THE WATER-ENERGY NEXUS: APPLICATION IN TWO PROJECTS FROM EPSEM

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Abstract

Climate change is one of today's biggest problems, and it is closely related to the fundamental resource that is water and the essential service that is energy; in other words, the water-energy nexus.

It is clear that the water-energy nexus is of vital importance today, and that its development is of great interest. As a result, two final master's projects at the Manresa School of Engineering (EPSEM) applied this nexus to the school's facilities. They explore the relationship between the water resource and the energy service.

It is important to note that water is needed to produce energy, while energy is needed to supply water. Each of the two aforementioned projects studied one of the two branches of the nexus:

- Study of EPSEM's water consumption, analyzing the related energy needs: This project analyzes water consumption with a study of its urban cycle; in other words, the process of collection, treatment, distribution, sanitation and purification. Using the data provided by the managers of Manresa's drinking water treatment station and wastewater treatment plant, the kWh required for both the purification and sanitation of water was determined.
- Study of EPSEM's energy consumption, analyzing water needs in relationship to energy production: This product looked at EPSEM's energy consumption and calculated the equivalent amount of water needed for a nearby micro-hydroelectric power plant. To achieve this calculation, data from the Catalan Water Agency's databases were analyzed, including the concession flows and the operating capacities of the micro-hydroelectric plants in the Bages region.

These two projects are part of the CAMPUS LAB program, which associates students' learning, the faculty's knowledge and guidance, and the expertise of technical management staff to improve the sustainability of the Universitat Politècnica de Catalunya · BarcelonaTech (UPC).

Keywords: Water-energy, Nexus, Campus Lab, Climate change, Sustainability.

1 INTRODUCTION

Water and energy are inextricably linked. Water is essential for the production, distribution and use of energy. Energy is crucial for the extraction and delivery of safe drinking water, and for the very safety of water itself [1].

The water-energy nexus is a concept that describes the interdependence and connections between water resources and energy production. This nexus is crucial for understanding how decisions in one of these sectors affect the other, and how integrated management can improve sustainability and efficiency in both fields.

It is true that the growing demand for energy and water, driven by population growth and economic development, presents significant challenges. The overexploitation of water resources and the pressure on energy generation are real concerns that can lead to shortages of both resources. Furthermore, the lack of coordination between water and energy policies can exacerbate the situation, as decisions made in one sector can negatively affect the other. It is essential to adopt an integrated approach to find sustainable solutions that benefit everyone.In order to provide modern, affordable and environmentally sound energy and drinking water services for all, we need a sustainable approach to the management of both freshwater and energy resources. This calls, in turn, for far greater coordination.

This interdependence calls for an improved cooperation between all actors, given the importance of freshwater and energy for sustainable development.

These questions have been addressed with students of Chemical Engineering at the Manresa School of Engineering (EPSEM) in the Universitat Politècnica de Catalunya (UPC), with the aim of raising awareness among engineering students about the need to save both water and energy simultaneously. The first objective of the work has been to determine the kWh required to obtain 1 m³ of water, taking into account the entire water cycle. Secondly, the m³ of water necessary to obtain 1 kWh of electrical energy has been evaluated, assuming that this energy is obtained using water as the source (hydropower).

2 METHODOLOGY

Two final master's projects at the Manresa School of Engineering (EPSEM) applied this nexus to the school's facilities. They explore the relationship between the water resource and the energy service. It is important to note that water is needed to produce energy, while energy is needed to supply water.

In both cases, it was first necessary to determine the total water and electrical energy consumption of the university campus. With this data, the Water-Energy Nexus has been analyzed from two perspectives:

- The energy needs of the urban water cycle, that is, the energy required to capture, treat, distribute, and purify water.

- The water necessary to produce energy in hydropower plants.

The methodology followed in this work involved researching public information on data related to water treatment for drinking and wastewater treatment, as well as data on hydropower energy generation, which allows for establishing the Water-Energy Nexus in Catalonia, specifically in the Bages region where the EPSEM university campus is located.

Each of the two aforementioned projects studied one of the two branches of the nexus:

- **Study of EPSEM's water consumption, analyzing the related energy needs**: This project analyzes water consumption with a study of its urban cycle; in other words, the process of collection, treatment, distribution, sanitation and purification. Each of these stages has an associated energy consumption. By examining the school's water usage, it was possible to determine the volume of potable water consumed as well as the wastewater emitted. Using the data provided by the managers of Manresa's drinking water treatment station and wastewater treatment plant [2], the kWh required for both the purification and sanitation of water was determined.
- **Study of EPSEM's energy consumption, analyzing water needs in relationship to energy production**: This product looked at EPSEM's energy consumption and calculated the equivalent amount of water needed for a nearby micro-hydroelectric power plant, considering that there is only one mini-hydroelectric plant while the rest are micro-hydroelectric, on the Llobregat River, which supplies water to the area (Bages region). To achieve this calculation, data from the Catalan Water Agency's databases [3] were analyzed, including the concession flows and the operating capacities of the micro-hydroelectric plants in the Bages region.

These two projects are part of the CAMPUS LAB program, which associates students' learning, the faculty's knowledge and guidance, and the expertise of technical management staff to improve the sustainability of the Universitat Politècnica de Catalunya · BarcelonaTech (UPC).

Both projects were experiential, as they were applied to the schools where the authors conducted their studies and, as a result, the conclusions can be evaluated and applied in a real setting. This has allowed for improvements in the optimization of water and energy consumption, and thus a more sustainable school.

3 RESULTS

In this section the results obtained in the two master's projects, about the two branches of the water-energy nexus, will be presented.

3.1 Study of EPSEM's water consumption, analyzing the related energy needs

The necessary data has been obtained from the public administration (Catalan Water Agency [2]) and from the company that supplies drinking water in Manresa, Aigües de Manresa [3].

The energy consumption of the integral water cycle in the city of Manresa includes several stages, from the intake and treatment of drinking water to the treatment of wastewater. Each of these stages requires a specific amount of energy, which can vary depending on factors such as the infrastructure used, the efficiency of the treatment systems, and the amount of water managed:

Intake: Water is taken from the Llobregat River using a gravity-based system, which can reduce energy consumption compared to systems that require pumping.

Drinking Water Treatment: This stage involves processes such as filtration, disinfection, and the addition of chemicals, all of which consume energy. The efficiency of the treatments can significantly influence total consumption.

Distribution: The transport of treated water to consumers also requires energy, especially if pumps are needed to overcome elevation changes.

Wastewater Treatment: The process of treating wastewater is one of the most energy-intensive, as it involves biological and physical processes that require energy to operate.

Return to the Environment: Finally, the treated water is returned to the river, completing the cycle.

3.1.1 Energy Consumption for the Obtaining and Treatment of Drinking Water

The most important source of water supply in Manresa is the Llobregat River. The water from the river is directed to Manresa from the *Manresans* Dam, located in the municipality of Balsareny, through the *La Séquia* canalization system, an infrastructure of about 27 km that reaches the *Parc de l'Agulla* in Manresa. This infrastructure operates by gravity, so the energy consumption for water supply is practically zero.

Table 1 shows the consumption provided by the *Aigües de Manresa* Company in the different stages of the purification process. The treated water flow rate is 900 m³/h (7.884.000 m³/year).

Table 1. Energy consumption of the integral water cycle in the city of Manresa

	kWh/ year	***kWh/ m3***
Intake	0	0
Drinking Water Treatment	208.771,00	0,026
Distribution	1.138.800,00	0,14
GLOBAL	1.347.571,00	0,17

The total consumption of drinking water at EPSEM during 2023 was 3.113,00 m³, which is equivalent to 0,355 m³/h. Therefore, the water consumption in relation to the entire city is 0,039%.

3.1.2 Energy Consumption for Wastewater Treatment

The flow of water treated by the Manresa Wastewater Treatment Plant is 7.420.126 m³/year. Considering the treatment equipment available, the energy consumption is 2.863.044 kWh/year. With this data, we obtain a value of 0,39 kWh/m³ of treated water. Considering the number of people at EPSEM, an estimation of approximately 2.916 m³ of wastewater generated during the year 2023 has been made. This value also represents approximately 0,039% of the wastewater treated in the city.

With these results, it is confirmed that the energy consumption for the treatment of wastewater is much higher than that for the treatment of drinking water.

In the case of drinking water, it is important to highlight that the city of Manresa is an exceptional case, as its consumption during water intake is zero. For this reason, a very low value (0,17 kWh/m³) is

obtained compared to the global average of 0,37 kWh/m³ [4] and 0,49 kWh/m³ at the Catalonia level [5]. It should be noted that if pumps are required for water intake, energy consumption increases significantly.

Regarding wastewater, the values indicated in reference [5] are 0.42 kWh/m³, which is also higher than the value obtained for the city of Manresa, 0.39 kWh/m³, but can be considered very similar.

3.2 Study of EPSEM's energy consumption, analyzing water needs in relationship to energy production

First, it was necessary to determine the annual electricity consumption of EPSEM. For this reason, the different facilities have been considered, as indicated in Table 2.

Table 2. Annual Energy Consumption of the Facilities at the Manresa Campus.

Element	*Consumption (kWh/year)*	*%*
Laboratories	94.761,19	30,23
Racks	59.537,10	18,99
Computer classrooms	18.722,40	5,97
Regular classrooms	11.221,28	3,58
Teacher offices	20.972,56	6,69
Outdoor	7.477,76	2,39
Offices	1.714,56	0,55
Library	99.049,00	31,60
GLOBAL	313.455,85	100

As seen in Table 2, the highest consumption is in the Laboratories and the Library of the Campus. The total consumption of the Campus is 858,78 kWh/day.

Based on the data obtained from the ACA [6], it has been verified that in the Bages region there are a total of 39 hydroelectric plants on the Llobregat River, of which only one is a mini-hydroelectric plant and the rest are micro-hydroelectric plants. Among them, the *Pont de Cabrianes* plant, located near Manresa, has been selected, and the operational data indicated in Table 3 has been obtained.

Table 3. Characteristics of the Pont de Cabrianes micro-hydroelectric plant.

Power (kW)	*Concession flow (m^3/day)*	*Energy generated (kWh/day)*	*m^3/kWh*
140	207.350,00	3.360,00	61,71

Finally, comparing the data from Table 3 with the energy consumption of the Manresa Campus, it would be possible to supply the Campus with 25.6% of the flow of the micro-hydroelectric plant's concession. This would represent 52.995,31 m³/day. It is important to note that the use of water in this type of plant is non-consumptive. Therefore, it cannot be considered consumed water, as it is returned to the Llobregat River once used.

4 CONCLUSIONS

In this work, to evaluate the kWh/m³ of water used and returned to the environment at the university campus, it was necessary to conduct a study of the supply and types of treatments in the city and region where the Campus is located.

For the drinking water, the obtained value is significantly lower than the values indicated in the consulted references, but this fact can be explained by considering the uniqueness of the water intake method in

the city of Manresa. Water is obtained from the Llobregat River using a gravity-based infrastructure built in the 14th century. The obtained value of kWh/m³ of water in the case of wastewater treatment is completely consistent with the values in the literature.

It is confirmed that the amount of water used at the university campus represents a very low percentage of the total water treated in the city.

Regarding the water necessary to obtain energy, if it were sourced from a micro-hydroelectric plant in the area, it is confirmed that the Campus could be supplied with 25% of the capacity of the selected plant. Although the amount of water needed to obtain energy is high, its use is non-consumptive, and while maintaining ecological flows, the water is returned to the river of origin.

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