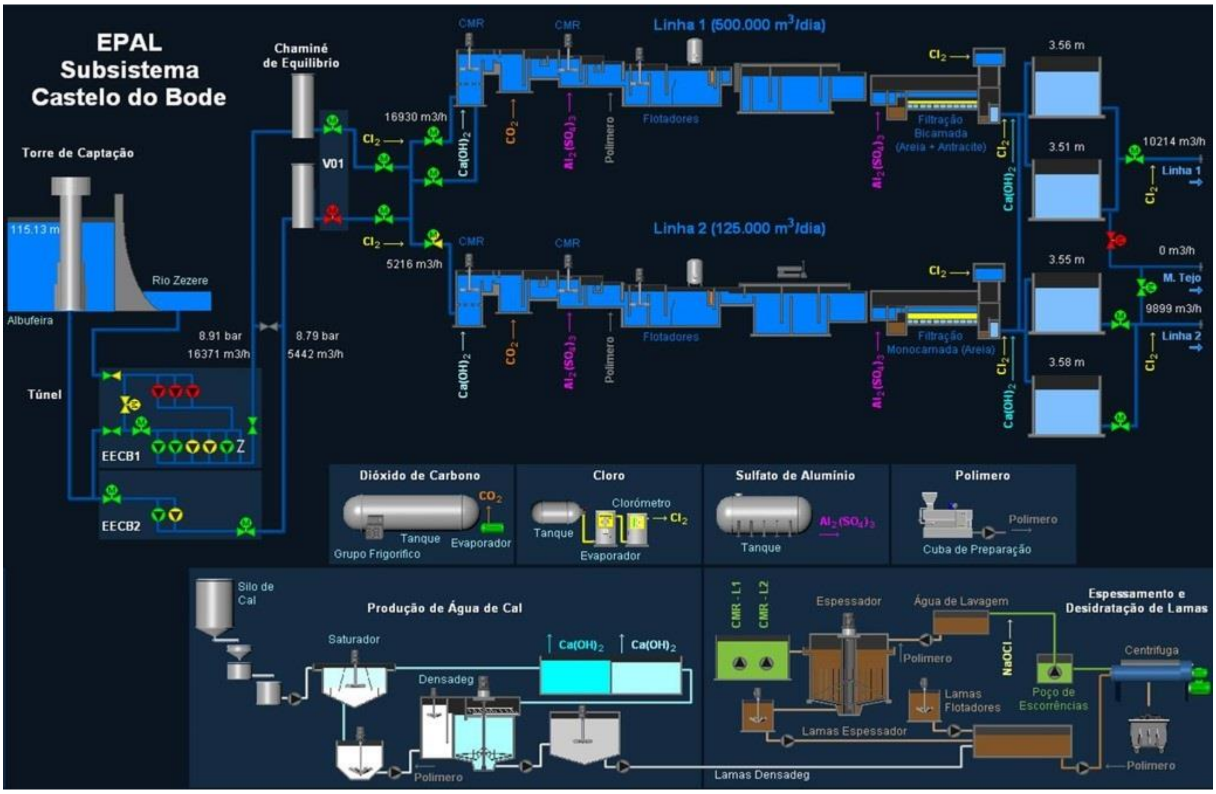

Figure 3 - Asseiceira WTP: diagram process

Approach used

Efficiency energetic measures

Over four to five months, the four person dedicated multidisciplinary team, along with the Operations, Maintenance, and Engineering divisions undertook an assessment of the overall treatment process including water abstraction and all of the stages of water treatment itself, as well as the transport system, in order to identify significant energy use (SEU) processes and those with the greatest opportunity for improvement.

The assessment was developed taking into account the following drivers:

- Reduction of energy consumption;
- Minimize daily power fluctuations
- Recovery, production of energy and storage;
- Sustainability;
- Safety & Security.

On the site, energy specific consumption (kWh/m^3), has been reducing since 2009 from 0,049, to 0.019 in 2015/2016. Nevertheless the increase in energy costs in Portugal as with other EU member states, has led to strong efforts as regards energy production. Figure 4.

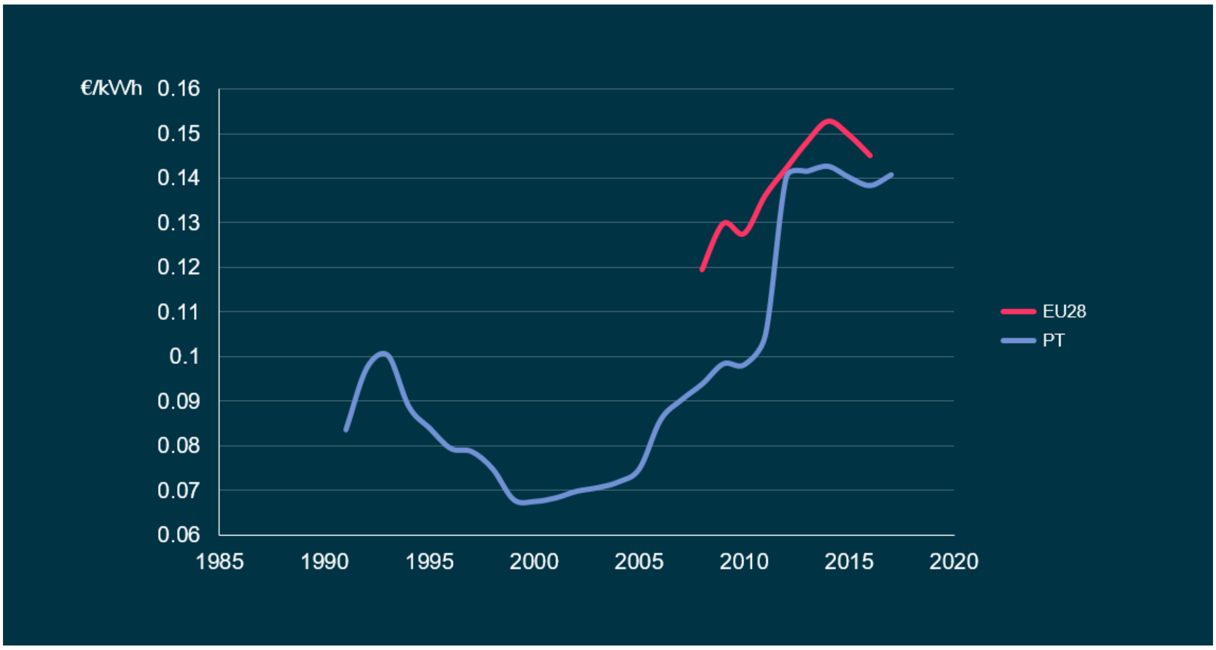

Figure 4 – Operational energy costs (€/KWh) Font:https://www.pordata.pt/Homepage.aspx)

The energy audit performed measured power for more than 75 equipment installations along all stages of the water treatment process:

- Correction of water aggressiveness;
- Lime saturators;
- Coagulation;
- Chlorination;
- Filtration;
- Mixing;
- Sludge thickening;
- Sludge dewatering;
- Lighting (indoor and outdoor);
- General support systems;
- ...

A number of opportunities for improvement, related to significant energy uses and others, were identified by the multidisciplinary team, with a strong commitment from the operations and maintenance divisions. These opportunities were mainly characterized as having a reduced investment, being eminently operational and associated with more vigilant and well thought out risk analysis.

The results allowed the team to build a daily diagram of energy consumptions at Asseiceira WTP, as represented in Figure 5 (black dashed line) and compared with grid supplier.

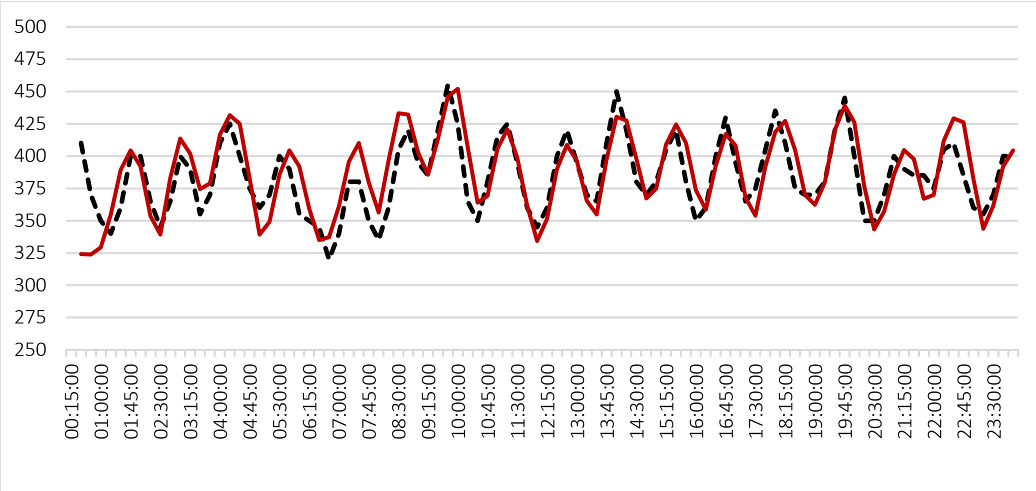

Figure 5 - Asseiceira's WTP: daily diagram (kW)

Figure 5 presents the model (black dashed) of power over one full day and the real (red line) power measured, noting that the daily deviation is less than 2% and the hourly deviation less than 5%.

At this point, the team defined a strategy considering, identifying and understanding the main function of each treatment stage, to eliminate or reduce energy consumption, minimize fluctuations and promote energy storage measures. All of these measures were taken under a process optimization approach, always considering the reversibility as well as health and safety aspects of each measure.

Systemic and system approach considering the unit / process used for accounting, maintenance and operation utility, this approach allows the methodology used to be applied over all facility infrastructure.

1. Rapid mixing
2. Backwash pumping
3. Wash water pumping
4. Recovery water pumping
5. Wash air
6. Remineralization
7. Compressed air
8. Outdoor lighting

9. Indoor lighting;
10. Service buildings.

A number of opportunities for improvement, related to significant energy uses and others, were identified by the multidisciplinary team, with a strong commitment from the operations and maintenance teams. These opportunities were mainly characterized as having a reduced investment, being eminently operational and associated to a careful, and well thought, risk analysis.

From this approach several actions were identified: measure and adjust gradient velocity, reducing the geometric pumping high by 1 to 2 meters, flow equalization in storage reservoirs instead of on/off pumping, new pumping group IE4 for backwash water, including energy flow pressure control measures to adjust flow to match real needs, interconnecting reservoirs to improve storage and flexibility, reservoirs level remote control, gravity flow whenever possible, change the continuous operation of all mixers to an alternate mode, eliminate load losses in air service circuit, heat recover form air compressor to $C0_2$ heating system, amongst others.

Adjustment of outdoor lighting intensity to actual requirements needs to consider safety and security aspects, whilst for indoor lighting, adjusting on/off settings to the presence or absence of personal in operational areas was considered.

More important, allowing more natural sunlight into some indoor areas was done by installing additional windows.

There were several areas for improvement, concerning operational aspects identified:

Develop and implement an energy management system, WattWater, to monitor and optimize (in development by an internal team from IT division), applying the business intelligence concept.

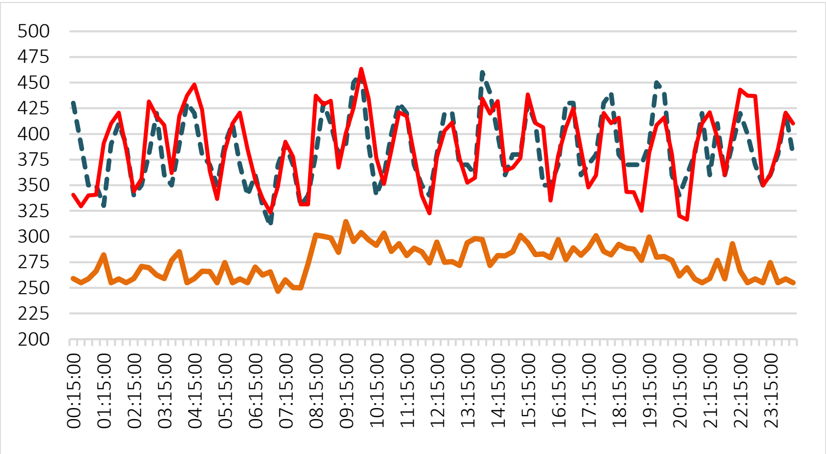

Figure 6 - Asseiceira's WTP: daily diagram (kW) and future consumption

After all these measures have been implemented, it is expected that annual medium daily power consumption will decrease from 385 kW to 275 kW, corresponding to about 27% of energy consumption reduction.

Each opportunity for improvement was evaluated based on criteria associated with the investment total, potential pay-back and its contribution to reducing energy consumption or increase energy production. This assessment was also based on International Organization for Standardization Annex SL and ISO 31000, evaluating each opportunity taking into consideration risks for the environment, workplace safety and health, production, image and reputation and asset management. A holistic approach to energy management was thus applied, being one of the main reasons behind the success of the project.

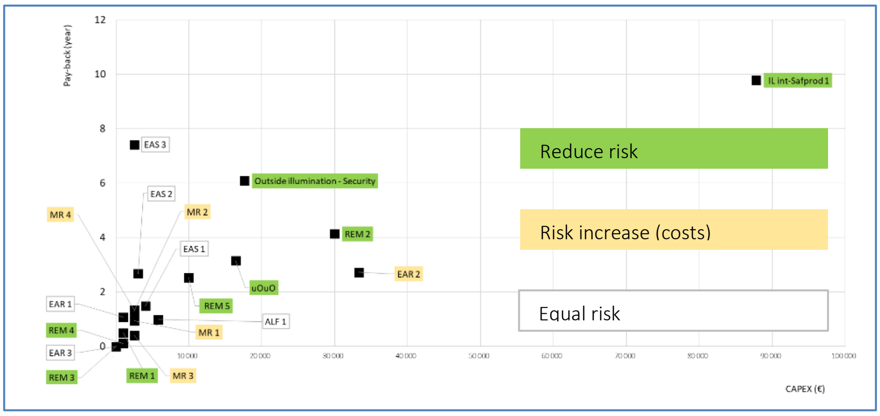

Figure 7 – Measures of energetic efficiency

As can be seen most of the measures have pay-back periods of under five years and reduce operational risk giving more flexibility to operational teams as actions were primarily operational management measures, with a strong commitment to operational planning and control, relying on the capacity of the human resources, knowledge and control of operational issues based on an efficient management approach. All of these measures together have a capex of under €500,000.

The reference situation was obtained by evaluating a two-year historical data period (2014-2015), adopting the principles of the International Performance Measurement and Verification Protocol (IPMVP) published by the Efficiency Valuation Organization (EVO). The WTP treatment stages were evaluated regarding energy consumption and energy production, through measurements of equipment energy usage. Based on this evaluation, significance criteria were defined taking into account energy consumption and improvement opportunities to increase efficiency, selecting the most significant energy uses. These significant uses correspond to around 65% of the total energy consume at the plant.

For the infrastructure as a whole, but also the treatment stages (energy uses), models, simple and absolute ratios were established according to energy use, seeking to accommodate relevant variables such as variability in water quality and quantity treated. Whenever possible and over a wide range of uses this objective was reached with a regression model with adjustment coefficients above 75%, according to the IMPVP methodology being sought. The regression model for Asseiceira WTP is greater than 99%.

EMS and ISO 50001 certification results in an optimization of all process stages that allow reduction of energy consumption throughout the facility water treatment process but also in other areas such as lighting and monitoring, for example.

Energy production

Besides the measures mentioned above, the potential to recover, produce and storage energy was also evaluated, considering renewable energy sources, such as hydro, wind, photovoltaic and, as mentioned, heat recovery from air compressors.

Two locations with high potential to recover potential energy were identified. Two mini-hydro power systems, one inside the plant and other outside in the transport system (1.4 MW and 140 kW), these two systems encompass energy reduction measures identified previously, cover all the water plant energy needs, even producing a surplus of energy that will be used at the water extraction point. The excess energy production will be consumed by the water intake pumping station, 10 km away from Asseiceira WTP.

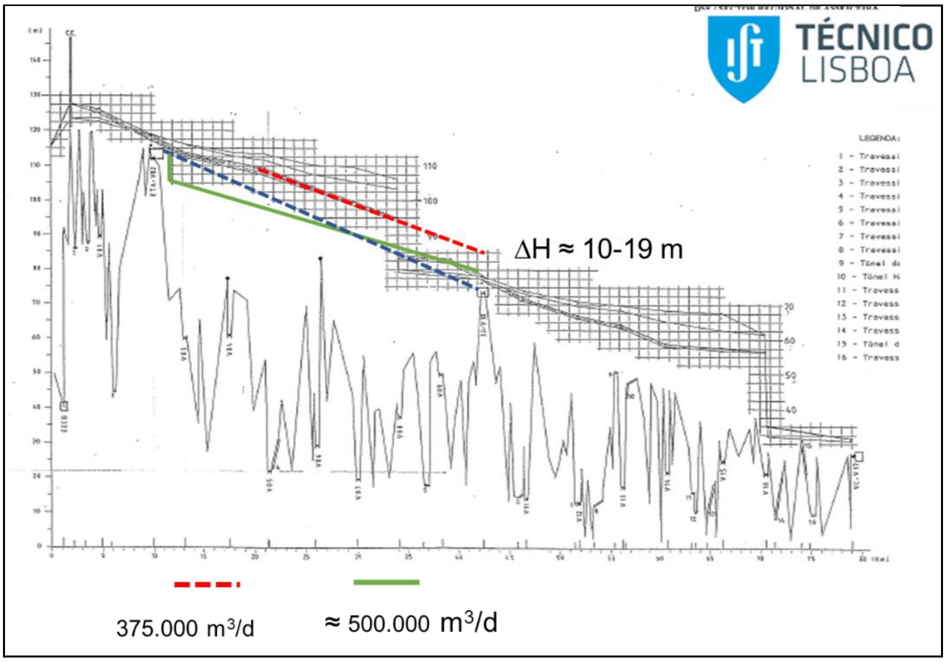

Figure 8 – Castelo do Bode transport system

EPAL's secure ffinancial health allows the financing of these actions (reduction and production) from within its own capital, nevertheless there are several financial instruments, such as the Energetic

Efficiency Fund (FEE) - available to finance measures considered in the National Action Plan for Energy Efficiency (PNAEE). FEE activity is in line with the economic, social and territorial development policy to be promoted between 2014 and 2020, under the "Portugal 2020" program, with support from the European Structural and Investment Funds. This is also in accordance with the established national targets, in order to improve the country's energy efficiency through a 25% reduction in energy consumption by 2020, with the state as an example with a specific objective of reducing energy consumption by 30%.

Solution, Impact & Lessons learned:

Due to process optimization based on measures (process approach) to enhance energy efficiency and simultaneously promote operational flexibility and the two mini-hydro systems, (one inside the plant and other in the transport system of 140 KW and 1,4 GW) it will be possible to cover the remaining energy consumption and also an excess that will be used in the abstraction.The energy balance considered energy saved and energy produced , being notable that the objectives set at the start of the project were achieved and indeed far exceeded the fulfilment of the legal obligations and challenge launched by the management board.

Complex problems may require integrated and disruptive approaches, hence the system/process approach was key to the success of this project and also which allowed the potential to be adopted for any utility inside the AdP Group or any other utility in the water sector. The Asseiceira WTP 0% energy project has the power to boost projects within urban water cycle sector.

The team that developed and implemented this project exclusively used internal resources, with external support only to study hydraulic transients in the transport system by IST Lisboa and action plan review by FCT Nova, being responsible for definition of energy assessment evaluation and consequent fulfilment of the main goal: to make the Asseiceira WTP energy self-sufficient.

Internal engineering, generated in-house business, is the most efficient, effective and quick solution to achieve the most risk-cost-effective results.

The main driver of energy efficiency is based on the knowledge applied to the integration of processes. After process integration, the predictive operation is a second level efficiency driver.

As for the reduction of energy consumption, the main constraints were the necessary investments and pay-back period to enhance energy efficiency measures further.

Regarding energy production: the main barrier is the risk to disturbance along the transport system, namely hydraulic transients. This potential bottleneck was clearly identified and utilised the cooperation of the University – Técnico Lisboa which developed a study on this. It was find and design a solution that provides the best performance for the hydraulic turbine, synchronous Kaplan type small head hydro turbine (20 m), without risk to the core function of providing water in quantity and quality to company customers

With this project it has been proven that the economic constraints, in times of scarce resources, can be overcome by engagement between planning and operational control, based on the competence of human resources and commitment of company management along with strong leadership to implement.

In electric motor pumps, the overall efficiency of the set is obtained by multiplying motor efficiency with pump efficiency. In a WTP, the overall efficiency of process follows the same rule and for the overall company itself. The only way to maximize cost effectiveness and removing bottlenecks, is to approach energy management in a holistic way, considering process links, process interdependences, operations and maintenance restrictions.

Of course this is the most complex way to undertake this but over the long term, it makes the difference on changing individual attitudes to energy efficiency, whilst making the EMS robust and sustainable.

Conclusion

The project started in February 2016, leading to certification of the EMS (NP EN ISO 50001), by an external entity, in October 2016.

Due to the process optimization developed by an internal dedicated team based on measures to enhanced energy efficiency and simultaneously promote the flexibility to operations, it was possible to reduce energy consumption by more than 25% and through the potential energy of the system (two turbines, one inside the plant and other at the transport system, 140 KW and 1,4 GW), it will be possible to cover the remaining energy consumption and also create an excess that will be used at the water intake point. The energy balance considering both energy saved and energy produced largely exceed the objectives set for the project and far exceed fulfilment of the legal obligations.

As for the reduction of energy consumption, the main constraints are the necessary investments and the pay-back period to enhance energy efficiency measures further.

The risk assessment and process approach, by removing the bottlenecks, was crucial to gain the operational and maintenance team confidence and compromise with the project development. This project proved that it is possible achieve efficiency without jeopardising reliability.

The project has the capacity to promote an organizational cohesion, cooperation among different divisions/areas of the company, promoting knowledge transfer and internalization of best practices.

EMS implementation and it's recognition by an external entity, has seen the development of a methodology that can easily be adopted by other facilities within the company.

To achieve an effective reduction of energy consumption, optimizing one of the KPI's that the company has to report to regulator, reduce operational costs, contribute to the economical sustainability of the company, reducing GHG emissions, and giving a great contribute to urban water cycle operators.

References & Acknowledgement

1) https://www.watershare.eu/projects/best-resources-from-water/#energy;
2) https://pt.weatherspark.com/y/32031/Clima-caracter;
3) Project leader – Pedro Fontes

This project was only possible with the commitment of the management board and the dedication and hard work of the multidisciplinary team from different areas of the company who constituted the energy committee, local management team and energy manager.