# CLIMA 2016 - proceedings of the 12th REHVA World Congress

*volume 3*

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*Publication date:*
2016

*Document Version*
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

*Citation for published version (APA):*
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 3*. Department of Civil Engineering, Aalborg University.

# Impact of using solar heat pumps for domestic hot water in Portuguese residential buildings.

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**Abstract**

*In recent years, we have seen an improvement of existing facilities in dwellings in Portugal. Within the heat pumps systems, there is a special type known as direct expansion heat pump assisted by Solar Collector (DX-SAHP). It was calculated the SPF indicator for 30 regions of Portugal. It was analyzed the potential of reductions of $CO_2$ and primary energy use for the retrofitting of DHW preparation systems. It was found that the performances of this type of equipment are benefiting from the Portuguese climate conditions, especially in the South and in the Autonomous Regions. Best SPF was obtained for Beja. It was found in all regions the high potential for reducing $CO_2$ emissions and verifying a potential significant reduction of primary energy consumption.*

***Keywords – DX-SAHP; SPF; Retrofitting***

## 1. Introduction

In recent years, we have seen an improvement of existing facilities in dwellings in Portugal. Between 1981 and 2011, the number dwellings with shower or bath increase from 57,4% to 98%, the number of dwellings that do not have any of these systems can be considered negligible [1]. There are numerous solutions installed for the production of Domestic Hot Water (DHW) in Portugal. The distribution of such solutions depends on several factors, among which we highlight the following: localization; type of accommodation; availability of energy source and historical and cultural factors. In Table 1, we can see the distribution of types of energy sources used in Portugal for DHW. Analyzing the data, we can see that most of the energy used, about 78%, is Liquefied Petroleum Gas (LPG) or natural gas, and within this group the highest prevalence lies with the LPG cylinder (butane), with about one-third of all energy used. This stems from the lack of piped gas network in many parts of the country. We can also see that electricity and solar thermal are use in a small amount, less than 7%.

Table 1 – Total energy consumption DHW - Portugal [2].

| Type of energy source | Consumption (toe) | % Total |
|---|---|---|
| Biomass | 41016 | 7,03 |
| Electricity | 19639 | 3,37 |
| Natural gas | 162782 | 27,92 |
| Heating Diesel | 49191 | 8,44 |
| LPG | 43396 | 7,44 |
| LPG cylinder (butane) | 201173 | 34,50 |
| LPG cylinder (propane) | 48284 | 8,28 |
| Solar thermal | 17559 | 3,01 |
| Total | 583040 | |

In this study, we will analyze de impact of replacing actual solutions like storage tank with electric resistance and LPG boiler for Direct Expansion – Solar Assisted Heat Pump (DX-SAHP).

## 2. Methodologies

There are several types of heat pump: Air-Air; Air-Water; Water-Water; Water-Air; Earth-Air and Earth-Water. Of the types listed above the most used for the preparation of DHW is the Air-Water. In this system, the existing heat in the cold source (outside air) is transferred to the hot source (storage tank). Within the air-water systems, there is a special type known as direct expansion heat pump assisted by Solar Collector (DX-SAHP). This system is unique in that besides using the heat from the outside air, also use the heat from solar radiation (direct and diffuse). Unlike other systems, heat pumps use as a reference the Coefficient of Performance (COP) that can be defined as:

$$COP = Q_Q / W_c \quad (1)$$

Where $Q_Q$ is the useful heat transfer to the water and $W_c$ is the power consumption of the compressor. The value of the COP announced by the heat pump manufacturers is determined according to European standards [3]. This represents the electrical energy used due to a hot water discharge profile and takes into account all the equipment and not only the vapor compression cycle. This test is carried out at rated operating conditions of the equipment. However, in the latest test methodologies take into account the local weather conditions, being presented a new indicator Seasonal Performance Factor (SPF) [4], which can be calculated by:

$$SPF = (\Sigma_i h_j * E) / (\Sigma_i h_j * E / SPF_j) \quad (2)$$

Where *E* is the daily total energy provided to the water and *h* is the frequency of daily average temperature. As we can see in this indicator, the value of the effectiveness of the heat pump depends on the climatic conditions of the installation location. Portugal due to its climate, it offers very favorable conditions for the installation of heat pumps for domestic hot water preparation.

As previously stated, SPF of DX-SAHP depends on the climate. In this study we determined the SPF of the Territorial Units for Statistics 3 (NUTS) [5]. This territorial level consists of 30 units, of which 28 are on the mainland and 2 corresponding to the Azores and Madeira. According to [6], the SPF of this type of heat pump can be obtained through empirical correlation.

$$SPF = 0{,}051T_{air} + 1{,}1091 \quad (3)$$

This relationship is valid for a system with refrigerant R134a, evaporator with 1.6 $m^2$, a storage tank with a nominal volume of 300 liters with static losses of 1,17 kWh/day and a compressor with a rated power of 455W. To estimate the average daily outside temperature, we used climate data used in the Energy Certification System (SCE) [7]. This analysis was performed for a dwelling of 4 people. To determine the annual needs of DHW, we use Equation 4 [8]:

$$Q_a = (M_{AQS} * 4187 * \Delta T * n_d) / 3600 \quad (4)$$

Where $\Delta T$ is the temperature increase necessary for the preparation of domestic hot water and for the purposes of this calculation, taking the 35 °C reference value, $n_d$ is the annual number of days of consumption of DHW for residential buildings, for the purposes of this calculation, it is considered 365 days. Considering a dwelling with 4 occupants, we get a yearly energy needs for the DHW of 2377,286 kWh. Considering 365 the number of days of consumption we obtain a value of 6,513 kWh/day.

For the analysis, we consider the renovation of 2% of the Portuguese dwellings with 4 occupants (1% with electric water heater and 1% with boiler butane LPG) for a total of 13382 [9]. It was considered a total efficiency of 100% and 93,2% for the electric water heater and the boiler respectively.

## 3. Results and discussion

The SPF calculations for NUTS considered can be seen in Figure 1. As expected, the value is higher in places with a higher average outside temperature. Despite the differences, the values range between 1,81 and 2,02 in Bragança in Beja, a difference of about 11%.

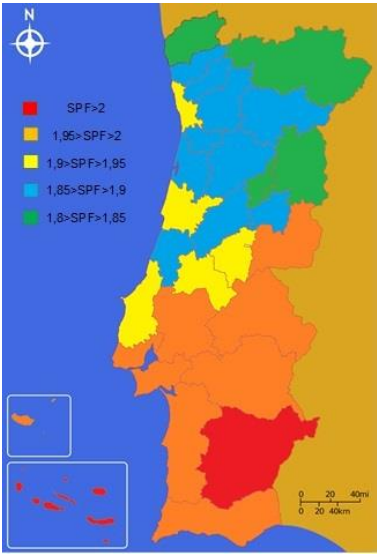


Fig. 1. SPF anual – NUTS 3.

As expected, the best values of SPF are obtained in the south of the country and in the autonomous regions of Madeira and the Azores, due to milder winters and higher average levels of solar radiation.

We can see in Figure 2 the value of reducing energy consumption of electricity and LPG butane for the dwellings according with region.

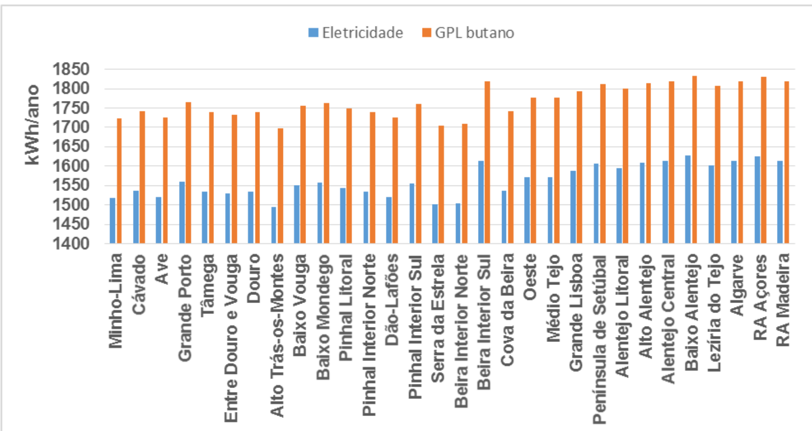


Fig. 2. Potencial of anual energy consumption reduction.

In total of the dwellings we get an annual reduction of 10,477 GWh of electricity and 11,846 GWh of LPG butane. In total we get a total annual reduction in $CO_2$ emissions of 3523 tons. Finally it calculated the annual reduction of primary energy by implementing the measure. In total we get a reduction of 4102 toe.

## 4. Conclusions

We can conclude that the DHW preparation systems that use heat pump systems including the DX-SAHP type are a good alternative for the Portuguese market.

It was found that the performances of this type of equipment are benefiting from the Portuguese climate conditions, especially in the South and in the Autonomous Regions. Best SPF was obtained for Beja. Despite this, the use of such systems throughout the national territory is advisable because even in the worst region (Bragança), the SPF value is only lower by about 11% of the national ceiling.

It was found in all regions of the high potential for reducing $CO_2$ emissions, by replacing the water heater type electric equipment and boiler LPG butane, verifying also a potential significant reduction of primary energy consumption.

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