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Evaluation of the potential energy savings of a centralized booster heat pump in front of conventional alternatives

X. Masip [a, b, *], Carlos Prades-Gil [a, b], Emilio Navarro-Peris [a], J.M. Corberán [a]

[a] *Instituto Universitario de Ingeniería Energética, Universitat Politècnica de València, València, Spain*
[b] *ImpactE, c/ Joan Verdaguer n16, València, 46024, Spain*

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ABSTRACT

The current technologies used for DHW production in the city of València (Spain) are mainly gas boiler and immersion electric heater that are individual installations, high energy consuming technologies and high CO2 emitters. There exists a high energy savings potential on DHW production based on the introduction of smart energy systems with Heat Pumps (HP) and also with the generalization of collective installations. To this purpose, this research aims to deeply analyze different DHW production scenarios, individual and collective, for a real district of the city of València in order to obtain its energy savings potential. The cases analysed are: immersion electric heater, HP water heater as individual installations and the smart energy system as a collective HP booster installation coupled with an Ultra Low District Heating network. The results of a first evaluation for a group of 315 dwellings show higher energy savings and higher system global efficiency for the collective installation in front of the individual installations considered. The improvements show up to 70% energy savings in front of the immersion electric heater and 1.5 points higher system global efficiency regarding the HP water heater for the specific case analysed. Furthermore, the collective installation needs lower power installed and tank volume.

1. Introduction

The European Union (EU) has settled the objective of reducing the global warming emissions of the residential sector to a level of 90%, regarding the levels of 1990, for 2050 [1]. Currently, the residential sector is responsible for 40% of the total energy consumption of the EU and 36% of the CO2 emissions in Europe [2]. The average EU household accounts for a 65% heating consumption and 14% Domestic Hot Water (DHW) consumption. In this way, the EU defined for first the concept of Near Zero Energy Building (NZEB) in the EPBD Directive 2010/31/UE. The NZEB concept intends to reduce the heating consumption to a near zero value Therefore, the DHW consumption will play a key role in the near future in the issue of decarbonization of the residential sector since the current percentage of 65% associated to heating will be reduced to near 0% value and, in this manner, the DHW will represent a much higher importance. Furthermore, the conventional technologies for DHW production are mainly: the immersion electric heater (in Spain accounts for 32.2% [3]) and gas boiler (67.7% [3]). These technologies are individual options, very low energy efficient and high CO2 emitters and in this manner the DHW production presents a high energy savings potential for a smart energy district.

With the objective of reducing the DHW energy consumption, high energy efficient facilities are needed. This can be addressed with smart energy systems such as Heat Pump (HP) technologies and furthermore with collective installations. HPs are for DHW application an interesting alternative to the conventional systems due to its considerable higher efficiency as stated in Refs. [4–6] and recognised as a renewable energy resource by Ref. [7]. Moreover, collective installations allow to high energy savings and reduced power needs for the installation. Nevertheless, the conventional collective installation, such as District Heating (DH) network with CHP-DH combination are struggling in front of more energy efficient commercially available individual Heat Pumps (HP) [8]. However, an interesting option that is emerging nowadays, as indicated by Refs. [9–11], is the combination of Ultra Low District Heating Networks (ULTDH) with collective booster HP. This option allows to reduce the temperature of the DH network and thus

* Corresponding author.Instituto Universitario de Ingeniería Energética, Valencia, Spain.
E-mail address: xmasip@iie.upv.es (X. Masip).

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reduce their energy losses as well as increase the COP of the booster HP [12]. Furthermore, it allows for a higher impact on profitability over renewable generators as stated in Ref. [13]. This concept is included in the 4th generation DH (4GDH) to deliver heat to sustainable energy systems as part of an overall smart energy systems including renewable energy as stated in Ref. [14]. A very interesting option, moreover considering the DHW production, is the 5th generation DH and Cooling (5GDHC) included in Ref. [15]. It consists of combined heating and cooling for smart energy districts. However, the option of DH is not much used in Spain. 134 (490 MW) cases are known in Catalonia [16] and only 9 (13 MW) in Valencian community and most of them are for heating.

In conclusion, there exist a problem regarding DHW production since the current situation is dominated by individual very low energy efficient facilities. Nevertheless, there exist several options for solving this problem; such as high energy efficient individual installations or collective installations. To this purpose, this research aims to analyze and compare four different possible scenarios of DHW production for a district of the city of València. The cases compared account for two typologies of individual installations in front of a collective installation. The individual installations are a tank with an immersion electric heater and heat pump water heater. The collective installation is a booster HP working with the net temperature as a source and with a ULTDH network at 20C.

2. System description

This section describes in detail the different cases analysed and the simulation procedure. A first subsection introduces and explains the features of the different cases considered and the next includes the description of the district selected and its demand calculation. Finally, the last subsection presents the optimization variables and model assumptions.

2.1. Cases analysed

Three different technologies have been selected for this research work:

- the immersion electric heater, representing a conventional individual DHW installation,
- a commercially available HP water heater, representing a more efficient option of individual DHW installation, and
- the smart energy system: a booster HP, representing a collective and highly efficient DHW installation

The models have been created and analysed by using the transient simulation tool TRNSYS [17]. In this section each of the features of the cases analysed and the models created with TRNSYS software are presented thoroughly in different subsections, one for each case. Whereas the features that all the cases have in common are presented next.

An environment constant temperature of 20C, similar to the one of a kitchen or a machinery room, has been considered as the most probable temperature for the location of the equipment. The temperature control was established with a set-point temperature of 60 °C and a lower dead band of 8 °C. However, the supply temperature to the user was considered to be 45 °C and a tempering valve was added to the models. The insulation of the tank was considered according to the Spanish normative for the three models as 0.8 W/m^{2}K. The water source temperature is shown in Fig. 1.

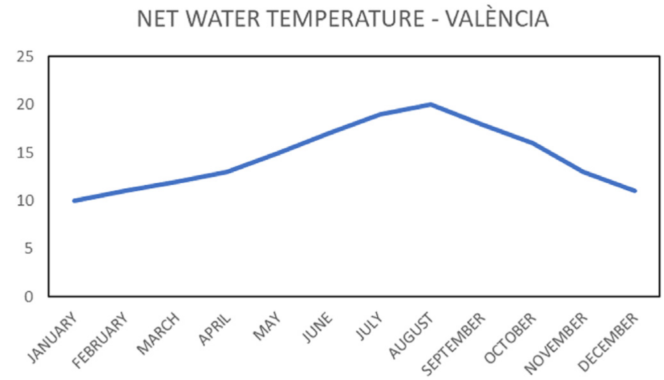

Fig. 1. Water source temperature throughout the year [18].

2.1.1. Immersion electric heater

The immersion electric heater was modelled using as a reference a commercially available immersion electric heater and has been validated with the energy label of it. The specifications of the model are described in the following.

The heater consists of an 80 L storage tank with an aspect ratio of 2 and the temperature sensor in the top node (considering 15 nodes for the tank model). The immersed electric heater has a nominal capacity of 1500 W and is allocated at one third of the height of the tank (starting from bottom). The inlet to the tank from the source was considered at 5% of the height of the tank and the outlet to the mixing valve at 95%, as specified in the commercial model.

2.1.2. HP water heater

The HP water heater consists of an air source HP with a wrap-around condenser coil in the storage tank, as the one described in Ref. [19] and shown in Fig. 2.

This case was also modelled taking as reference a commercially available system and validated against the datasheet of the manufacturer. The HP water heater consists of an 80 L storage tank with an aspect ratio of 2 and the temperature sensor control in the top node of the tank. The air source HP has 250 W capacity compressor, 900 W of heating capacity and an immersion electric

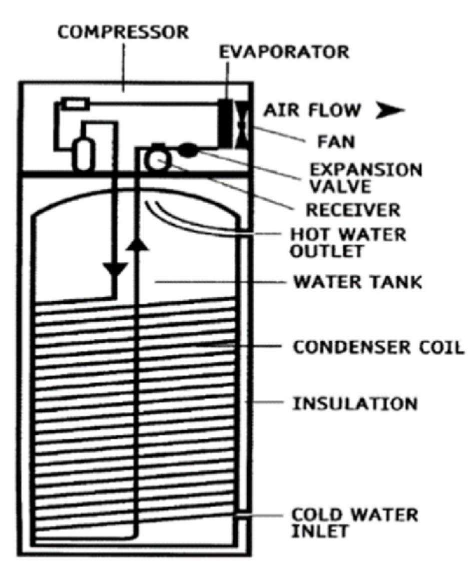

Fig. 2. HP water heater illustration with wrap-around condenser [19].

heater of 2000 W as auxiliary equipment. The condenser is wrapped-around the tank around the 25% of the height of the tank and the immersion electric heater is located at the 10% of the height of the tank. The commercial model only allows the HP to work until 55 °C and from 55 °C until 60 °C works the auxiliar immersion electric heater.

2.1.3. Booster HP

The booster HP installation consists of a variable-volume storage tank, a booster HP and a heat recovery unit, as illustrated in Fig. 3. This HP installation corresponds to the one developed and analysed in Ref. [20].

The main components are a Braze Plate Heat Exchanger (BPHE), a variable-volume storage tank and the HP model. The BPHE that takes profit of the DH network to preheat the inlet water to the condenser, but if the case does not consider heat recovery the BPHE is bypassed. For the analysis two cases have been considered: one considering an ULTDH network and another one with no DH network in which the HP takes the water at source temperature. For this ULTDH network the sewage water could be used as has been demonstrated in Ref. [21]. The variable-volume storage tank (aspect ratio of 4) consists of a fully-mixed tank (pressurized) with 1 inlet fixed and 1 outlet fixed so that the water volume inside reduces when there is demand and increases when the system is on, as shown in Fig. 3. In this way, the facility has two different controls. One of the controls for the temperature in the tank and the second for the volume inside the tank. The temperature control corresponds to the set-point and dead band previously commented and the control volume corresponds to a minimum value of volume inside the tank defined with one optimization parameter '*alpha*' further explained in section 2.3. Model assumptions and optimization variables. For a proposal of implementation of this tank with the HP installation see Ref. [23].

For this collective production systems, the circulation losses suppose a non-negligible consumption. In Spanish building code [24,25] consider a value of 10% over the total consumption of the system for this loss. However in Ref. [22] they say as cited in Ref. [26] that this efficiency can be as low as 30%. According to this paper, the circulation loss can range from 25% in well-insulated systems to 300% with poor pipe insulation. Considering the wide ranges of potential circulation losses, a parametric study on this value was undertaken for the evaluation of this collective installation. However, considering that a new installation (well-insulated) will be of application for the case study, a value of 30% circulation losses over total system consumption was selected for presenting the results. It also has to be taken into account that the case study applies over a group of big buildings and not on unfamiliar apartments.

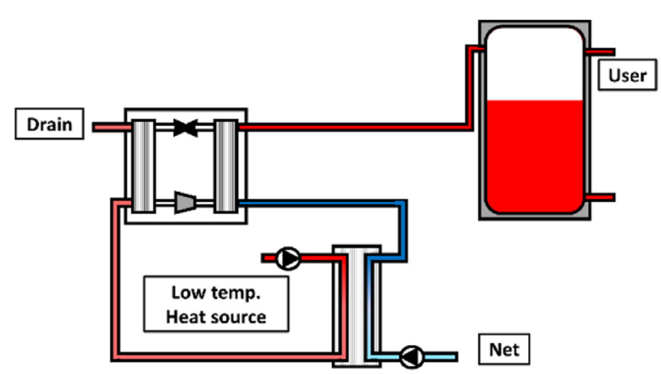

Fig. 3. Illustration of the booster HP installation.

The HP model consists of the Subcooled HP (SHP) developed under the frame of the EU project "Next Heat Pump Generation (NxtHPG)". The SHP model consists of a 47 kW heating nominal capacity working with R290 (Propane) as refrigerant and capable of working with a variable degree of subcooling. More details about the SHP can be found in Ref. [20]. The SHP has been experimentally tested and fully characterised in the laboratory [27] and the model, developed with IMST-ART [28], shows deviations lower than 4%. In the model, a constant temperature lift of 4.5 K is maintained in the evaporator through a PID controller since it maximizes the COP of the SHP.

2.2. Characterization of the demand

For the analysis, the district of *"Illa Perduda"* in the city of València has been selected, as shown in Fig. 4 in red. The district was selected for the analysis since the chair of urban energy transition of the Polytechnic University of València (funding entity) is focusing all the work in different fields to this district. Furthermore, the district comprises many social dwellings buildings.

For the analysis of the district, an initial case of 315 dwellings was selected. This corresponds with one group of buildings, concretely 9 different buildings remarked in black in Fig. 4. This, according to the municipal population census corresponds with 753 people.

The yearly DHW demand was calculated accordingly to Ref. [18]. A total demand of 39.2 m3/year and 12,365 m3/year corresponds to the cases selected at 45 °C for 1 and 315 dwellings respectively. In order to obtain the draw-off profile the software *DHWcalc* was used [31]. As an input, the exact same conditions considered in Refs. [20,32] and shown in Table 1 have been used, regarding the different types of draw-off in a building. The resulting draw-off profile are shown in Fig. 5. The blue lines represent the hot water demand at every minute (litres/hour) and the orange one represents the accumulated consumption for each hour (litres). The draw-off profile considering 1 building and representing the average consumption of the 315 dwellings will be used for the individual installations (immersion electric heater and HP water

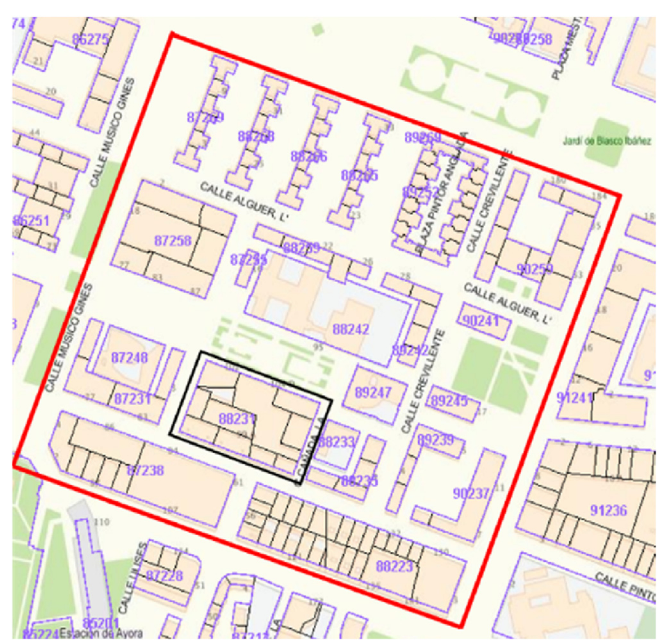

Fig. 4. District of "Illa Perduda" in the city of València [29].

Table 1
Inputs considered in Refs. [20,30] to DHWcalc [31].

Type of draw-off	Temperature [°C]	Mean flow [lpm]	Probability [%]	Duration [min]	Standard deviation [l/h]
Hand-washing/cleaning	45	3	45	5	2
Shower	45	9	17	10	2
Bath	45	9	5	25	2
Cooking	45	3	33	15	2

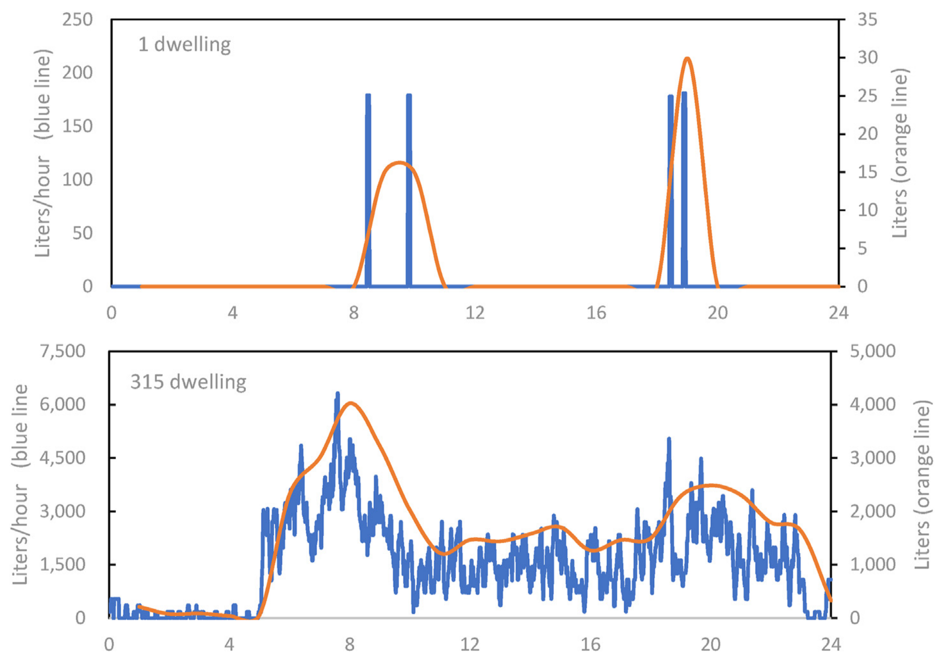

Fig. 5. 1-day draw-off profile for 1 and 315 dwelling.

heater), whereas the profile of 315 dwellings will be used for the case of the collective installation (the booster HP).

2.3. Model assumptions and optimization variables

In order to compare the different system configurations proposed two energy performance indicators have been selected: the SPFuser and the total annual energy consumption.

$$SPF_{user} = \frac{Q_{user}}{W_{equipment} + W_{auxiliaries}} \quad (1)$$

The SPFuser is defined, as shown in Equation (1), as the quotient between the Quser, which is the useful heat that the user receives, calculated as the energy contained in the water flow exiting the mixer valve to the user at 45 °C. The denominator of the formula corresponds to the total energy consumption of the facility, being W the electrical consumption of the components i.e. HP, immersion electric heater, compressor or circulation pumps.

Several restrictions have been imposed to the model in order to guarantee the user comfort as well as the system reliability. These criteria have only been applied to the booster HP case, since the other two cases are commercially available models and are simulated as specified by the manufacturer. Regarding the comfort restrictions, the discomfort is considered when the system is not capable of supplying the DHW to the user at 45C. A maximum annual discomfort of 0.05% has been imposed and a maximum value of 30 min per year of discomfort for each different hour of the day that corresponds with a maximum value of 5 s of discomfort per day for each hour of the day. Regarding the system reliability, a maximum of 9 starts/hour has been imposed and a limit to the overflow of 0% of the tank was also settled. Each of the above commented restrictions are implemented in the integrated TRNSYS model, in such a way that the simulated cases for the optimization are discarded if any of the restrictions are reached.

Parametric studies have been settled for the analysis of the cases. The variables studied are: the temperature sensor position in the tank and the volume of the tank for the immersion electric heater and the HP water heater. For the HP booster case, the minimum control volume (alpha), the size of the SHP and the tank volume. The values considered are shown in Table 2. Considering all the simulations, more than 3000 simulations have been performed for the study.

3. Results and discussion

This section presents the main results of the performed work. A parametric study has been performed with the optimization variables of each cases and the commercially available cases have been simulated. The objective of the parametric study consists of identifying the different trends as well as determine in a first approach the optimal case for the SHP.

This section introduces the main results obtained regarding each case as well as the comparison between them. The results for the immersed electric heater and the HP water heater are presented for an individual dwelling, whereas the results for the booster HP correspond to the collective installation.

Table 2
Optimization variables considered for the study.

Immersion electric heater		HP water heater		Alpha	Booster HP	
Sensor position	Tank volume	Sensor position	Tank volume		Tank volume	SHP size
Node	Litres	Node	Litres	%	Litres	Heating kW
1.0	50.0	1.0	50.0	10.0	250.0	41.7
2.0	71.4	2.0	71.4	20.0	708.3	55.6
3.0	92.9	3.0	92.9	30.0	1166.7	69.5
4.0	114.3	4.0	114.3	40.0	1625.0	83.4
5.0	135.7	5.0	135.7	50.0	2083.3	97.3
6.0	157.1	6.0	157.1	60.0	2541.7	111.2
7.0	178.6	7.0	178.6	70.0	3000.0	125.1
8.0	200.0	8.0	200.0	80.0	–	–
9.0	–	9.0	–	90.0	–	–
10.0	–	10.0	–	–	–	–
11.0	–	11.0	–	–	–	–
12.0	–	12.0	–	–	–	–

3.1. Parametric study results

As it has been commented before, a parametric study was conducted in each case considering the optimization variables and their values presented in Table 2. The results for the selected indicators (SPFuser and annual energy consumption) are shown for each of the cases considered. In the following, one subsection for each case analysed was included in which the results are presented and discussed.

3.1.1. Immersion electric heater

First, the results for the commercially available immersion electric heater are included in Table 3. The results of discomfort included in Table 3 are then fixed in the parametric study for the immersion electric heater, in this manner the results with a higher level of discomfort than the commercially available case of the parametric study have not been included in the performance map shown in Fig. 6.

Fig. 6 a) presents the annual energy consumption of the commercially available immersion electric heater of one dwelling and Fig. 6 b) the corresponding SPFuser. The results have been plotted in a performance map in which the axis X and Y correspond with the two variables of the parametric study and axis Z with the performance indicator selected. A trend of minimum energy consumption and maximum SPFuser with the minimum tank volume and highest position of the control sensor in the tank is identified. The commercially available option coincides with the optimal case simulated, the SPFuser is near 1 but not exactly because the temperature supply to the user is 45C whereas the DHW production is held at 60C. However, it should be pointed out that the commercial solution is far from the restrictive conditions of discomfort defined for the booster HP case in section 2.3. Model assumptions and optimization variables (Maximum level of discomfort of 0.05%).

3.1.2. HP water heater

The results for the commercially available option of HP water heater are included in Table 4.. The SPFuser result of 1.56 is almost one point under the nominal COP (2.65) of the commercial unit due to the difference between the supply temperature and the production temperature and also because the effect of the auxiliary immersion electric heater of the system is also considered inside the SPFuser indicator. The value of discomfort obtained for the commercial option, in the same way than the immersion electric heater case, limits the results of the parametric study shown in Fig. 7.

Table 3
Results of annual energy consumption, SPFuser and discomfort for the commercially available option of immersion electric heater.

SENSOR POSITION	VOLUME	kWh	SPFuser	DISCOMFORT
Top Node	80 L	1,372.55	0.89	8.00%

Similarly, to the previously presented case, Fig. 7 a) shows the annual energy consumption of the HP water heater for one dwelling and Fig. 7 b) the SPFuser of this case both in the form of a performance map. The trend observed coincides with the previous case. The lowest annual energy consumption, the highest value of SPFuser are obtained for the smallest tank volume and the highest sensor position inside the tank. Again, the results are far from the restrictive conditions of discomfort imposed to the booster HP case in section 2.3. Model assumptions and optimization variables.

3.1.3. Booster HP

Considering that the SHP simulated for the booster HP case is a prototype, a wider parametric study has been performed in order to determine the best system size (SHP and tank size). In the parametric study, the size of the SHP and the tank volume have been simulated for each of the alpha values considered. The alpha value corresponds with the minimum water volume settled for the volume control in the variable-volume tank. Finally, two different temperatures of the network have been considered. The first, considering that the booster HP works with water source temperature (without heat recovery application) and the second considering an ULTDH network temperature of 20C.

For the complete analysis, two parametric studies should be performed. The first parametric, that serves as an evaluation and a first approximation, gave as an output a wide range about the optimal zone considering the three variables commented. Once completed and analysed a second parametric study should be performed in a small range of the previous one in order to obtain the precise optimal conditions. Nevertheless, this work only includes a first evaluation and the second parametric is not one of the objectives here considered.

For the analysis of the smart energy system, two cases inside the booster HP case are considered. The first one considering the most restrictive comfort conditions defined in section 2.3. Model assumptions and optimization variables (maximum level of discomfort of 0.05%) and a second case considering the less restrictive comfort conditions that are the ones obtained for the HP water heater (maximum level of discomfort of 12%). The results for the booster HP working with water source temperature for 315 dwellings are included in Fig. 8, for most restrictive comfort conditions, and Fig. 9, for less restrictive conditions. Both figures show

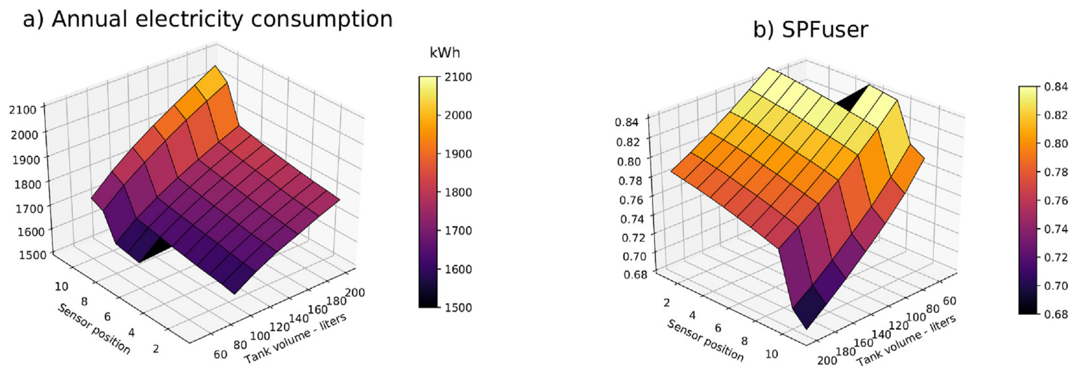

Fig. 6. Results of the parametric study conducted for the immersion electric heater for one dwelling.

Table 4
Results of annual energy consumption, SPFuser and discomfort for the commercially available option of immersion electric heater.

SENSOR POSITION	VOLUME	kWh	SPFuser	DISCOMFORT
Top Node	80 L	822.83	1.56	12.03%

the results of the parametric study considering all the values in the parametric study for SHP and tank size, but only the graphs for the optimal alpha value are shown (0.9 and 0.5 for most and less restrictive comfort conditions). In a similar way, Fig. 10 and Fig. 11 include the results for the booster HP case considering a ULTDH network temperature of 20C and only the optimal alpha values results are shown (0.8 and 0.1 respectively) (see Fig. 12).

The performance maps show the tendencies commented in the following:

- The region not covered by the performance maps corresponds to SHP-volume combinations that do not comply with the comfort criteria
- A decreasing tendency of the annual energy consumption (and increasing of the SPFuser) is observed with the decrease of both, the SHP size and the tank volume for both network temperature cases.
- The maximum system performance takes place for the lowest SHP sizes, however the tank volume should be also designed to minimize the energy consumption of the system.

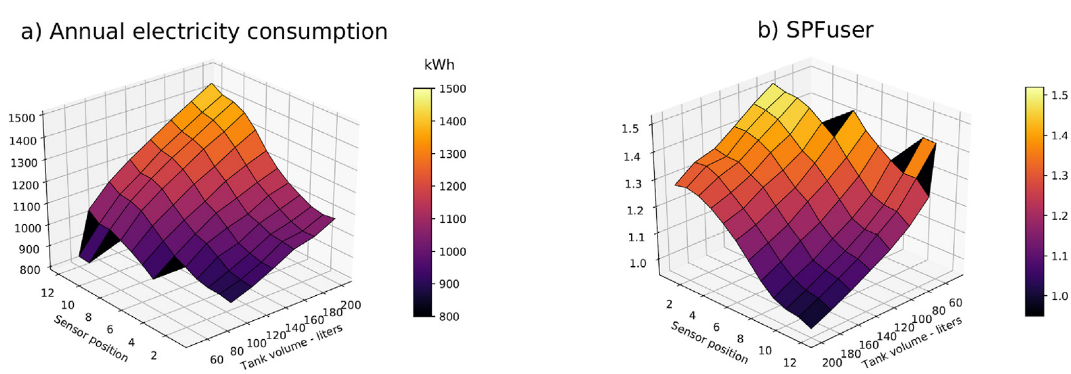

Fig. 7. Results of the parametric study conducted for the HP water heater.

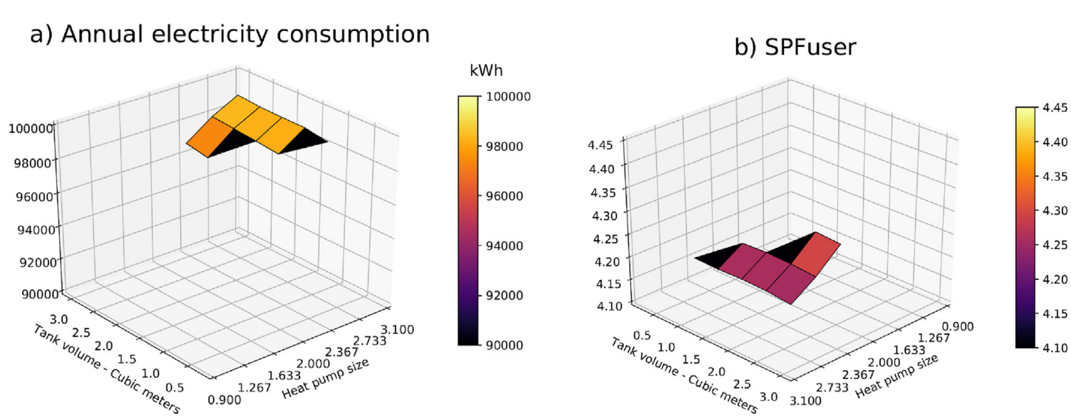

Fig. 8. Results of the parametric study conducted for the booster HP considering the comfort conditions above defined (0.5%) and a network temperature corresponding with water source temperature of València.

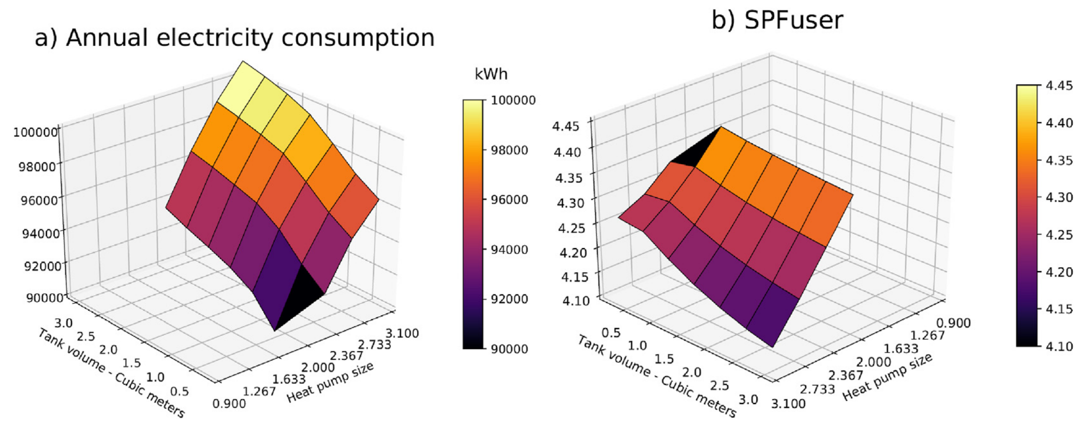

Fig. 9. Results of the parametric study conducted for the booster HP considering the comfort conditions less restrictive (12%) and a network temperature corresponding with water source temperature of València.

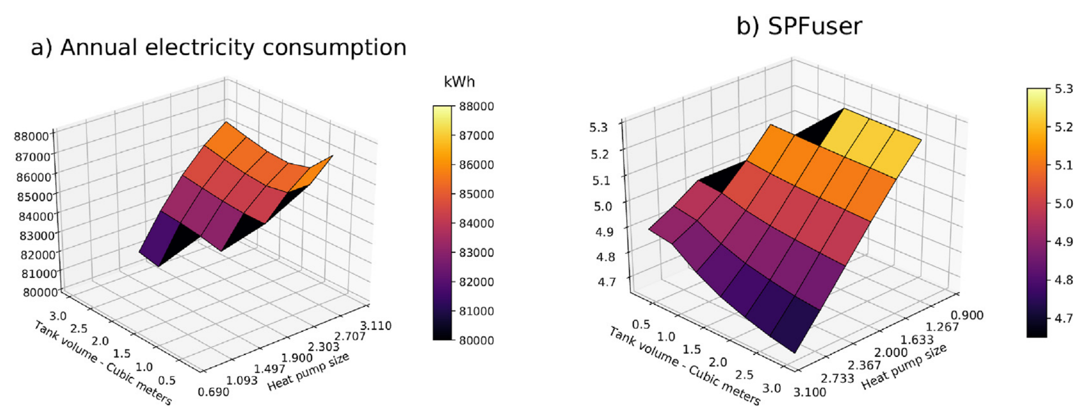

Fig. 10. Results of the parametric study conducted for the booster HP considering the comfort conditions above defined (0.5%) and network temperature of a ULTDH network of 20C.

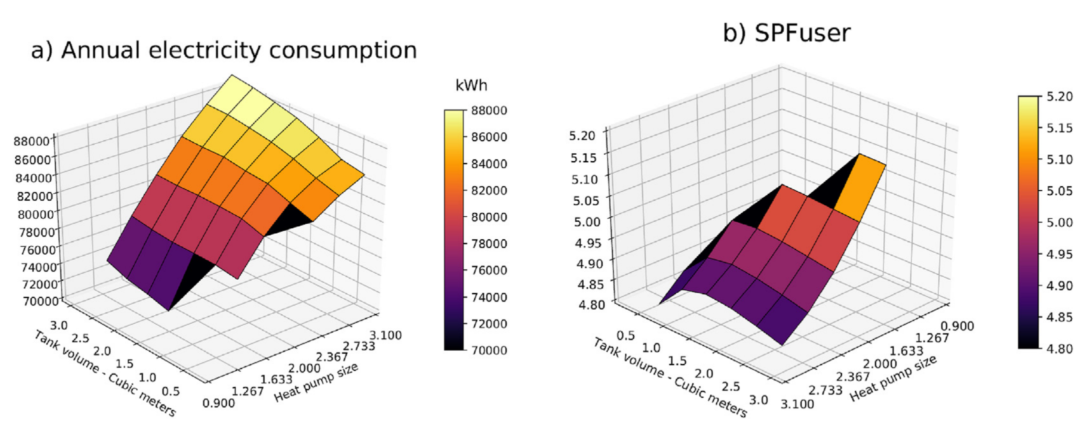

Fig. 11. Results of the parametric study conducted for the booster HP considering the comfort conditions less restrictive (12%) and a network temperature of a ULTDH network of 20C.

- When the SHP size increases in size, reduced tank volumes penalize the efficiency of the system.
- For each SHP size an optimum alpha value and tank volume exist.
- Regarding the alpha value, its influence to the energy consumption is indirect. As this value increases, more combinations of SHP size and tank volume comply with the restrictions allowing thus to include more cases with low values of SHP size and tank volume that usually correspond with the lowest energy consumption cases. In this way, higher alpha values tend to show the lowest energy consumptions since they allow the system to comply with the restriction with the smallest combinations of SHP size and tank volume.

The optimal results extracted from the first evaluation are shown in Table 5.

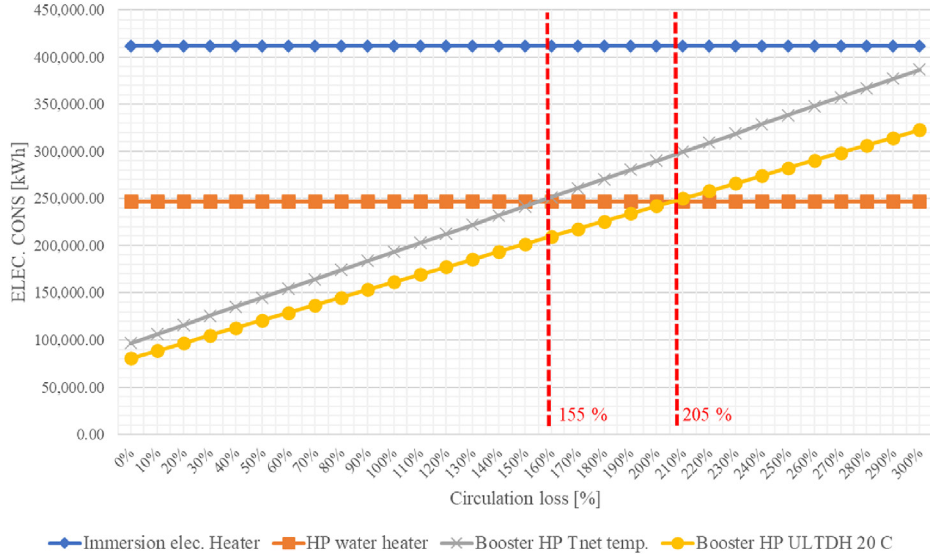

Fig. 12. Parametric study results on the effect of the circulation losses over the consumption.

Table 5
Results of annual energy consumption, SPFuser and discomfort for the optimal of the different cases considered for the booster HP.

CASE	CONDITIONS	SHP SIZE	VOLUME	ELEC. CONS	SPFuser	DISCOMFORT
–	–	kW	Litres	kWh	–	%
Booster HP	Optimal case Tnet temp.	119.7	2538.9	125,659.3	3.3	0.28
Booster HP	Optimal case Tnet temp.	100.8	708.75	115,327.16	3.4	7.6
Booster HP	Optimal case ULTDH 20C	85.05	2538.9	104,861.9	3.9	0.44
Booster HP	Optimal case ULTDH 20C	69.3	1887.05	92,827.8	4.1	11.91

3.2. Optimal cases results

In Table 6 the results for the commercially available options of electric immersion heater and HP water heater are included together with the results for the HP booster for covering the demand of 315 dwellings, considering a circulation loss of 30%. As explained, the results for the HP booster are obtained considering a draw-off profile of 315 dwellings, whereas the ones from the other two cases are extrapolated from those of 1 dwelling to 315. Furthermore, the results presented for the HP booster are not the exactly optimal ones but the resulting from a first evaluation from only the first parametric study. In the table are included the indicators selected for the analysis, the SPFuser and the annual energy consumption, together with the percentage difference regarding the immersion electric heater and the tank volume and heating capacity that corresponds to each building.

The results included in Table 6 show the case of the HP booster as the best case for the smart energy district with an energy saving above 0.3 GWh/year and above 70% in comparison with the conventional option of immersion electric heater for any case of HP

Table 6
Results comparison for the different cases simulated considering the commercially available cases and the optimal results for the booster HP.

CASE	CASE CONDITIONS	SPFuser	ELECTRICITY CONSUMPTION	ELEC. CONSUMPTION DIFFERENCE	VOLUME PER DWELLING	HEATING CAPACITY PER DWELLING
-	-	-	kWh	%	Litres	kW
Immersion elec. Heater	Commercially available case 8% annual disc.	0.89	411,765.00	–	80	1.5
HP water heater	Commercially available case 12% annual disc.	1.56	246,849.00	40.05	80	0.9 HP + 2 EWH
Booster HP Tnet temp.	Optimal case 0.28% annual disc.	3.3	125659.3	69.5	8.06	0.38
Booster HP Tnet temp.	Optimal case 7.6% annual disc.	3.4	115327.16	72.0	2.25	0.32
Booster HP ULTDH 20C	Optimal case 0.44% annual disc.	3.9	104861.9	74.5	8.06	0.27
Booster HP ULTDH 20C	Optimal case 11.91% annual disc.	4.1	92827.8	77.5	5.17	0.22

booster. The SPFuser of the HP booster is more than 2 points above the HP water heater and 3 of the immersion electric heater. Furthermore, the collective solution that comprises the booster HP has a 10 times lower need of tank volume compared with the individual options. Regarding the comfort results, it is possible to see a big difference when changing the discomfort restrictions in the booster HP cases. However, the most restrictive discomfort requirements have to be taken for the booster HP since it is a collective installation. Considering the circulation losses, described in 2.1.3. Booster HP, a parametric study on this value shows that the loss has to reach a value of 155% and 205% in the booster HP case without and with heat recovery respectively to equal the total energy consumption of the HPWH. Those values are substantially far from the values found in the literature for well insulated installations.

Considering the legionella risk and according to the Spanish regulation about it, the HP booster installation is a risk installation. Thus, it has to comply with a set-point temperature of 60C in the tank. However, the individual installations are not considered a risk installation and the set-point temperature in the tank could be reduced to 45C instead of the analysed cases at 60C. This would make these cases to improve their SPFuser and reduce the yearly energy consumption.

Comparing the HP booster cases, the case simulated with an ULTDH network at 20C shows energy savings above the one considering water source temperature of València. However, the savings are not high, around 2–4% only, that is due to the conditions of water source temperature that are higher due to the warmer climate as shown in Fig. 1. This results for an average or colder climate condition in the EU would present a much higher SPFuser as well as higher energy savings.

4. Conclusions

The research work presented in this paper includes the comparison of different DHW production facilities for a real district in the city of València. The main objective of the research works consists of comparing the energy performance of the smart energy systems, as a collective installation in front of an individual installation. For the analysis, two different individual facilities are considered: the conventional option of immersion electric heater and a HP water heater. As collective installation two cases have been considered: a booster HP case coupled with a ULTDH network at 20C is considered as well as a case without the ULTDH network and working with water source temperature of València. To this extent, this paper should not be taken as general conclusions.

The objective was to obtain a first evaluation of the potential of a collective installation in front of conventional and innovative alternatives for DHW production. The results show:

- The booster HP present energy savings above 0.3 GWh/year and 70% in comparison with the conventional option of immersion electric heater
- The booster HP has a 1.5 and 2.5 points higher system global efficiency (SPFuser) than the HP water heater and the immersion electric heater respectively.
- The HP booster has a 10 times lower need of tank volume in total, compared with the individual options as well as a lower heating capacity required (total kW installed).
- The HP booster allows the installation to reach a much higher comfort requirement through the year than the commercially available options of individual installation.
- The case of the booster HP with an ULTDH network at 20C shows energy savings around 2–4% in comparison with the HP booster working with water source temperature. The small percentage is only due to the warm temperature of the heat source.

In conclusion, this first evaluation work concludes with the high benefits of the smart energy system for DHW production compared with the conventional individual installations used nowadays.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Nomenclature

DHW	Domestic Hot Water
NZEB	Near Zero Energy Building
EPBD	Energy Performance of Buildings Directive
HP	Heat Pump
DH	District Heating
CHP-DH	Combined Heat and Power District Heating
ULTDH	Ultra Low Temperature District Heating
COP	Coefficient of Performance
BPHE	Braze Plate Heat Exchanger
SHP	Subcooled Heat Pump
SPFuser	System global efficiency
Quser	Useful heat for the user
Wequipment	Energy consumption of the DHW production system
Wauxiliaries	Energy consumption of the circulation pumps

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