GAZ RÉSEAU
DISTRIBUTION FRANCE

POSITIVE EXTERNALITIES OF HYBRID HEAT PUMPS

BENEFITS NOT VALUED IN THE CURRENT PRICING SYSTEM

Artelys
SOLUTIONS EN OPTIMISATION

AUTHORS

Research was carried out by the following:

- Project Director (Artelys): Arnaud Renaud
- Project Manager (Artelys): Claire Lucas
- Modelling, quantification, economic calculations (Artelys): Quentin Gruet

Artelys specialises in optimisation, forecasting and decision support. Having carried out around one hundred studies and software projects in the energy sector, Artelys has become a key player in the optimisation and techno-economic analysis of large-scale energy systems. Artelys has developed a software suite, Artelys Crystal, dedicated to the economic optimisation of the management of and investment in energy systems.

As the number one gas distribution grid operator in France, **GRDF** distributes gas to more than 11 million customers for their heating, cooking and transport needs, irrespective of their supplier. To do this, in accordance with its public service remits, GRDF designs, builds, operates and maintains Europe’s largest distribution network (204,239 km) in more than 9,500 municipalities, guaranteeing the safety of people and property and ensuring quality distribution. With the rise of green gas, renewable gas produced locally, the gas network is an essential link in the ecological transition chain. The concessionary authorities are the owners of the public gas distribution networks. As concession holder, GRDF helps them use this infrastructure as part of their local policies: development, construction, renovation, mobility, regional planning and forecasting, energy policies. GRDF has become a partner for local authorities, helping them implement carbon neutrality via their energy and sustainable mobility policy choices.

Executive Summary

CONTEXT AND OBJECTIVES

The french National Low Carbon Strategy (SNBC) published in March 2020 sets a goal of carbon neutrality for France by 2050. This strategy relies heavily on the electrification of uses and the development of renewable energies, in line with the multi-year energy program for the 2020 – 2028 period. These changes are likely to impact deeply the energy system: nature and location of production capacities, structure and volume of energy demand, etc.

The SNBC considers a very ambitious program of renovations and the installation of a large number of electric heat pumps (HP) for the residential sector, in new and renovated housings. The electrification of building uses, and in particular heating, raises the question of the future role of gas networks. In addition, the hybrid heat pump (HHP, air/water heat pump with a gas condensing boiler as back-up) is a mature technology with multiple advantages for the energy system.

The objective of this study is to compare the benefits of the hybrid heat pump for the energy system with the impact of the electric heat pump, the latter including an electric back-up and being widely preferred by current consumers. A first reflection on economic incentive measures is then carried out for consumers to benefit from the advantages of hybrid heat pumps.

A COMPARATIVE ANALYSIS ON A CASE STUDY

The analysis carried out compares the operating costs of a hybrid heat pump and a purely electric heat pump, in a single-family housing corresponding to a situation representative of the French housing stock. Two approaches are considered:

- A **system approach**, which evaluates the costs of using the heat pumps from the point of view of the energy system.
- A **consumer approach**, which evaluates the operating expenses of the heat pumps from the point of view of the consumer.

The two heat pumps studied operate with a backup. The **purely electric heat pump** works alone most of the time. The electric resistance is used as a back-up when the heat pump capacity is not sufficient to compensate for the housing heat loss. The **hybrid heat pump** operates in three modes: the heat pump alone, the boiler alone or the heat pump and boiler simultaneously. The modes are managed to minimize the system costs (market price and capacity valorisation).

THE HYBRID HEAT PUMP DIRECTLY REDUCES THE PEAK POWER DEMAND ON THE POWER SYSTEM

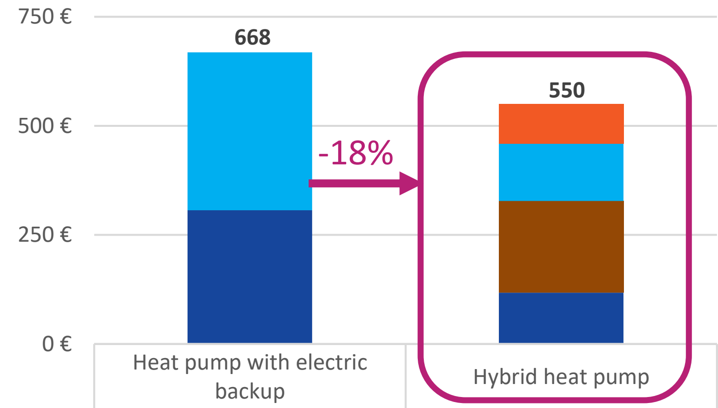
The hybrid heat pump is composed of a smaller heat pump capacity than the purely electric heat pump and therefore requires less power from the power network. In addition, **during periods of extreme**

cold, the hybrid heat pump operates on its gas back-up and provides significant flexibility to the power system (peak production capacity and network).

In the case under study, the **power peak of the heating system** is significantly reduced, from **5,2 kW** for the electric heat pump to **3,6 kW** for the hybrid heat pump.

THE HYBRID HEAT PUMP PROVIDES ECONOMIC BENEFITS FOR THE ENERGY SYSTEM

Over the 2005-2014 calculation period and with optimized control of the heating equipment in the housing under study, the hybrid heat pump leads to annual "system" costs that are 18% lower than those of the heat pump with an electric back-up. The hybrid heat pump is switched off when the power system is strongly constrained. Investments in peak production capacities are therefore reduced. And, the use of transmission and distribution networks during periods of congestion is reduced.

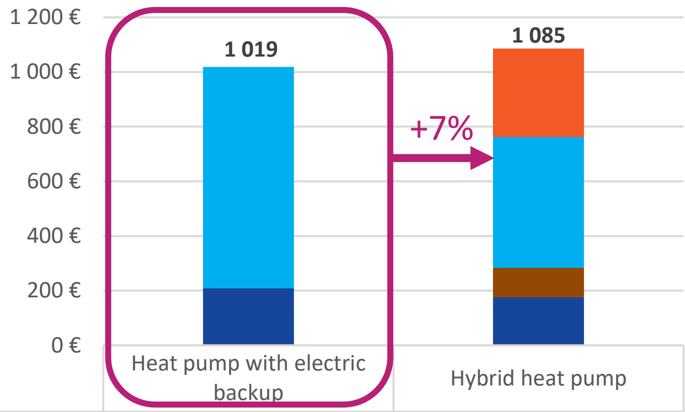


	Heat pump with electric backup	Hybrid heat pump
Gas - Energy	-	91
Electricity - Energy	362	132
Gas - Network	-	210
Electricity - Network	306	118

Figure 1 : Average costs before tax for residential heating from a system point of view for the heat pump with electric back-up and for the hybrid heat pump

HOWEVER, THE CURRENT PRICING INCITES CONSUMERS TO CHOOSE HEAT PUMPS WITH ELECTRIC BACK-UP

The heat pump with electric back-up is more profitable for the consumer: the hybrid heat pump costs 7% more than the electric heat pump. The current pricing system incites consumers to choose heat pumps with electric back-up, even though they result in higher costs for the community.



	Heat pump with electric backup	Hybrid heat pump
Gas - Variable part	-	323
Electricity - Variable part	810	479
Gas - Fixed part	-	108
Electricity - Fixed part	209	175

Figure 2 : Average residential heating costs (including tax) from the consumer point of view for the heat pump with electric backup and for the hybrid heat pump

PROPOSAL OF 3 TARGET MEASURES

To better match consumer incentives with the costs incurred by the French energy system, three types of non-exclusive measures could be considered:

- **Proposal n°1: Dynamic pricing of electricity to enhance the value of load management made possible by the hybrid heat pump.** With the ever-increasing development of intermittent power production, demand flexibility appears to be a key issue for the energy transition. The hybrid heat pump can be one of the instruments for this flexibility. To this end, the amounts paid by the consumer and the costs for the system must be brought closer together dynamically. This dynamic pricing (e.g., on a time-season basis) should take into account the costs generated by peaks and heavy loads for the power generation system but also for the transmission, dispatch and distribution network**.**
- **Proposal n°2: Financial support for investment in hybrid equipment.** Currently, subsidies (via *MaPrimeRénov*' or the Energy Savings Certificates) are available for the purchase of heat pumps (hybrid or with electric back-up). These subsidies do not distinguish between the type of auxiliary system (condensing boiler or electric auxiliary system). A specific additional bonus to promote the condensing boiler compared to the electric booster heater would be justified.
- **Proposal n°3: Joint electricity and gas subscription conditioned on the use of a hybrid heat pump.** Reducing the fixed part of electricity subscriptions for users of hybrid heat pumps is justified by the fact that the power network is less loaded during critical periods. This concern is currently very present, particularly in Quebec, which has already implemented such a joint subscription.

Table of contents

1 Hybrid heat pumps, a lever for a rapid, secure and sustainable energy transition

France's energy transition policy, set out in particular in the SNBC and the PPE, is moving towards a reduction in controllable generation resources and the electrification of uses. This means that the constraints on the electricity system are changing dramatically. **The development of intermittent renewable energy** requires more solutions to meet energy demand when production is stopped or reduced, for example at night or on windless days. **The electrification of heat** is putting increasing pressure on electricity generation and network infrastructures, to the detriment of gas infrastructures in particular, which until now had supported part of the demand (Figure 3). The efficiency of electric heating systems and renovation will eventually reduce these constraints, without eliminating them.

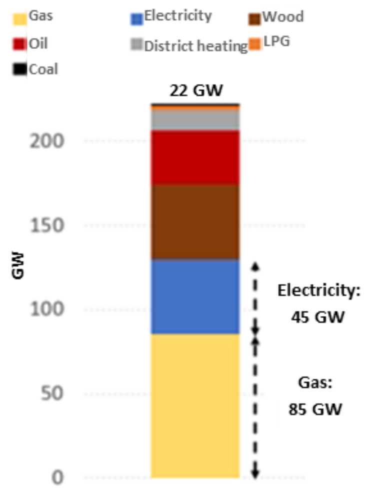


Figure 3: Breakdown of average power demand on 28 February 2018 (peak consumption) to cover the heating needs of buildings in mainland France (excluding Corsica). Source: GRDF based on data from RTE, GRTgaz, Téréga and CEREN

Hybrid heating solutions, such as hybrid heat pumps, which combine an electric heat pump with optimised power with a high-performance gas-fired boiler, have been identified as a way decarbonising and making heating demand more flexible, with three-fold benefits:

- **Ensuring supply-demand balance** by using existing gas infrastructure resources (storage, transmission, distribution) when electricity infrastructure is not sufficient to meet instantaneous demand. These existing gas resources are designed to meet the most extreme peak demand.
- **Increasing the resilience** of the energy system by relieving the local power grid in the event of a failure of a generating facility or transmission line, by switching all or part of the heating demand from electricity to gas.
- **Stepping up carbon intensity reduction in buildings.** Hybrid heat pumps can be set to optimise the integration of electrical renewable energy when available. The back-up gas boiler is a relevant outlet for biomethane, which is produced locally and easy to store for seasonal use.

The benefits of these solutions are already recognised in France's latest prospective energy scenarios[1]. However, current development is far from reflecting this need looking forward to 2050, as current sales of hybrid heat pumps in France do not exceed 5,000 units per year.

The objectives of this study are therefore to:

- **Analyse and quantify the economic obstacles to the development of hybrid solutions.** The costs of hybrid heat pumps are assessed (i) for the consumer under the current pricing system and (ii) for the energy system as a whole. These costs are compared with those of an electric heat pump using an electrical resistance as back-up. The analysis helps quantify the economic penalties currently associated with hybrid heat pumps in terms of purchase investment and energy supply contract.
- **Identify financial incentives** that would enable users of hybrid heat pumps to share in the economic gains generated by hybrid heat pumps on the energy system.

[1] *RTE anticipates at least 2.5 million hybrids in 2050 (https://assets.rte-france.com/prod/public/2021-10/Futurs-Energetiques-2050-principaux-resultats_0.pdf), ADEME anticipates up to 5.7 million (https://transitions2050.ademe.fr)*

2 Methodology and main assumptions

APPROACH

The methodology used consists of modelling the operation of a hybrid heat pump in a single-family home corresponding with a situation representative of an average of the existing and new housing stock in France. The 110 m² single-family home selected is reasonably well insulated, located in a French intermediate climate zone, connected to the gas distribution network and has an internal water circuit for central heating.

The use of hybrid heat pumps is analysed from two angles:

- **A system approach,** which assesses the costs to the energy system involved in using the hybrid heat pump. These costs fall into two categories: energy costs and network costs. Taxes are not included in this approach.
- **A consumer approach**, which assesses the costs to the consumer of operating the hybrid heat pump. These expenses include energy bills for both electricity and gas. The taxes currently applied for a consumer are included.

Next, these costs and expenses are compared with those of the same single-family home heated by a heat pump with electric back-up, a heating system that is currently being deployed more and more widely in France.

The methodology enables the costs of the hybrid heat pump and the heat pump with electric back-up to be compared from the point of view of the community (i.e. the overall energy system) as well as the consumer.

DESIGN OF HEATING EQUIPMENT

The operation of the heating equipment in a typical home is simulated at hourly intervals over ten climatic years, using temperature data from 2005 to 2014 for the Centre-Val de Loire region. Based on this temperature data, a heat loss model for the building is developed to calculate the heating requirements, in useful energy, for each hour in the home, taking into account the outside temperature, a setpoint temperature ranging from 16°C to 19°C depending on the time of day, and the building’s thermal inertia, which reduces the model’s sensitivity to very specific weather-related hazards. This heat loss model is supplemented by taking into account three types of yield representing the ability of the heating system to meet the setpoint temperature requirement: emission, distribution and regulation yields.

Yield	Value
Emission	0.97
Distribution	0.95
Regulation	0.99

Table 1: Emission, distribution and regulation yield used in the heat loss model

The model gives an average annual useful heating requirement of 13.3 MWh_{th} over a heating period from early October to the end of April.

Based on this heat loss model, two heating systems are designed[2]. The heat pumps considered in this study[3] are compatible with both hybrid heat pumps and heat pumps with electric back-up:

- **Hybrid heat pump**: this system consists of a low-power electric heat pump, supplemented by a VHEP condensing boiler. The following rule has been agreed upon by the industry on the design of the hybrid heat pump (and will be set out in a design guide to be published shortly): the capacity of the heat pump for an outside temperature of 0°C and a flow temperature of 50°C must be between 40% and 60% of the heat loss of the home at baseline temperature[4]. A heat pump model with a thermal output of 4.5 kWh_{th} meets these conditions[5]. It is accompanied by a 25 kW VHEP condensing boiler with a yield assumed to be constant at 0.92 (based on GCV).
- **Heat pump with electric back-up**: this system consists of a higher-powered electric heat pump, supplemented by an electric back-up. French standards for heat pump installations[6] stipulate that the heat pump's thermal output should be between 70% and 100% of losses at baseline temperature. The 6 kWh_{th} heat pump meets these conditions[7]. It is accompanied by a 6 kW electric back-up with a yield of 1.

The COPs of heat pumps depend on the outdoor temperature and the water outlet temperature, and are illustrated in Figure 4 below.

[2] The rules for designing heating systems include the concepts of baseline temperature (-6°C in this study) and heat loss at baseline temperature (6.3 kWh_{th} in our case).
[3] The models used are those provided by the *De Dietrich* manufacturer.
[4] *A common vision for designing hybrid heat pumps - GRDF.FR*
[5] Its thermal output for an outdoor temperature of 0°C and a flow temperature of 50°C is 3.55 kWh_{th} (i.e. between 40% and 60% of 6.3 kWh_{th}).
[6] Standards from Building Code 65.16 dated June 2017
[7] Its thermal output at baseline temperature is 4.54 kWh_{th}

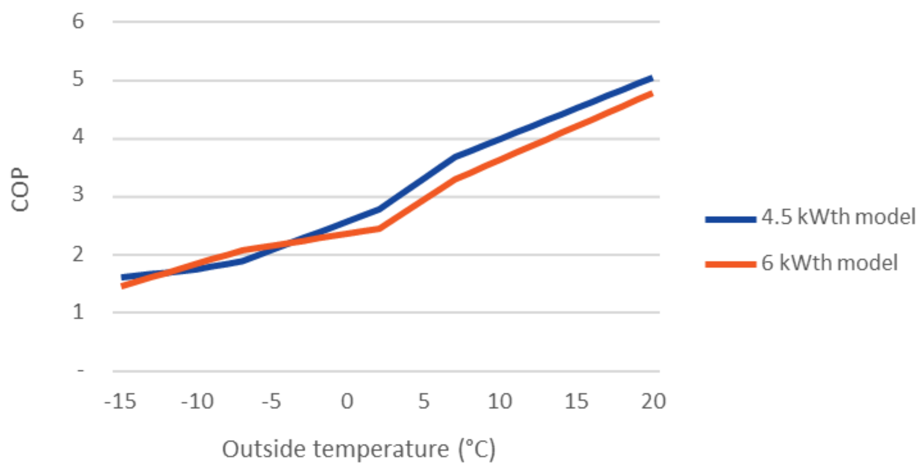


Figure 4: COP of heat pumps used in modelling as a function of outdoor temperature, manufacturers' data, excluding back-up

Although the heat pump is known to be a high-performance piece of heating equipment, temperature-related COP fluctuations should be taken into account: these fluctuations have a direct impact on the system's consumption and therefore on the electricity system. An ex-post assessment was conducted to make sure the heat pumps were used with a SCOP of over 2.8. SCOP is the seasonal coefficient of performance, which can be calculated as the ratio of energy produced by the heat pump to electricity used by the heat pump in a year.

ENERGY SUPPLY COSTS

The system approach takes into account the costs associated with purchasing and transporting energy (network costs). Taxes are not included in this approach. The costs are based on historical data from 2005 to 2014. This period is consistent with the historical temperatures used to simulate heating equipment.

- For **electricity**, the cost of the network is modelled by chronological unit network costs, capped at marginal costs, with loss costs and cascading costs drawn up by CRE. The cost of energy comes from Spot day-ahead prices (source: EPEX Spot), which includes amortisation of capacity values.
- For **gas**, the cost of energy is represented by average monthly prices on the NBP hub[8] and, from its creation, average monthly prices on the PEG[9]. The cost of the network was determined based on the value of the ATRD (*Accès des Tiers au Réseau de Distribution du gaz naturel* or third-party access to the natural gas distribution network) of a home with the same characteristics as the typical home selected in the study, heated exclusively with gas via a VHEP condensing boiler. From the point of view of the network, a home heated by a hybrid heat pump has to reserve the same network capacity as a home heated with gas, and therefore generates the same costs.

[8] The NBP is the National Balancing Point, a virtual trading point for the sale, purchase and exchange of natural gas in the UK

[9] The PEG is France's *Point d'Echange de Gaz*, equivalent to the NBP.

The consumer approach integrates the fixed and variable components of gas and electricity supply prices. The 2021 regulated sales tariffs have been taken into account to represent the current price, including VAT, paid by consumers for the operation of their heating system.

- For **electricity**, a *Peak Hours/Off-peak Hours* supply contract was selected, corresponding with a contract power level determined on an ex-post basis with reference to peak demand of the heating systems in question. For example, a 9 kVA supply contract was chosen for the system with a hybrid heat pump, and a 12 kVA contract for the home using a heat pump with electric back-up.
- For **gas**, a residential supply contract was also determined on an ex-post basis with reference to the volume used by the hybrid heat pump. The B0 tariff was selected, suitable for individuals consuming 1 to 6 MWh GCV of gas per year.

The various costs are summarised in Table 2 below.

Energy	System approach *(2005-2014 data)*	Consumer approach *(2021 data)*
Electricity	**Network**: LV hourly unit costs of networks **Energy**: Spot electricity prices	*Peak Hours/Off-peak Hours* supply contract, 9 kVA for the hybrid heat pump, 12 kVA for the electric heat pump
Gas	**Network**: ATRD value equivalent to that of a home heated with a VHEP condensing boiler **Energy**: Monthly gas prices, NBP then PEG	TRV - supply contract corresponding with a B0 profile

Table 2: Summary of energy supply costs

CONTROL OF HEATING SYSTEMS

The gas or electric back-up of the heating systems considered in this study are controlled in a number of ways, as described below.

The **electric heat pump** can run on its own or with its electric back-up when the maximum thermal output of the pump is not sufficient to compensate for heat loss in the home. Thus, the heat generated by the back-up system supplements that generated by the heat pump to guarantee thermal comfort for the occupants of the home. This control mode means that the back-up system runs for an average of 269 hours a year, i.e. 6% of the heating period.

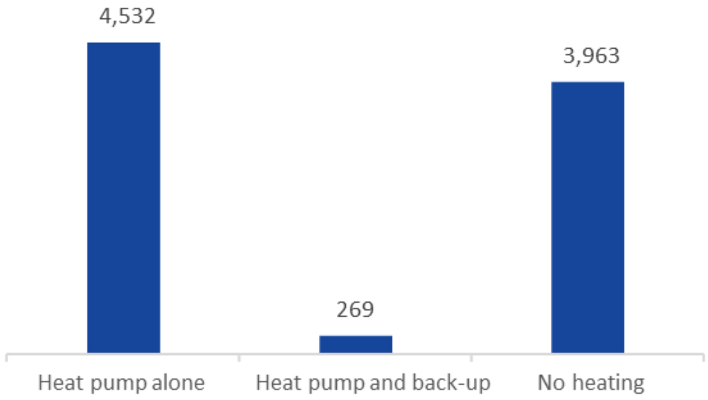


Figure 5: Average annual number of hours of use of each heating appliance for the heat pump with electric back-up

The **hybrid heat pump** runs in three modes: (1) heat pump alone, (2) boiler alone and (3) heat pump and boiler simultaneously. The control system is designed to minimise energy expenditure, calculated on the basis of system energy costs. As a result, when the electricity system is under severe strain and electricity is very expensive on the market, the gas boiler is used. Conversely, when electricity is the cheapest option, the heat pump is used to generate heat. The third mode (simultaneous use of the heat pump and boiler) is only used when it is economically preferable to use the heat pump but the pump's output is not sufficient to compensate for heat loss in the home. In this case, the boiler provides the additional heat needed to guarantee comfort in the home (in a similar way to electric back-up). With this control mode, the boiler is used for an average of 1,533 hours a year, i.e. 32% of the heating period. Of these 1,533 hours, it operates alone for 867 hours (19% of the heating period) and with the heat pump for 666 hours (13% of the heating period).

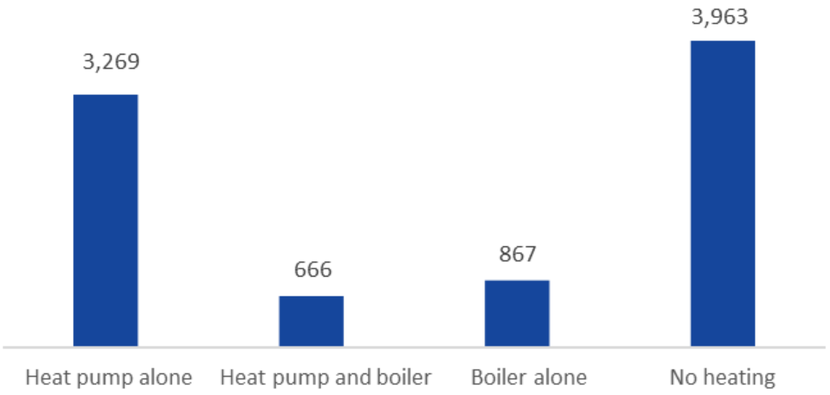


Figure 6: Average annual number of hours of use of each heating appliance for the hybrid heat pump

3 Main results

THE HYBRID HEAT PUMP DIRECTLY REDUCES THE MAXIMUM POWER DEMAND ON THE ELECTRICAL SYSTEM

Hybrid equipment helps reduce peak demand for the heating system, from **5.2 kWe** for the heat pump with electric back-up to **3.6 kWe** for the hybrid heat pump (Table 3). These peak values also justify the contract power in each of the cases studied: 12 kVA for the heat pump with electric back-up and 9 kVA for the hybrid heat pump.

Heating system	Peak demand	Contract power
Hybrid heat pump	3.6 kW_e	9 kVA
Heat pump with electric back-up	5.2 kW_e	12 kVA

Table 3: Peak demand and contract power for the various heating systems

Furthermore, peak demand of the electric heat pump is not in synch with that of the hybrid heat pump. Peak demand for the heat pump with electric back-up occurs when heating requirements are highest (in particular in very cold spells) and, consequently, when the power grid is under severe strain. During these periods of intense pressure, **the hybrid heat pump generally switches off** to run on its gas back-up and relieve the electricity network. The timing of the peak can be seen in Figure 7 below: the gas boiler is widely favoured when temperatures are at their harshest[10] and electricity withdrawal is zero during these periods. In addition, the “price” controllability of the hybrid heat pump encourages its use when market electricity prices fall. As a result, the hybrid heat pump uses electricity for a few hours outside the peak demand period.

[10] The period shown corresponds with the day of peak demand for the heat pump with electric back-up

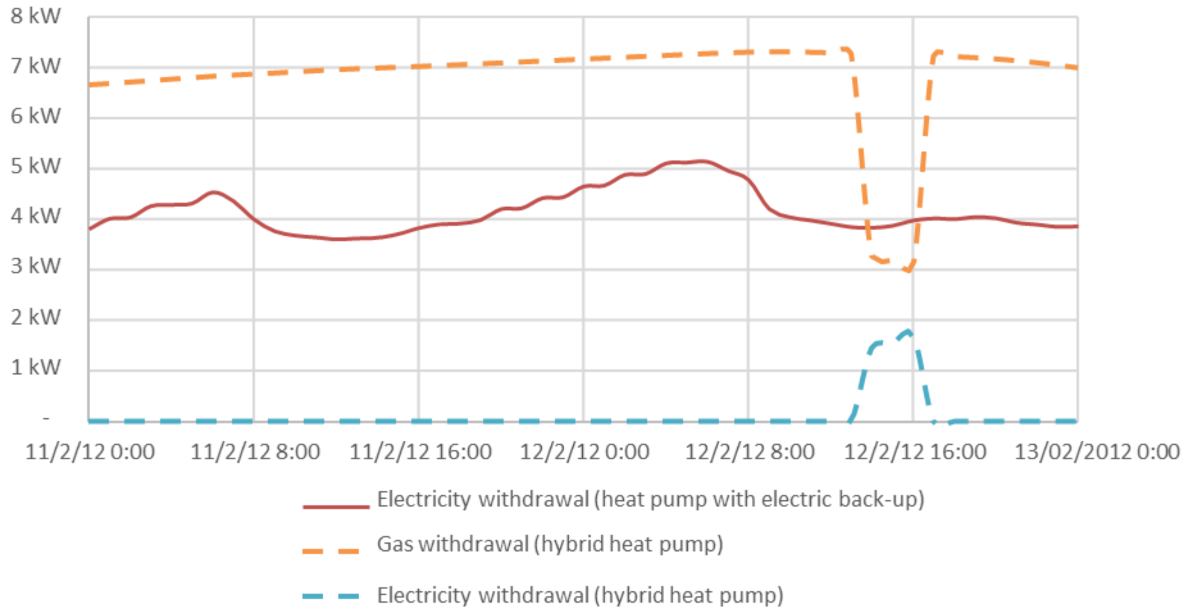


Figure 7 - Withdrawals from the electricity (kW_e) and gas (kW GCV) networks for the heat pump with electric back-up and the hybrid heat pump on 11th and 12th February 2012

Lastly, the hybrid includes electricity withdrawals 40% lower than that of the heat pump with electric back-up. However, it consumes more final energy than the heat pump with electric back-up: 7 MWh_{fe} all energies combined vs 4.8 MWh_{fe}. The difference in energy consumption is smaller in primary energy terms, and this time favours the hybrid heat pump: 10.6 MWh_{pe} vs 11 MWh_{pe} for the heat pump with electric back-up[11]. The energy consumption results for each heating system can be found in Table 4 below.

Heating system	Final energy consumption	Heat generation	Contribution to heating requirements
Hybrid heat pump	Heat pump: 2.8 MWh_e Boiler: 4.2 MWh GCV	Heat pump: 9.4 MWh_{th} Boiler: 3.9 MWh_{th}	Heat pump: 71% Boiler: 29%
Heat pump with electric back-up	Heat pump: 4.7 MWh_e Back-up: 0.1 MWh_e	Heat pump: 13.1 MWh_{th} Back-up: 0.1 MWh_{th}	Heat pump: 99% Back-up: 1%

Table 4 - Contribution of various items of equipment to heating requirements

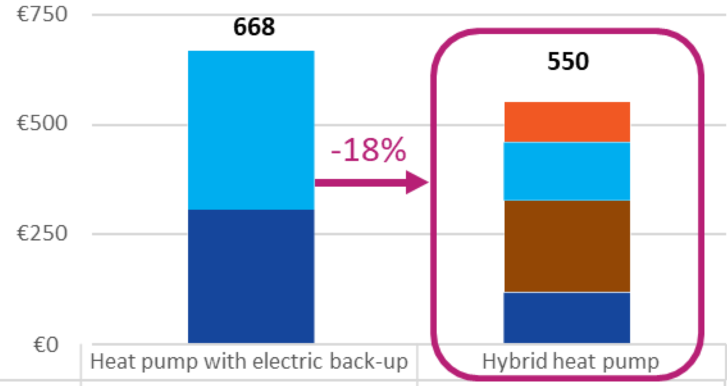
THE HYBRID HEAT PUMP IS ADVANTAGEOUS FROM THE POINT OF VIEW OF THE ENERGY SYSTEM

The hybrid heat pump has lower system costs than the heat pump with electric back-up: annual network and energy costs of €550 excl. VAT vs €668 excl. VAT for the heat pump with back-up, i.e. an

[11] The ratio of final energy to primary energy is considered to be 2.3 for electricity and 1 for gas

18% difference between the two heating systems, in favour of the hybrid heat pump. This advantage is due to a number of factors. Firstly, the controllability of the hybrid heat pump means it can choose the least costly energy supply for the system at hourly intervals. The heat pump switches off when the electricity system is under severe strain, which limits the need for investment in peak load capacity. Therefore, despite consuming more final energy per year than a heat pump with electric back-up (7 MWh vs 4.8 MWh), the energy supply is less expensive than that associated with the latter. In addition, the hybrid heat pump generates less power demand on the power distribution network (3.6kW_e max vs 5.2 kW_e for the heat pump with back-up). Lastly, most of this power demand is outside periods of congestion on the distribution network, which again limits costs.

The hybrid heat pump is therefore a relevant solution for minimising the overall costs of the energy system.

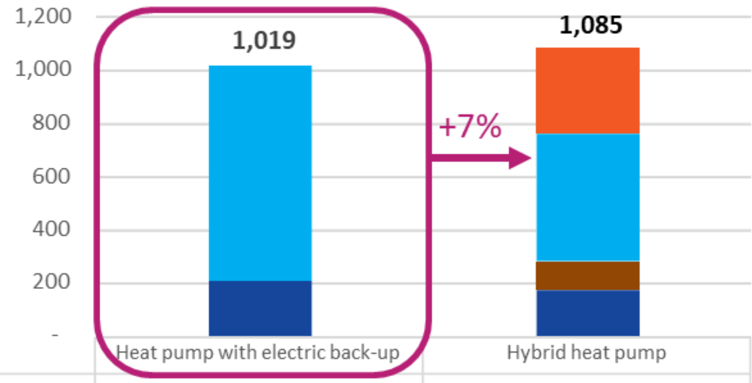


	Heat pump with electric back-up	Hybrid heat pump
Gas - Energy	-	91
Electricity - Energy	362	132
Gas - Network	-	210
Electricity - Network	306	118

Figure 8: : Average home heating costs excl. VAT from the point of view of the system for the heat pump with electric back-up and for the hybrid heat pump

HOWEVER, CURRENT PRICING ENCOURAGES CONSUMERS TO OPT FOR HEAT PUMPS WITH ELECTRIC BACK-UP

The heat pump with electric back-up is the most advantageous system for the consumer, with annual expenditure of €1,019 incl. VAT compared with €1,085 for the hybrid heat pump, i.e. **a 7% difference in favour of the heat pump with electric back-up**. Consumers are therefore encouraged to choose a heat pump with an electric back-up for the same thermal comfort, even though it entails higher costs for the energy system.



	Heat pump with electric back-up	Hybrid heat pump
Gas - Variable part	-	323
Electricity - Variable part	810	479
Gas - Fixed part	-	108
Electricity - Fixed part	209	175

Figure 9: Average home heating costs incl. VAT from the point of view of the consumer for the heat pump with electric back-up and for the hybrid heat pump

Current electricity pricing does not allow to take advantage of the curtailment capacity of hybrid heating equipment. The hybrid heat pump reduces the maximum power drawn by 31%, while the fixed part of the electricity bill is only reduced by 16%. In addition, the hybrid heat pump requires two supply contracts (electricity and gas), which means additional fixed costs for the consumer.

The analysis in this study therefore shows a significant imbalance between the pricing incentive given to consumers and its economic impact on the energy system as a whole.

4 Target measures

PROPOSAL NO. 1: DYNAMIC ELECTRICITY PRICING TO INCENTIVISE THE CURTAILMENT MADE POSSIBLE BY OPTING FOR A CONDENSING BOILER AS A BACK-UP SYSTEM FOR THE HEAT PUMP

With intermittent generation, demand flexibility is emerging as a key challenge for the energy transition: **hybrid heat pumps can be one of the tools for increasing this flexibility**.

This requires dynamically aligning the amounts paid by consumers with the costs to the system. This **dynamic pricing** must take account of the costs generated by peaks and heavy loads for the generation system, **but also for the transmission, dispatch and distribution network**.

The fixed part of the supply contract could also depend, at least in part, on peak demand on the busiest days (PP1, PP2[12]) and not just on the annual peak.

PROPOSAL NO. 2: FINANCIAL SUPPORT FOR INVESTMENT IN HYBRID EQUIPMENT

There are currently a number of grants available (via MaPrimeRénov' and *Crédits d'Economie d'Energie* - Energy saving certificates) for the purchase of heat pumps (hybrid or with electric back-up). These grants do not distinguish between the ideal type of back-up for the system (condensing boiler or electric back-up)

It would be worth introducing another specific premium to encourage the use of condensing boilers rather than resistance-based electric back-up. Switching from Joule electric heating to gas heating on peak days results in gains for the system. Based on the estimates made in this study, an additional €3,000 premium could be justified. This is only an initial estimate based on a representative example of the average housing stock, which needs to be refined and further developed. However, **there is no doubt that a bonus for the hybrid solution is justified**.

This measure, which is not exclusive in relation to the other proposals, is currently being implemented in Italy, where hybrid heat pumps are more subsidised than heat pumps with electric back-up, thereby enabling the sector to grow.

PROPOSAL NO. 3: JOINT ELECTRICITY AND GAS SUPPLY CONTRACTS CONDITIONAL ON THE USE OF A HYBRID HEAT PUMP

Reducing the fixed part of supply contracts for users of hybrid heat pumps is justified by the lower load on the power grid during critical periods. This is currently a major concern, particularly in Quebec, where joint supply contracts of this kind have been introduced between HydroQuébec (the Quebec

[12] PP1 and PP2 days, "Peak Period 1" and "Peak Period 2", are days of high electricity consumption. They are determined on D-1 by RTE, 15 days per year for PP1 and 25 days per year for PP2.

state-owned company responsible for generating, transmitting and distributing electricity in Quebec) and Energir (leading natural gas distributor in Quebec).

On the basis of this initial study, **a €200 reduction in the subscription fee** for this type of supply contract could be envisaged. To make sure the hybrid heat pump is used effectively to increase flexibility, the contract could include a guarantee that it will be managed in a way that takes account of the constraints on the electricity system. This would help recoup the investment made in the large-scale roll-out of Linky smart electricity meters.

A simpler control system based solely on the outside temperature could also be envisaged, at least initially, as is being done in Quebec.

In exchange for a contractual commitment guaranteeing a benefit for the energy system, financial compensation for consumers would be a way of rewarding their decision to invest in a hybrid heat pump. There are a number of ways in which all or part of this €200 could be passed on to the consumer: an annual tax credit (which can be checked using proof of annual maintenance), an adjustment to energy pricing or to the categories of supply contract on offer. This issue could be explored in more depth to determine one or more measures which could be applied in France and that would be in line with the deployment of hybrid heat pumps, beneficial to both the energy system and consumers.

Glossary

ATRD	*Accès des Tiers au Réseau de Distribution* (Third-party access to the natural gas distribution network)
COP	Coefficient of performance
CRE	*Comité de Régulation de l'Energie* (Energy Regulation Committee)
DHW	Domestic hot water
Excl. VAT	Excluding VAT
HP	Heat pump
Hybrid HP	Air-to-water heat pump with back-up gas condensing boiler
Incl. VAT	Including VAT
kVA	KiloVolt-Ampere, unit of power used in the choice of power supply contract
kW	Kilowatt, unit of power
kW_e	Kilowatt electric, unit of power
kWh	Kilowatt-hour, unit of energy corresponding with one kilowatt of power for one hour
kW_{th}	Kilowatt thermal, unit of power
MW	Megawatt, unit of power
MW_e	Megawatt electric, unit of power
MWh	Megawatt-hour, unit of energy corresponding with one megawatt of power for one hour
MWh_e	Megawatt-hour electric, unit of energy corresponding with one megawatt electric of power for one hour
MWh_{th}	Megawatt-hour thermal, unit of energy corresponding with one megawatt thermal of power for one hour
NCV or GCV	Net or gross calorific value
SCOP	Seasonal coefficient of performance
TRV	*Tarifs Réglementés de Vente de l'énergie* (Regulated energy selling prices)
VHEP	Very High Energy Performance

5 Appendices

5.1 Literature review: summary of the long-term benefits of hybrid heat pumps

Hybrid heat pumps are efficient heating systems, consisting of a low-power heat pump and a VHEP condensing boiler for back-up. At present, public authorities, in particular through the SNBC, are focusing mainly on the deployment of heat pumps with electric back-up. However, numerous studies have analysed the impact of the large-scale installation of hybrid heat pumps. The long-term benefits of hybrid heat pumps can be classified into three categories:

- Benefits for the consumer
- Benefits for the energy system
- Environmental benefits

5.1.1 Benefits for the consumer

THE HYBRID HEAT PUMP IS EASY TO INSTALL AS A REPLACEMENT FOR A GAS BOILER

For homes currently heated with a gas boiler, installing a hybrid heat pump is all the easier in that it does not require replacing the entire heating system inside the home, such as the **hydraulic network** and **all the radiators**, whereas for optimum use of electric heat pumps, all the emitters need to be changed to low-temperature emitters. [1, 5] This replacement of the internal heating system is costly and inconvenient for households wishing to install electric heat pumps.

AS A HEATING SYSTEM, THE HYBRID HEAT PUMP TAKES UP LESS SPACE THAN AN ELECTRIC HEAT PUMP

Unlike electric heat pumps, hybrid heat pumps do not require the addition of a hot water tank, as the high energy performance boiler produces DHW instantaneously. The smaller size of the heat pump reduces the size and noise of the equipment, which should also improve the acceptability of large-scale deployment. [5]

THE HYBRID HEAT PUMP IS COMPATIBLE WITH PHASED RENOVATIONS TO SPEED UP THE PACE OF RENOVATION

Major renovations are currently very **expensive** to carry out on a large scale. You should expect to pay €700 to €1,200/m² for insulation improvements[13]. Given that the average price of a house is €2,200/m², a major renovation project costing more than 30% of the average price of a house is difficult to implement on a large scale.

Moreover, the current pace of renovation is too slow compared with the SNBC's expectations for France. 100,000 to 200,000 equivalent complete renovations are currently carried out each year, when the pace should be in the region of 340,000 equivalent BBC[14] renovations per year until 2030 and 740,000 renovations per year until 2050 [9]. This discrepancy is all the greater given that the majority of renovations are currently being carried out on social housing owned by public entities, where large-scale renovation is easier to implement. [7]

Because of its size and flexibility, the hybrid heat pump is **suitable for homes with varying degrees of renovation**. [1, 2] As a result, there are no obstacles to the immediate deployment of hybrid heat pumps, and any further renovation stage will reduce the energy consumption of the home while avoiding costly initial over-sizing of the heating system, which would subsequently lead to sub-optimal use of the heat pump, which has limited modulation capacity. By comparison, with an electric heat pump, it is strongly recommended to carry out a complete energy renovation of a home prior to installation, as over-sizing the heating system entails significant additional purchase and running costs.

HYBRID HEAT PUMPS ARE LESS EXPENSIVE THAN ELECTRIC HEAT PUMPS AND ALLOW TO BENEFIT FROM THE FLEXIBILITY AND RESILIENCE OF DUAL-ENERGY SYSTEMS

The **investment and installation costs of a hybrid heat pump are lower** than those of an electric heat pump, by around 25% to 50%. [2, 5, 7]

Hybrid heat pumps help reduce the energy bills of homes if they are developed on a large scale and **appropriate markets are put in place to promote flexibility and resilience**. Even at current prices, the installation of a hybrid heat pump compared with a heat pump with electric back-up can reduce energy bills by up to 50% in the UK today [1], and the democratisation of the **curtailment market** on the electricity system could bring a benefit of around £150/year for a home equipped with a hybrid heat pump in the UK [2]. A hybrid heat pump allows the temperature to be raised quickly and efficiently, enabling a home to turn off its heating system during a period of absence without seeing a spike in consumption when it is turned back on, as is currently the case with gas boilers, which follow the heating needs of the home (an electric heat pump is more efficient when used regularly and constantly). [5]

---

[13] Order of magnitude for insulation improvements recommended by La Maison Saint Gobain

[14] An equivalent BBC renovation transforms a home into a *Bâtiment Basse Consommation* (low-energy building), a certification awarded when the energy consumption of the home falls below a regulatory threshold that depends on the geographical area and altitude. Find out more in the Effinergie Renovation Guide

At the moment, no value is placed on equipment resilience. Yet, this **resilience** is a real **advantage** of the hybrid heat pump compared with the electric heat pump: in the event of technical incidents (power cut due to a power station being shut down) or natural disasters (a tree falling on a power line), the hybrid heat pump can meet the heating needs of a home while greatly reducing its electricity consumption, thereby avoiding supply interruptions on the grid. [2] Also, in the event of a widespread power cut, the use of an electric vehicle battery (in Vehicle-To-Grid mode) can guarantee the power needed for the condensing boiler to run effectively for several days, the time needed for the grid to be restored.

THE HYBRID HEAT PUMP ENABLES CONSUMERS TO PLAY AN ACTIVE ROLE IN THE TRANSITION

Hybrid heat pumps enable consumers to become active contributors to the energy transition. Hybrid heat pumps make it easier to integrate renewable energy and optimise the energy system. As a result, they contribute to the societal transformation project, in every home.

LIKE AN ELECTRIC HEAT PUMP, THE HYBRID HEAT PUMP PROVIDES GOOD THERMAL COMFORT

As well as being highly efficient, heat pumps are multi-purpose equipment: heating, domestic hot water and air conditioning. As the need for air conditioning will no doubt increase over the coming decades as a result of climate change, installing a heat pump in a home is an attractive option for both reducing the carbon intensity of home heating and maintaining thermal comfort in extreme temperatures, during cold spells and heat waves. [3] It should be pointed out that a heat pump can only be used as air conditioner in homes with underfloor or ceiling heating, which is quite rare in homes undergoing renovation.

5.1.2 Benefits for the energy system

THE MASS DEPLOYMENT OF HYBRID HEAT PUMPS HELPS REDUCE PEAK DEMAND, THEREBY REDUCING THE NEED FOR INVESTMENT IN PEAK LOAD CAPACITY

With its efficiency, the hybrid heat pump, like the electric heat pump, can reduce the peak demand of a home compared with a home currently heated with electricity. [3]

However, the hybrid heat pump offers a considerable degree of flexibility, and can be controlled to limit its consumption at times of peak demand on the grid: compared with an electric heat pump, a hybrid heat pump can reduce the annual peak in electricity consumption by around 2 kW_e per home, i.e. reduce electricity consumption by almost 30% at the time when the power grid is under the most severe strain. [5] In some cases, the peak demand of an electric heat pump is more than twice that of a hybrid heat pump. This result is also illustrated in this study: the capacity reserved by a single-family home heated with an electric heat pump is much greater than with a hybrid heat pump, which requires a 12 kVA supply contract vs 9 kVA for a hybrid heat pump.

Alternative scenarios to the SNBC, which include the widespread deployment of hybrid heat pumps, predict a 5 to 10 GW reduction in installed peak capacity for the whole of France by 2050, compared with the SNBC. As peak capacity means, by its very nature, facilities operating for short periods of the year, it struggles to make a profit and runs counter to the ambitions of the environmental transition. [6 and 7] As an order of magnitude, the installed capacity of oil- and coal-fired power stations in France was 5.4 GW in 2020. By 2035, the deployment of hybrid heat pumps in place of electric heat pumps would reduce peak demand by 1.4 GW per million installations. [11]

THE REDUCTION IN PEAK DEMAND BROUGHT ABOUT BY THE WIDESPREAD DEPLOYMENT OF HYBRID HEAT PUMPS REDUCES THE NEED FOR GRID INFRASTRUCTURE (PARTICULARLY ON THE DISTRIBUTION SIDE)

The electrification of residential consumption, and heating in particular, will account for a significant proportion of the increase in peak demand between now and 2050. The subsequent cost to grid infrastructure is likely to be much higher if energy efficiency targets are not met. For example, if the rate of renovation were lower than expected, failing to renovate 3% of homes would lead to a 10% increase in peak demand compared with the SNBC forecast. [8]

Hybrid heat pumps offer an opportunity to limit this risk by reducing net peak demand. [8] Installing 6 million hybrid heat pumps would reduce this additional cost by nearly 40%, mainly for local grids (LV and MV). Should efficiency efforts be in keeping with targets, the installation of hybrid heat pumps will lead to a 4% reduction in average net peak demand per municipality.

Compared with a 100% electric scenario to meet heating needs, the deployment of hybrid heat pumps could reduce the surplus of electricity transmission and distribution network facilities by 16% to 50% in the UK by 2050. [1]

THE FLEXIBILITY OF HYBRID HEAT PUMPS ENHANCES THE RESILIENCE OF THE ENERGY SYSTEM

With the large-scale deployment of intermittent sources of electricity generation, the need for flexibility is increasing significantly, making it crucial to find new sources of flexibility from demand-side controllability. The installation of hot water tanks to accompany electric heat pumps and the deployment of electric vehicles helps bring daily flexibility to the energy system as a whole (directly in keeping with the generation of electricity by solar panels, with daily production cycles). The controllability of hybrid heat pumps can provide the flexibility needed on a weekly basis. [10]

The ability of hybrid heat pumps to switch off on power grids can be used to relieve the grid in the event of intense pressure (e.g. during specific weather events such as a ten-day high-pressure system in Europe, greatly reducing wind generation, or local incidents that render certain power grid lines unusable, thus increasing pressure on the grid). [1, 2, 8] Trade-offs can be made in favour of curtailment linked to the size of local grids and/or curtailment linked to the electricity generation capacity. These trade-offs could include a price signal communicated to the home taking these two aspects into account.

THE LARGE-SCALE DEPLOYMENT OF HYBRID HEAT PUMPS REDUCES OVERALL ENERGY SYSTEM COSTS

On a European scale, the large-scale installation of hybrid heat pumps (70% of heating is provided by electric heat pumps and 30% by hybrid heat pumps) could reduce the operating costs of the energy system by €1.6 billion per year by 2050, compared with a scenario in which all home heating needs are covered by electric heat pumps. [4]

By taking into account more global costs and greater optimisation of the energy system, some studies show much higher savings on a European scale. The savings made on the cost of heating systems (€4.7 billion to €47 billion per year, with hybrid heat pumps costing less than electric ones) and the savings on infrastructure costs (€9.5 billion to €17 billion per year, with hybrid heat pumps reducing peak demand) more than offset the additional costs associated with heating energy (up to €7 billion per year, with the cost of producing biomethane being higher on average than the cost of generating renewable electricity). Depending on the scenario for the deployment of hybrid heat pumps, the large-scale installation of hybrid heat pumps could result in savings of €3.4 billion/year to €81.8 billion/year for European society as a whole, including electricity generation costs, which could either decrease by up to €17.8 billion/year or increase by up to €3.8 billion/year. [1]

For Wales, savings of up to £1.5 billion a year [2] could be made, taking into account savings achieved by optimising the installed capacity and the power grid.

With the economic benefits that hybrid heat pumps bring to the system as a whole, this technology is considered a “no-regret technology” [7], i.e. one in which large-scale investments can be made in the coming decades. The development of such technology will almost certainly bring benefits to the system in its entirety.

HYBRID HEAT PUMPS ARE CONTROLLABILITY AND OPERABILITY TOOLS FOR THE ENERGY SYSTEM IN ITS ENTIRETY

Deploying hybrid heat pumps introduces an additional operational controllability tool for smart grids, responding to an unmet need for curtailment capacity for periods longer than a day. What’s more, this helps make the most of smart meters to optimise the integration of renewable energy and the optimisation of infrastructure. The operational benefits of the controllability of hybrid heat pumps not only reduce the constraints on the electricity generation system, but also make it easier to manage the transmission, dispatch and distribution networks.

5.1.3 Environmental benefits

THANKS TO THEIR EFFICIENCY, HYBRID HEAT PUMPS AND ELECTRIC HEAT PUMPS IMMEDIATELY REDUCE FOSSIL FUEL CONSUMPTION

Using efficient heating equipment can reduce primary energy consumption, and therefore reduce fossil fuel consumption, when replacing heating systems that run on fossil fuels (gas boilers, oil boilers and even electric heating in the event of a carbon-based electricity mix). As a result, CO2 emissions are reduced thanks to the installation of heat pumps, whether 100% electric or accompanied by an efficient gas back-up (high energy performance boiler). [3]

With the near-systematic deployment of hybrid heat pumps in the UK, the cumulated reduction in emissions(between 2020 and 2050 could be as much as 106 Mt CO2. [2] This is made possible by the ability of hybrid heat pumps to choose the least carbon-intensive energy at any given time, through fine-tuned control that may be implemented via the extensive use of smart meters. [1]

THE CONTROLLABILITY OF THE HYBRID HEAT PUMP ALLOWS TO CHOOSE TO USE THE LEAST CARBON-INTENSIVE ENERGY AT ANY TIME, THUS REDUCING THE CARBON INTENSITY OF HOME HEATING

Hybrid heat pumps, with the advantage of dual energy, can choose at any time to operate using the least carbon-intensive energy between gas and electricity. Low-carbon electricity can easily be used by the hybrid heat pump to meet the heating needs of a home.

In the event of a cold spell during which renewable energy is not sufficient to reduce the carbon intensity of the electricity mix, it may be more advantageous to use gas directly via the very high energy performance boiler of the hybrid heat pump than to use this gas to generate electricity in gas-fired power stations and use this electricity via the heat pump.

With their controllability, hybrid heat pumps could reduce CO2 emissions by 3.5 Mt CO2/year in France by 2035, if 2 million hybrid heat pumps were deployed to replace gas-fired boilers. In 2035, compared with electric heat pumps, hybrid heat pumps would **reduce peak demand without increasing CO2 emissions. [11]**

HYBRID HEAT PUMPS CAN REDUCE THE CARBON INTENSITY OF HOME HEATING AT A LOWER COST TO THE OVERALL SYSTEM

At European Union level, annual energy-related greenhouse gas emissions could be reduced by 42.5 Mt CO2/year by hybridising 30% of the heat pumps in all European homes in 2050, compared with the current situation. This carbon intensity reduction is more economical than what is achievable in a 100% electric scenario, with savings of around €1.6 billion per year without taking into account the optimisation of installed capacity. [4]

At the moment, reducing the carbon intensity of home heating is envisaged as a major renovation coupled with the installation of an electric heat pump, which is not affordable to all social groups. The large-scale development of hybrid heat pumps, combined with a phased building renovation, would help reduce the carbon intensity of housing in France at a lower cost. By using the vectors and technologies best suited to each sector, decarbonisation costs could be cut by €14 billion per year, including €5 billion per year for the residential sector, by focusing on the large-scale deployment of hybrid heat pumps in alternative scenarios to the SNBC. [8] Peak load curtailment is the main factor in these cost savings for the system in its entirety.

THE HYBRID HEAT PUMP TECHNOLOGY IS NOT ONLY MATURE, IT CAN ALSO EASILY REPLACE A BOILER IMMEDIATELY, MAKING IT QUICKLY DEPLOYABLE ON A LARGE SCALE

The ease of installation mentioned in the previous section on consumer benefits is also valid here, based in particular on the fact that it is not necessary to replace the entire heating system inside the home, such as the hydraulic network and all the emitters. [1, 5] As a direct replacement for gas-fired boilers, hybrid heat pumps lead to an immediate and rapid drop in greenhouse gas emissions.

This ease of installation, combined with their ability to reduce the carbon intensity of home heating, makes hybrid heat pumps an attractive option for home heating systems to be deployed on a large scale right away. The number of installations in 2019 was only 32,000 in France, Germany, the UK, Italy and the Netherlands [1]

Their relatively low investment cost, efficiency, resilience, environmental benefits and smart grid compatibility make hybrid heat pumps a workable solution for large-scale deployment today. [1, 5]

THE HYBRID HEAT PUMP ALLOWS THE USE OF BIOMASS TO BE OPTIMISED BOTH GLOBALLY AND LOCALLY, WHICH CAN HELP TO GET THE POPULATION ON BOARD WITH A CIRCULAR ECONOMY PROJECT THAT IS ESSENTIAL FOR THE ENVIRONMENTAL TRANSITION

The development of hybrid heat pumps is a useful way of showing the public the benefits of a multi-energy system, in terms of resilience and security of supply. Raising public awareness of the issues of climate change and security of energy supply will speed up local biogas production, which could boost rural areas [1, 2]

The large-scale deployment of heat pumps (electric or hybrid) will help develop an industry while creating jobs, estimated at nearly 54,000 for production, installation and maintenance in Europe. [3] As the boiler industry is well developed in Europe and high value-added parts for heat pumps are essentially imported from Asia, the widespread introduction of hybrid heat pumps will create value directly in Europe, thanks to the small size of the heat pump for the hybrid system.

Hybrid heat pumps also provide a hedge against two major risks directly linked to the transition: the pace of renovation and deployment of renewable energy. With the possibility of installing a hybrid heat pump in a home being renovated, and its ability to choose the least carbon-intensive energy, the hybrid heat pump is suited not only to the environmental transition, but also to a post-transition society where carbon neutrality has been achieved.

6 References

1. **Guidehouse.** *Unlocking the hybrid potential in European buildings.* 2021.

2. **Navigant, a Guidehouse company.** *Benefits of Hybrid Heat Systems in a Low Carbon Energy System.* 2020.

3. **European Copper Institute.** *Integrating technologies to decarbonise heating and cooling.* 2018.

4. **European Commission, Directorate-General for Energy.** *Decentralised heat pumps: system benefits under different technical configurations: METIS Studies, study S6.* 2019.

5. **Element Energy Limited.** *Hybrid Heat Pumps.* 2017.

6. **Artelys/Coénove.** *Quelles alternatives en 2050 pour une neutralité carbone dans le résidentiel.* 2019.

7. **ENGIE, TSE et Terra Nova.** Quelles solutions pour une Transition Energétique économique et résiliente. 2022.

8. **GRDF.** *Estimation de l'impact sur les réseaux électriques entre 2020 et 2050 du scénario AMS de la SNBC.* 2021.

9. **Direction Générale de l'Energie et du Climat.** *Synthèse du scénario de référence de la stratégie française pour l'énergie et le climat.* 2020.

10. **European Commission, Directorate-General for Energy.** *Mainstreaming RES: flexibility portfolios: design of flexibility portfolios at Member State level to facilitate a cost-efficient integration of high shares of renewables.* 2019.

11. **RTE et ADEME.** *Evaluation de scénarios possibles pour décarboner le chauffage dans le secteur du bâtiment à l'horizon 2035.* 2020.