Water efficiency in buildings: assessment of its impact on energy efficiency and reducing GHG emissions

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Abstract: - Nowadays humanity uses about 50% of existing drinking-water, but in the next 15 years this percentage will reach 75%. Consequently, hydric stress risk will rise significantly across the entire planet. Accordingly, several countries will have to apply efficient hydric measures in the water-supply sector, including at the building level. These measures, in addition to reducing water consumption, will contribute towards increasing energy efficiency and decreasing the emission of greenhouse gases (GHG), especially CO_2 emissions. This paper is focused on the study of a region in the center of Portugal (Aveiro). Its aim is to assess the impact of the implementation of efficient devices in water consumption facilities in the global urban water cycle, as well as the increase of energy efficiency and the decrease of GHG emissions.

Keywords: - Hydric efficiency, efficient water devices, energy efficiency, GHG emissions.

1 Introduction

The risk of hydric stress is increasing significantly across the entire planet, especially in the Mediterranean basin, and in some European countries such as Portugal. Accordingly, very serious problems are likely to appear in the short to medium term in most of the territory of these countries [1]. This situation is critical and needs urgent intervention through the application of measures to rationalize water use.

On the other hand, cities generally have a high concentration of energy demand and consequently are responsible for a high amount of greenhouse gas (GHG) emissions, including CO_2 [2]. Globally, buildings are responsible for approximately 40% of total annual world energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air-conditioning [3].

In Portugal, the building sector presents the second highest growth rate of energy consumption, immediately following the transport sector. According to recent data from energy balances of the General Ministry for Energy and Geology [4], residential and service buildings are responsible for the consumption of about 30% of total energy and for more than 60% of total electricity consumed at the national level. Nearly 50% of energy consumption by residential buildings is due to heating sanitary hot water (SHW) [5].

In the European Union, buildings through their life cycle (construction, operation, and demolition) consume approximately 50% of the total energy demand and contribute almost 50% of CO_2 emissions, the basic gas responsible for the greenhouse effect [5].

To obtain a reduction of CO_2 emissions, effective measures must be taken during its use phase, because the latter represents 80-90% of the total energy consumed throughout its entire life cycle [6].

It should be noted that increased efficiency in water use in buildings leads to the reduction of water consumption and wastewater effluents, increasing energy efficiency and contributing to the reduction of GHG emissions [1][7][8].

Thus, the increase of water efficiency consumption in buildings – in addition to being a strategic necessity in many countries – should be seen as a key measure to consider for the overall sustainability of buildings.

This paper, studying a municipality located in the central region of Portugal as a case study (Aveiro, with 73 000 inhabitants), evaluates the impact of the use of efficient products in buildings to reduce consumption of drinking-water in the global urban cycle, to increase energy efficiency and reduce emissions of greenhouse gases.

2 Water efficiency in buildings

The construction of an efficient water cycle in buildings can be summarized by analogy with the 3R principle (used for waste) which is known as the 5R principle [1] (Figure 1).

- Reduce consumption
- Reduce loss and waste
- Re-use water
- Recycle water
- Resort to alternative sources

} *- Water efficiency in buildings*

Fig. 1 – The 5R principle for water efficiency in buildings [1]

The need for efficient water usage has already been recognized in Portugal as a national priority through the publication of a National Program for Efficient Water Use (PNUEA) [9]. Amongst the actions suggested in this Plan to reduce consumption is the proposal for labeling building devices (flushing systems, showers, etc.) in order to provide consumers with information about water efficiency.
The PNUEA also predicts the involvement of companies, management organizations, and non-governmental organizations for the implementation of the referred measures. Accordingly, a Portuguese NGO dedicated to the promotion of quality and efficiency in building services – ANQIP (National Association for Quality in Building Services) – decided to launch a certification and labeling model for the water efficiency of products. Figure 2 shows the labels used [1]. The base colours, which cannot be seen in the Figure, are green and blue.
"A" represents the efficiency that is considered ideal. It also takes into account the user-friendly devices, performance, and aspects of public health. The A+ and A++ ratings are intended for special or regulated applications.

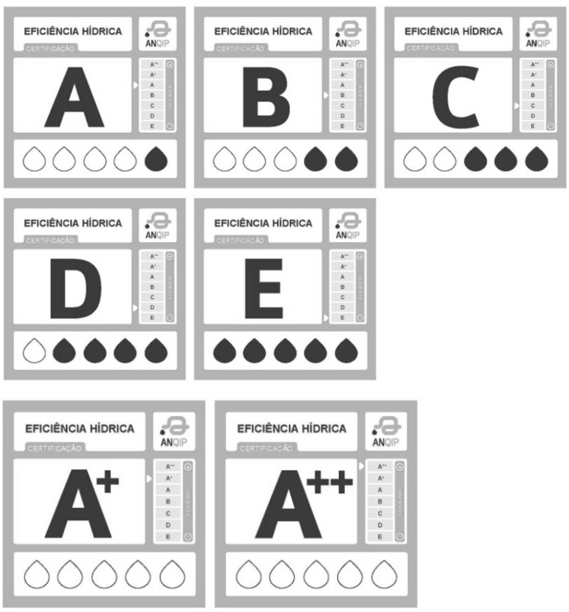

Fig. 2: Portuguese water efficiency labels [1]

ANQIP has drawn up Technical Specifications (ETA) for different products to create and establish the necessary benchmark values to be assigned to each letter. These Technical Specifications also establish the certification testing conditions.
Table 1 presents, for example, the categories defined in the Technical Specification ANQIP ETA 0806 for showers and shower systems.
Shower systems and showers represent more than 30% of the daily average of domestic water consumption volume in Portugal [10] [11]. At this level, efficiency reduces both water consumption and the energy consumption required for hot water production.
The taps for bathtubs were not rated, because water consumption in this case depends on the volume of the tub when full, and not on the device discharge.

Table 1: Water efficiency ratings for the labeling of showers and shower systems [11]

Discharge (Q) (l/min)	Showers	Shower systems	Shower system with a thermostatic tap or an eco-stop function	Shower system with a thermostatic tap and an eco-stop function
$Q \leq 5$	A+	A+	A++ (1)	A++ (1)
$5.0 < Q \leq 7.2$	A	A	A+	A++
$7.2 < Q \leq 9.0$	B	B	A	A+
$9.0 < Q \leq 15.0$	C	C	B	A
$15.0 < Q \leq 30.0$	D	D	C	B
$30.0 < Q$	E	E	D	C

(1) The use of an eco-stop is not considered in these cases

3 Evaluation of the impact of the use of efficient products

ANQIP has developed a study to analyze and estimate consumption reductions and corresponding energy savings in a typical house with efficient products (letter A), in comparison with a house equipped with non-efficient products, which is a common occurrence in Portugal [1].
This study assumed an average occupancy of 2.7 persons per house, and can be easily transposed to the region that is the subject of the present study (the municipality of Aveiro).
Taking into account the accumulated time of usage or the usual number of uses per person, water and energy consumption and costs were obtained as depicted in Table 2. It was considered that a typical house should be equipped with showers, washbasins, WC flushing, sink dishwasher, and washing machines.
With regard to water tariffs, the value adopted in Aveiro is currently 1.1 €/m^3. Regarding energy costs, and considering the use of electricity, the price in Portugal is about 0.12 €/kWh. For natural gas, the

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value is approximately the same. Note that these figures are "conservative", because VAT and fixed terms are not included.
Accordingly, in order to heat 1 m^3 of water to 37ºC, 30 kWh of energy are required; 0.0036 €/l are thus spent using gas or electricity.
The Tables 2 and 3 show the results of the application of these values.
For washing machines and dishwashers, weighted average values were adopted from the catalogs of the manufacturers (1.20 kWh and 1.05 kWh per wash, respectively).

Table 2: Water and energy costs in a typical house with conventional products

Product	Total (l/day)	Water cost (0.0011 €/l)	Energy cost (0.0036 €/l)	Total cost (€/day) Water + Energy	Total cost (€/ /month) Water + Energy	Total cost (€/year) Water + Energy
Shower	121.5	0.134	0.437	0.571	17.13	208.42
Bathroom tap	64.8	0.071	0.233	0.304	9.12	110.96
Kitchen tap	60.0	0.066	0.216	0.282	8.46	102.93
Product	Total l/day	Water cost (0.0011 €/l)	Energy cost (€/per cycle)			
Flushing cisterns	145.8	0.160	-	0.160	4.80	58.40
Washing machine	90.0	0.099	0.140	0.239	7.17	87.24
Dishwasher	22.0	0.024	0.130	0.154	4.62	56.21
TOTAL	504.1	0.772	1.156	1.71	37.93	624.16

Table 3: Water and energy costs in a typical house with efficient products (letter "A")

Product	Total (l/day)	Water cost (0.0011 €/l)	Energy cost (0.0036 €/l)	Total cost (€/day) Water + Energy	Total cost (€/ /month) Water + Energy	Total cost (€/year) Water + Energy
Shower	81.0	0.089	0.292	0.381	11.43	139.07
Bathroom tap	19.4	0.021	0.070	0.091	2.73	33.22
Kitchen tap	18.0	0.020	0.065	0.085	2.55	31.03
Product	Total (l/day)	Water cost (0.0011 €/l)	Energy cost (€/per cycle)			
Flushing cisterns	97.2	0.107	-	0,107	3.21	39.06
Washing machine	45.0	0.050	0.071	0,121	3.63	44.17
Dishwasher	16.0	0.018	0.060	0,078	2.34	28.47
TOTAL	276.6	0.305	0.558	0.843	25.89	315.02

Analyzing these tables, it was concluded that the total estimated savings for a medium-sized house are extremely significant, amounting to approximately 45% (227.5 l/day = 83 m^3/year), considering only water savings in volume, or 50%, considering the cost of water and energy (309 €/year per family).
The showers represent, in Portugal, near 40% of water consumption in buildings and the main consumption of sanitary hot water (SHW). So, the Portuguese Government is planning to introduce the use of efficient products as a factor to consider for the energy certification of buildings.
Considering only these types of device, it is now possible to compare the savings obtained using efficient showers and showers systems (Table 5), in comparison with conventional ones (Table 4).

Table 4 – Energy costs (sanitary hot water) in a house with conventional products

Product	Total consumpt. l/day	Energy cons. (0,03 kWh/l)	Energy cost (0,0036 €/l)	Total energy cost (€/ /month)	Annual energy consumpt. (kWh/year)	Total annual cost (€/year) Energy
Shower (family)	121,5	3,645	0,437	13,11	1330,64	159,51
Per person	45	1,350	0,162	4,86	492,83	59,13

Table 5 – Energy costs (sanitary hot water) in a house with products in category "A"

Product	Total consumpt. l/day	Energy cons. (0,03 kWh/l)	Energy cost (0,0036 €/l)	Total energy cost (€/ /month)	Annual energy consumpt. (kWh/year)	Total annual cost (€/year) Energy
Shower (family)	81,0	2,43	0,292	8,75	886,00	106,43
Per person	30,0	0,90	0,108	3,24	328,15	39,42

As depicted in these tables, a saving of 33% per person (15l/day=5.5m^3/year and person) is achieved, corresponding to a decrease of about 445 kWh/year and family (or 165 kWh/year and person).
As the municipality of Aveiro has 73 000 inhabitants (27 000 homes), if these measures were applied to the whole population, the result would involve an energy saving of about $12x10^6$ kWh/year.
This is not however the only saving obtained, because the reduction of water consumption in buildings implies a reduction of the volume extracted treated and pumped, and also a reduction in the volume of treated and pumped wastewater.
In the municipality of Aveiro, energy consumption in the public network is 0.838 kWh/m^3 for water supply, and 0.818 kWh/m^3 for wastewater drainage and treatment.
Moreover, the percentage of water losses in the public water supply system of the municipality of Aveiro is almost 38%, i.e., for every m^3 in the consumers' home, 1.38 m^3 must be produced at the origin.
Regarding wastewater, it is estimated in Aveiro that approximately 90% of normal domestic water consumption reaches the sewers; the explanation for this is that some water consumption refers to expenditure deriving from garden watering, washing of pavements, etc. However, the water saving obtained with efficient products corresponds to

volumes that in general are going to be conducted to public sewers, and should thus in this case be considered 100%.

Returning to Tables 2 and 3, and considering these figures, it can be concluded that a saving of 83 m^3/year per family implies a potential reduction in the production of drinking-water of 115 m^3/year per family, i.e. a total of about $3.1x10^6$ m^3/year for the Aveiro municipality (considering 27 000 homes). For wastewater, the value is 83m^3/year per family, i.e. a total reduction of about $2.24x10^6$ m^3/year.

Taking into account energy consumption per cubic meter, a saving of $2.6x10^6$ kWh/year was obtained in the water supply system, and $1.8x10^6$ kWh/year in the drainage and treatment system, representing a total saving of $4.4x10^6$ kWh/year. Considering, in addition, prior economy (Tables 4 and 5) in the heating of SHW in buildings (only for showers), a very significant value of $16.4x10^6$ kWh/year is obtained for global potential saving.

4 Energy saving and reduction of GHG

Savings in the public system of water supply and wastewater are thus $4.4x10^6$ kWh/year, as determined previously. The type of energy used in public systems is electrical power.

In Portugal, electric power is produced from a mix of technologies, including hydro, coal, wind, nuclear, natural gas and others, involving also importation.

The most significant contribution to GHG emissions in Portugal, in the energy sector, corresponds to CO_2.

According to the Portuguese Energy operator (EDP), emissions of CO_2 are weighted to 369.23 g/kWh of electricity. Other gases such as SO_2 (1.60 g/kWh) or NO_x (1.06 g/kWh) have a negligible contribution.

In this scenario, it is easy to conclude that energy savings in these systems allow for a reduction in CO_2 emissions close to 1.625 tons/year.

In building systems, the energy source mostly used in the Aveiro region for heating SHW is LPG (propane or butane), although electricity is also significant. More recently, solar energy and natural gas have also undergone increasing applications.

There are no known studies that examine the corresponding percentages for each of these sources in the region of Aveiro. So, this paper takes as a reference the LPG, because its emissions are lower than those of electricity and other sources are not yet prevalent. For LPG, CO_2 emissions of around 248 g/kWh can be considered.

Taking into account the estimated savings on heating SHW, according to Tables 4 and 5, a reduction in CO_2 emissions of almost 3.000 tons/year can be obtained.

In summary, it can be argued that the widespread implementation of water efficiency measures can lead, for a population of around 70 000 inhabitants, to a reduction of GHG emissions of 4.625 tons per year, meaning about 66 kg CO_2 per inhabitant and year.

5 Conclusion

Efficient water use is an environmental priority in all countries of the world.

In Portugal, the use of efficient products, for example, can provide a saving close to 45% in water consumption, but should be reflected not only in relation to the parameter of water, but also in relation to energy efficiency.

Indeed, an estimate of savings through the use of efficient products in housing in Portugal could reach more than 1.15 billion Euros per year, considering water and energy (309 €/year and family).

A study conducted in the city of Aveiro (in the center of Portugal), with a population of 70 000 inhabitants, has revealed that the potential savings in terms of energy spending in the urban water cycle and in the heating of water in the residential sector, with the use of efficient products, can afford a reduction in CO2 emissions of about 4.625 tons/year, i.e. about 66 kg CO_2 per inhabitant and year.

These results underscore the importance of water efficiency in buildings, not only as a means for rational use of water, but also for its significant contribution to the energy efficiency of buildings and reducing the emission of greenhouse gases.

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