Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

HPT-Annex 46

Domestic Hot Water Heat Pumps

Annex 46

Task 4 Research & Development

Country Report France

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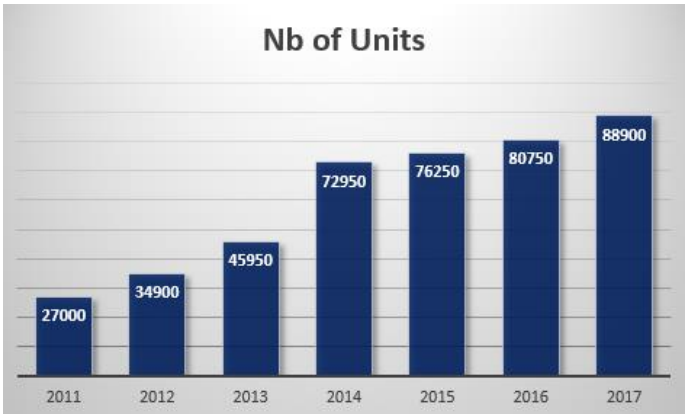
1. Introduction

In the French market, a heat pump water heater (HPWH) consist of a heat pump which condenser is connected to a sanitary hot water tank. For the moment, this type of product addresses mostly to individual houses.



The French market of Heat Pump Water Heaters (HPWH) is quite recent but highly dynamic. In 2017, the overall number of units sold in France was nearly 90 000. An increase of 10% with respect to 2016.

Sales are mainly supported by the market of new individual houses [1]. However, sales in retrofit market increase gradually. Technologies seem to be mature and quite basic but, due to European and national regulations, they are expected to evolve.

Fig 1. Market development of DHW HP

2. State-of-the-Art

In France, 4 types of HPWH have a significant market share [1]:

- Ambient air one-piece system;
- Outside air split system;
- Outside air duct (one-piece) system;
- Exhaust air one-piece system.

Until the entry into force of the RT2012 building regulation in January 2013, the ambient air systems sold in existing individual houses were predominant. Since 2013, the development of sales in new built individual houses make the market shares of other technologies increase.

Nowadays, the ambient air systems represent 40% of the whole sales but remain predominant on existing buildings market, due to particular costs and installing constraints. By contrast, ambient air systems are a minority in new built individual houses.

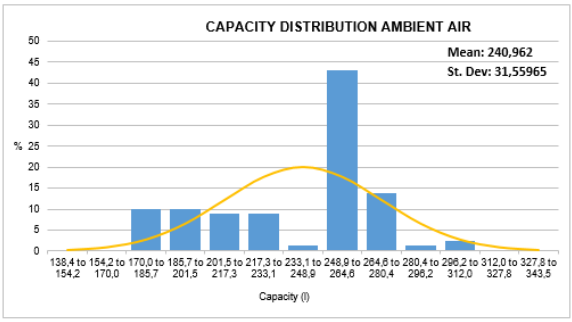
Besides these classical products, some other technologies, more innovative, appear on the market.

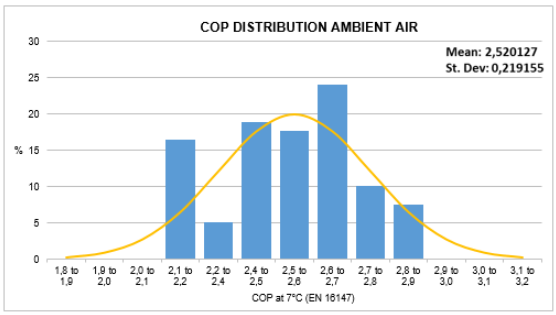
2.1 Reference products

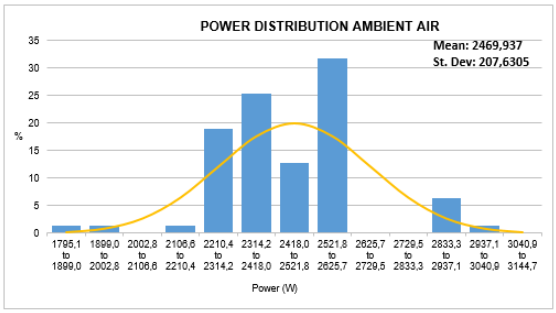
The products characteristics listed below correspond to the certified products on the French market in 2016.

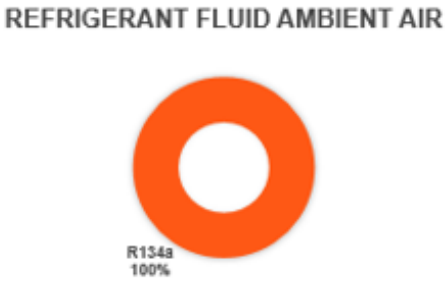
Ambient air HPWH

Historically the reference product, is an ambient air HPWH. This product has an average water capacity of about 250 litters, and an average heating capacity of about 2.5 kW. The performances of HPWH are evaluated thanks to a specific european standard EN 16147 [3]. Under this standard, the average annual COP of ambient air HPWH sold in France is about 2.5 (air at 15°C, hot water at 55°C). All the ambient air HPWHs use the R134a refrigerant and the major part of them has a wrap-around tubular condenser [1],[2]. This type of HPWH is usually running on HP down to an air temperature of 5°C. Below this temperature, the direct electric backup is heating the water.









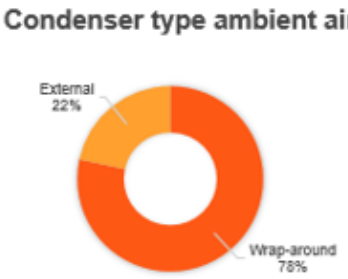
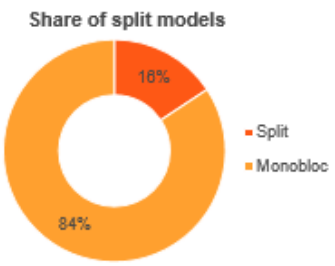


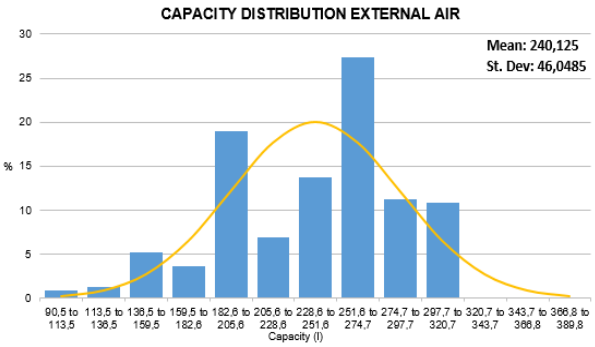
Fig 2.1 Characteristics of ambient air HPWH's

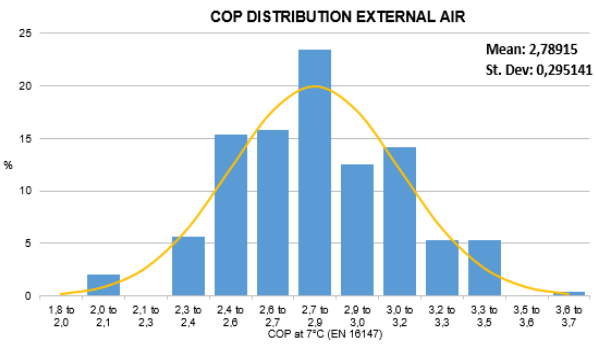
Outside air HPWH

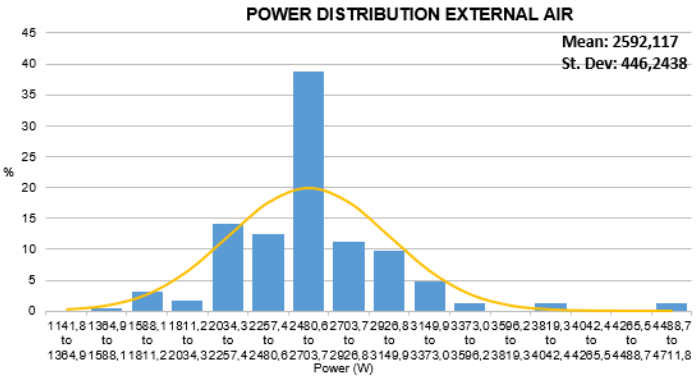
Nowadays, the real reference product is the outside air HPWH. The main characteristics remain the same as ambient air HPWH ones. The greater part of outside air HPWH is constituted by monobloc products that can be sold as outside as well as ambient air HPWH.



This product has an average water capacity of almost 250 l, an average annual COP (air at 7°C, hot water at 55°C, EN 16147) of 2.8 and an average heating capacity of 2.6 kW. The majority of the products run on HP down to -5°C. Below this temperature the direct electric backup is heating the water.







90% of outside air HPWHs uses R134a refrigerant and 85% have a wrap-around condenser.

Fig 2.2 – Characteristics of outside air HPWH's

2.2 Innovative products

Heating return flow water HPWH

The best example of innovative product already on the market is a HPWH which cold source is heating system return flow water [5]. The EDEL HPWH uses the return-flow water from your underfloor heating or any other very low temperature heating circuit to heat your domestic water.

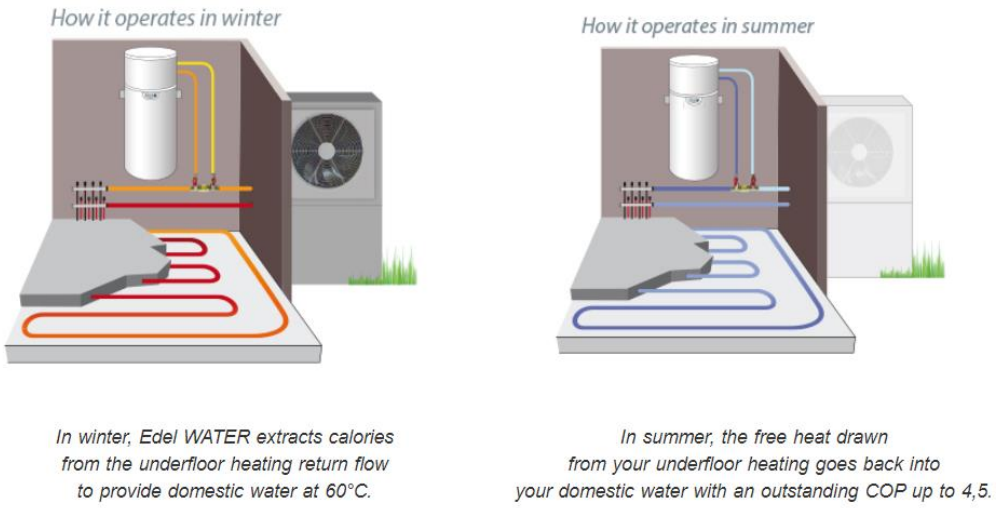


Fig 2.3 Function of HPWH on underfloor system

In a regulatory and environmental point of view, this type of HPWH is necessarily associated to a heat pump for heating. Then, the performances have to be considered in a global way, including heating heat pump ones.

The return flow water from the low temperature heating system (underfloor or equivalent low temperature system) is used as the cold source of the evaporator.

In summer, the heating heat pump is off but a circulating pump allows the water flow from the underfloor to the evaporator. This water is at about 20°C, implying high COP for the HPWH. Moreover, this water circulation in the underfloor slightly refresh the ambient air in the house. In winter, the heating HP is on. The return flow water is at about 30°C, the COP of HPWH is high but this heat extraction induces a slight decreasing in the heating HP COP.

The COP of such a HPWH can be more than 3.

Solar supported Heat Pump Water Heater

Another innovative system already sold by several manufacturers is a HPWH which evaporator is an unglazed solar collector [6].

- The evaporator, constituted by an unglazed solar collector, is installed on the roof.
- It is well adapted for new individual houses in sunny regions, like South of France.
- However, refrigerant pipes length is quite important. The installation cost is very high.

Fig 2.4 Solar supported HPWH

HPWH with propane Auer [5] developed and now sells a range of HPWH with propane as a refrigerant. The smaller products of the range are wall-mounted and contain about 100g of propane. The biggest ones contain 150g of products, maximum fluid load accepted by the regulation for products installed inside a building.

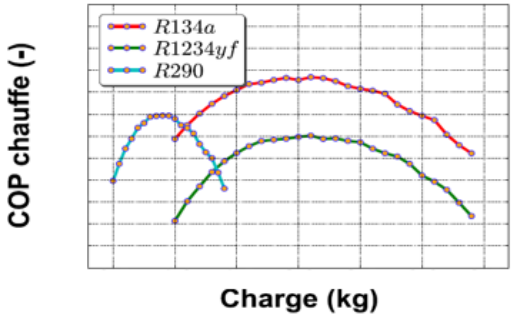
3. R&D on Heat Pump Water Heaters in France

The developments presented previously highlight the main concerns of the sector. These fields are the same in a R&D point of view: new refrigerants application, optimization of performances, and use of alternative cold sources.

3.1. Refrigerants

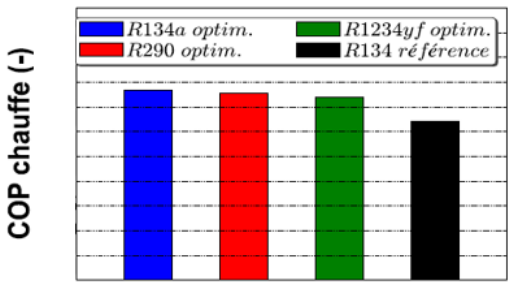
As seen previously, the refrigerant almost exclusively used in HPWH in France is R134a. In the framework of the F-Gas regulation, this refrigerant will be banned in few years and R&D on alternatives is under progress. The two main alternative refrigerants to R134a, which GWP is around 1600, are propane (R290, GWP of about 20) and HFO R1234yf (GWP of 4).

A French study [4] shows by modelling that performances and behaviour of HPWH equipped with R290 or R1234yf are quite comparable as R134a HPWH ones.



A first step was to study the COP for a water heating phase from 10°C to 55°C of an air-source HPWH equipped with R134a and then, in drop-in operation, with R1234yf and R290. Figure 3.1 shows the COP depending on the refrigerant charge for this R134a reference HPWH. Obviously, the COP is higher for R134a as the HPWH was designed for this refrigerant. However, the performances degradation is relatively low, taking in account this purely drop-in operation.

Fig 3.1 COP dependent on refrigerant



In a second step, the HPWH components were optimized for each type of refrigerant (compressor size, condenser and evaporator heat transfer surfaces). Results are shown on the figure 3.2. One can see that if the machines are redesigned, the alternative refrigerants are really suitable for DHW production. This study also shows that the alternative refrigerants lead to a reduced load for the same performance.

Fig 3.2 Effects of redesign on COP for alternatives

A challenge for these natural refrigerants as alternative is the flammability of the refrigerants, classified as A3 (highly flammable) for propane and as A2L (lightly flammable) for R1234yf. As a consequence, they can't be used in a drop-in operation. These alternatives become valued for new products only.

3.2. Components

All studies concerning HPWH components are clearly dedicated to the increase of performance, usually with an impact on the product capital cost as low as possible.

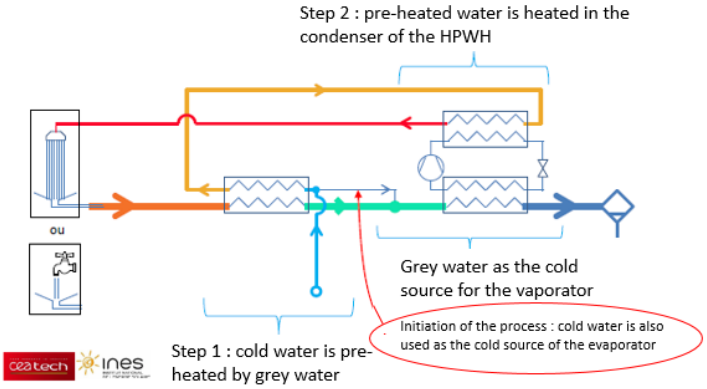
Some studies assess the potential of using micro-channel condensers, wrap-around the water tank. They could lead to better performances, a reduction of refrigerant load compared to classical condensers but are quite expensive. Cost-benefit analysis are under progress.

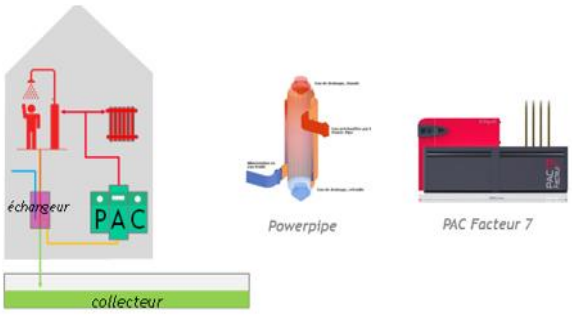
Other studies explore the potential advantages of variable speed compressor. It could offer large possibilities to improve HPWH control strategies. French study [4] shows that a control optimization can lead to an important

performance increase. This optimized control strategy could be based on a water need learning coupled with a multi-criteria optimization algorithm. Associated with a variable compressor, it allows to reduce compressor sizing and ensures the comfort on a wider range of DHW needs. These interesting results have to be experiment on-field to be confirmed.

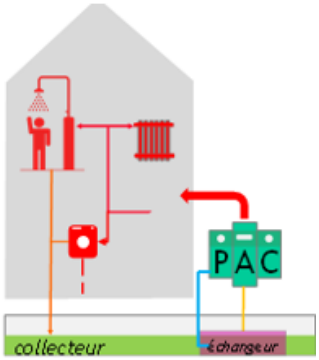
3.3. Cold sources

French institute CEA-Ines studies a direct HPWH system, without any storage [7]. The grey water coming from a shower is directly used as a cold source for the HPWH heating the water for the same shower. The heating process is initiated with cold water: during few seconds (about 30), cold water is redirected in the evaporator, until grey water can be collected.





Another study realised by CSTB [8] describes two types of configuration to recover energy from grey water at building scale : one configuration without any storage, with a system like a Powerpipe®, and one configuration with storage (PAC F7®).



This CSTB study also describes the heat recovery on the scale of the city or at least a district.

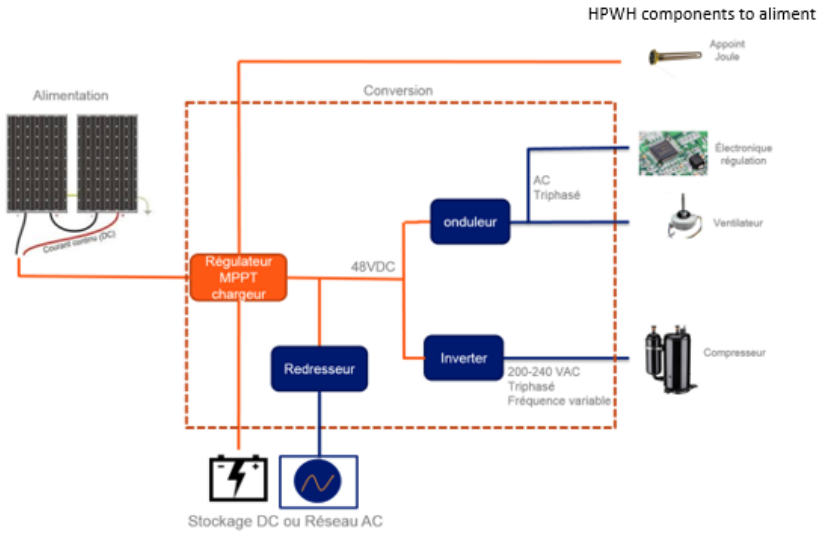
The grey water flow collected is a permanent source, compared to the solution at building scale but the flow remains very fluctuating.

3.4. Self-consumption of photovoltaic production

In France, in particular for residential buildings, there is a lot of activity around the self-consumption of electricity produced locally, by photovoltaic panels.

In 2017, 20.000 households self-consumed their own electricity production, totally for 15.000 households and partially for the others. This process could accelerate in France, thanks to regulatory measures (JO 25/02/2017) and incentives that promote use of photovoltaic systems dedicated to self-consumption.

If electrical connexion systems (boxes, kits, etc.) are already well developed, ways to use this electricity in an optimal manner are not so clear. However, more and more studies obviously target water heaters using storage tanks for that. The objective is to design water heaters, in particular heat pump water heaters, well-adapted to photovoltaic production in terms of storage capacity, functioning temperatures, control strategy. A possibility is to create a heat pump water heater totally autonomous, namely off-grid. It implies the introduction of a battery. A possible structure of the system is shown below [9].



4. Conclusion

French market of heat pump water heaters (HPWH) is mainly composed of storage based products with low thermal capacity and quite low investment. The purpose of these HPWH is to replace the direct electric water heaters in renovation market and to compete with double function gas boilers in the new building market. As a consequence, the performance is not as high as one can expect for a thermodynamic product.

As a consequence, a great part of R&D works is dedicated to performance improving without significant increase in the capital cost.

Another important concern that govern R&D projects is the evolution of regulations, in particular on the refrigerants.

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