

Olympic mindset: Making France a heat pump leader

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Introduction

Decarbonising space and water heating in buildings has emerged as a critical part of France's transition towards a sustainable energy system. French residential and commercial buildings still rely heavily on fossil fuels for space and water heating. Consequently, buildings contribute significantly to the country's carbon footprint, making heat decarbonisation a key area of focus. Government and civil society have identified key levers, notably rapidly adopting clean heating technologies such as air-to-water heat pumps, and renovating existing buildings.

Heat pumps have a long history in France. The country is a European leader in heat pump adoption and has introduced a variety of policies that have helped it achieve this status, including tiered subsidy schemes that benefit low-income households. Communication efforts have improved consumers' access to information, and the carbon price on heating fuels has improved the relative economics of heat pumps.

Yet challenges remain. As in many European countries, the upfront cost of heat pumps has risen in France. Although the subsidy framework is generous, it is complex. Instances of fraudulent behaviour by some companies have lowered consumer trust in the sector. Energy prices are tilted against heat pumps, making it harder for them to gain further market share. Finally, the future of gas boilers is uncertain, and guidance on hybrid heating solutions is lacking.

Our analysis¹ investigates the economic barriers to heat pump deployment and suggests several solutions. It should be noted that, although heat pumps are a key technology for heat decarbonisation, they are not appropriate for all situations and their cost and performance depend heavily on building fabric efficiency and a high-quality installation. Simply put, it is important for decision-makers to strike a balance between ramping up heat pump deployment and renovating the worst-performing buildings.

Recommendations for boosting the role of heat pumps in France:

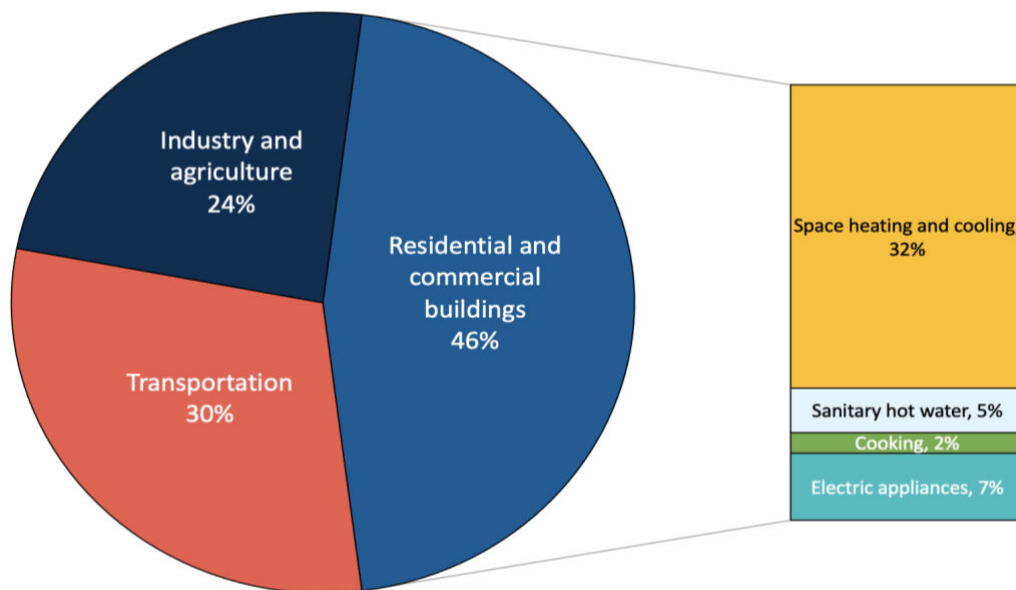
- **Streamline the grant application process** and simplify the wide variety of technology categories.
- **Provide comprehensive and clear technical guidance to consumers**, including identifying cost-effective solutions and defining the necessary conditions for a hybrid heat pump system.
- **Focus technology-specific financial support on air-source heat pumps.** Make support for hybrid heat pumps contingent on a technical review by an energy expert and their recommendation in heating and cooling plans from the local government.

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Status of heat decarbonisation in buildings

France's buildings sector is responsible for a significant portion of its energy use and subsequent greenhouse gas emissions. Residential and commercial buildings account for around 46% of the country's final energy use, compared to 30% in transport and 24% in industry and agriculture as depicted in Figure 1.² Approximately 37% of France's final energy is used for space heating, space cooling and hot water production.³

Figure 1. Final energy consumption in France, by sector, 2021



Source: National Institute of Statistics and Economic Studies (Insee). (2023). *Energy Balance for France*. French Statistical Data and Studies Department. (2023). *Energy consumption by residential use*.

How France heats its buildings

French buildings are heavily dependent on fossil fuels for heating. In recent years, as shown in Figure 2,⁴ around 52% of space heating and hot water needs were met directly

² Margo, M. & Grillet, C. (2022, November). *Chaleur renouvelable: la grande oubliée de la stratégie énergétique française?* [Renewable heat: the forgotten element in France's energy strategy?]. Carbone4, <https://carbone4.com/fr/publication-chaleur-renouvelable>. Institut national de la statistique et des études économiques (Insee) [National Institute of Statistics and Economic Studies]. (2023). *Bilan énergétique de la France* [Energy balance for France]. <https://www.insee.fr/fr/statistiques/2015823>

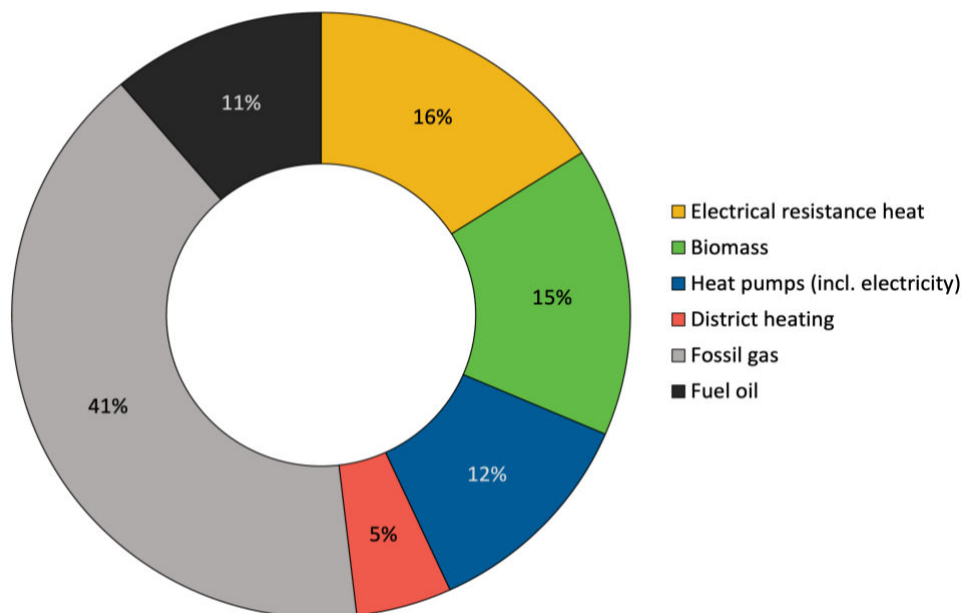
³ Service de la donnée et des études statistiques (SDES) [French Statistical Data and Studies Department]. (2023). *Données et études statistiques pour le changement climatique, l'énergie, l'environnement, le logement et les transports: Consommation d'énergie par usage du résidentiel* [Statistical data and studies for climate change, energy, environment, housing and transport, 2021: Energy consumption by residential use]. <https://www.statistiques.developpement-durable.gouv.fr/consommation-denergie-par-usage-du-residentiel>

⁴ Latest data available is 2021 for residential buildings and 2020 for tertiary buildings. SDES, 2023; *Données et études statistiques pour le changement climatique, l'énergie, l'environnement, le logement et les transports: Consommation d'énergie par usage du tertiaire* [Statistical data and studies for climate change, energy, environment, housing and transport, 2021: Energy consumption by commercial sector use]. <https://www.statistiques.developpement-durable.gouv.fr/consommation-denergie-par-usage-du-tertiaire>

with fossil fuels, primarily fossil gas and fuel oil.⁵ These polluting fuels are also used in the production of electricity and district heating, both of which serve home heating. The share of fossil fuels in space heating has only slightly declined over the previous decade, from 62% in 2011 to 52% in 2021.

Many French buildings also use heat from renewable sources. Biomass supplies the bulk of the renewable heat share, at around 15% in 2021. A consistent 16% of French heating needs is met by direct electric resistance heat, excluding the electricity used to power heat pumps. This level has remained stable over the past 10 years. Over the same decade, the share of heating provided by heat pumps has more than doubled, from 5% in 2011 to 12% in 2021. This growing use of heat pumps reflects their rising popularity and overall successful performance.

Figure 2. Energy consumed for space heating and hot water production, by energy source, 2021



Note: Energy sources providing less than 1% of heating needs have been omitted for clarity. Data for residential buildings is from 2021 and for commercial buildings from 2020 (latest data available).

Sources: French Statistical Data and Studies Department. (2023). *Energy consumption by residential use*;
French Statistical Data and Studies Department. (2021). *Energy consumption by commercial sector use*.

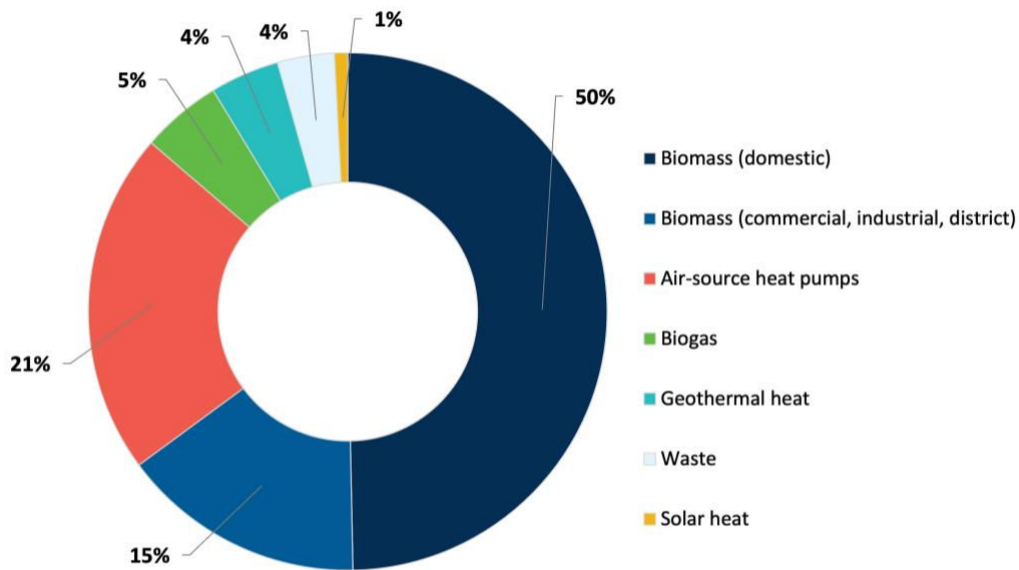
France's target to have renewable energy meet 38% of its heating needs by 2030 applies not just to buildings, but to industrial processes as well. As a result, it is important to discuss the overall share of renewable energy in heat production. Currently, renewable sources provide around 23% of France's heat production, including buildings and industry. These sources continue to be predominantly biomass: around 65% of French renewable heat was from biomass in 2021, as

⁵ SDES, 2023.

shown in Figure 3 below.⁶ Domestic biomass furnaces and boilers contributed half of France’s renewable heat production. This dependence is significant, as burning biomass for heat has been associated with negative sustainability impacts and health outcomes.

Air-source heat pumps, both air-to-air and air-to-water, are widely used in France. They make up the second-most significant renewable heat technology and provide an increasing share of heat in buildings. In terms of overall heat production, they account for about 21% and rising.

Figure 3. Renewable heat production in France, by source, in 2021



Source: French Renewable Energy Association. (2022). *Overview of renewable heat and recovered heat, 2022 edition*.

Policy framework for decarbonising heat

France has two overarching policy frameworks that set its decarbonisation pathway in all sectors, including buildings: the national low-carbon strategy — *Stratégie nationale bas-carbone (SNBC)*⁷ — and its multi-year energy plan — *Programmation pluriannuelle de l'énergie (PPE)*.⁸ It is worth noting that both the SNBC and PPE were undergoing revision at the time of publication, which the government expects to impact the targets for heat pumps and the overall consumption of renewable heat.

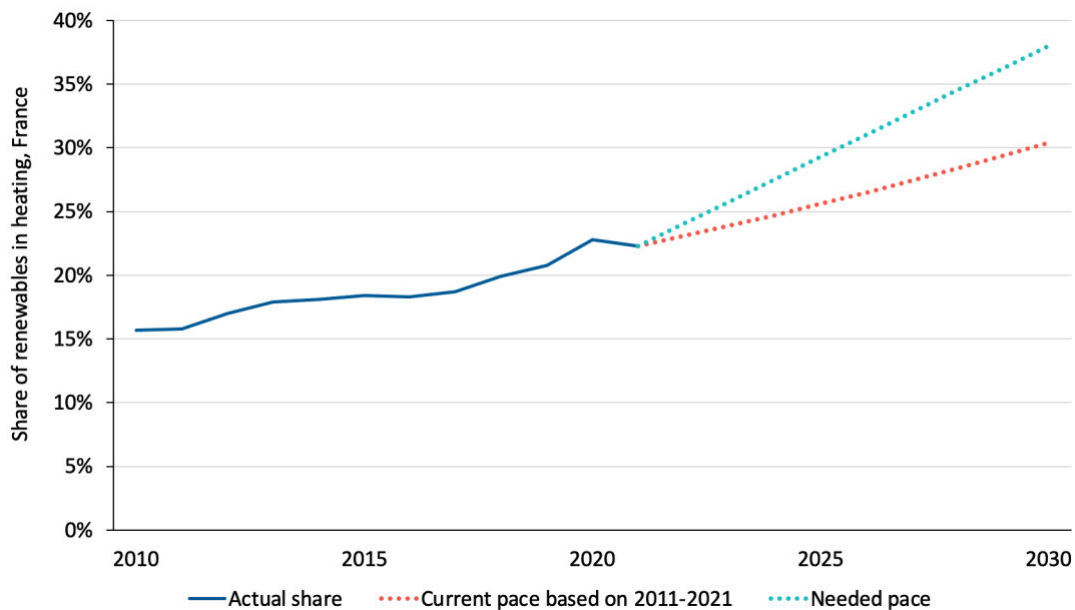
⁶ Syndicat des énergies renouvelables [French Renewable Energy Association]. (2022). *Panorama de la Chaleur Renouvelable et de Récupération – Édition 2022* [Overview of renewable heat and recovered heat, 2022 edition]. <https://www.syndicat-energies-renouvelables.fr/wp-content/uploads/basedoc/panorama-chaaleur-2022-web.pdf>

⁷ Ministère de la Transition Écologique (MTES) [French Ministry for the Ecological Transition]. (2020). *Stratégie Nationale Bas-Carbone* [National low-carbon strategy]. <https://www.ecologie.gouv.fr/strategie-nationale-bas-carbone-snbc>

⁸ MTES. (2020). *Programmations pluriannuelles de l'énergie* [Multi-year energy plans]. <https://www.ecologie.gouv.fr/programmations-pluriannuelles-lenergie-ppe>.

With respect to buildings, the current SNBC aims for a 60% reduction in greenhouse gas emissions by 2030 and complete decarbonisation by 2050. The PPE sets, among many objectives, targets for final energy consumption and renewable heat production and share. The current PPE targets 38% renewable energy in heating by 2030. With a share of just 23% in 2021 it still has a long way to go, having increased only marginally from 15.8% in 2011. At this pace, it will only reach 30.4% by 2030, as shown in Figure 4.⁹ Clearly, greater efforts are needed, and heat pumps can be a key source of growth.

Figure 4. Share of renewables in heating in France, and pace needed to meet decarbonisation goals



Sources: French Statistical Data and Studies Department. (2023). *Energy consumption by residential use*;
 French Statistical Data and Studies Department. (2021). *Energy consumption by commercial sector use*;
 French Renewable Energy Association. (2022). *Overview of renewable heat and recovered heat, 2022 edition*.

If the share of renewables in heating is to rise, France is betting heavily on an increase in the consumption of biomass and biogas. The PPE targets biomass consumption of 157-169 terawatt hours (TWh) by 2028, an increase of 35%-45% compared to 2021 levels of 117 TWh. This means roughly 70% of total renewable heating and cooling consumption in 2028 should come from biomass, a level even higher than the current share of around 65% shown in Figure 3.¹⁰

⁹ SDES, 2023; SDES, 2021; French Renewable Energy Association, 2022.

¹⁰ MTES. (2023). *Publication Indicateurs de Suivi de PPE (Janvier 2023 – Données Définitives) pour l'année 2021* [Publication of EPP monitoring indicators (January 2023 – final data) for 2021]. <https://www.ecologie.gouv.fr/programmations-pluriannuelles-lenergie-ppe>

The PPE objective for biogas is to inject 14-22 TWh into the French gas grid by 2028. This represents a massive 220%-410% increase from the 2021 level of 4.3 TWh.

Deep decarbonisation of buildings will require a significant increase in heat pump deployment. This reality is not, however, reflected in the PPE objectives. The plan targets heat pumps reaching 44-52 TWh, an increase of 2%-21% compared to 2021 levels of 43.1 TWh. Fortunately, air-to-water heat pumps are on the rise: the PPE already reached its 2023 target of 39 TWh in 2021.

The changing heating appliance market in France

France has a dynamic heating appliance market. Although gas boilers do not feature as prominently as in some of its neighbouring markets, such as Germany, Belgium and the United Kingdom, they do nonetheless make up a significant share.

Air-to-air heat pumps dominate the French heating and cooling market, with around 45% of total sales in 2022.¹¹ Condensing gas and oil boilers account for about 27%, followed by air-to-water heat pumps at 21%, non-condensing gas and oil boilers at 4%, and biomass boilers at 3%.¹²

Sales of gas and oil boilers fell 30% in 2022, following a post-Covid surge in 2021, as shown in Figure 5.¹³ According to heating appliance association Uniclimate, shrinking boiler sales have been due to several factors: the impact of rising gas prices on consumer sentiment, a ban on fossil boilers in new construction, and the elimination of public funding for boiler replacements in existing buildings. By contrast, biomass boilers grew 24% in 2022 to reach 42,000 units sold — up from 12,000 in 2018 — albeit well below the 500,000 condensing boiler sales each year.¹⁴

To a certain extent, the growth in air-to-water heat pumps has compensated for the decline of boilers. These devices sold a record 346,000 units in 2022, nearly a quadrupling since 2018. The market for air-to-air heat pumps stayed relatively stable over the previous three years, with a slight decline in 2022 due in part to the surge in air-to-water heat pumps and an incremental phaseout of public subsidies targeting these appliances. The market for hybrid heat pumps has remained stable year-on-year, with roughly 4,000 units sold. Finally, around 3,000 ground-source heat pumps are sold in France every year, a market that has remained consistent since 2018.¹⁵

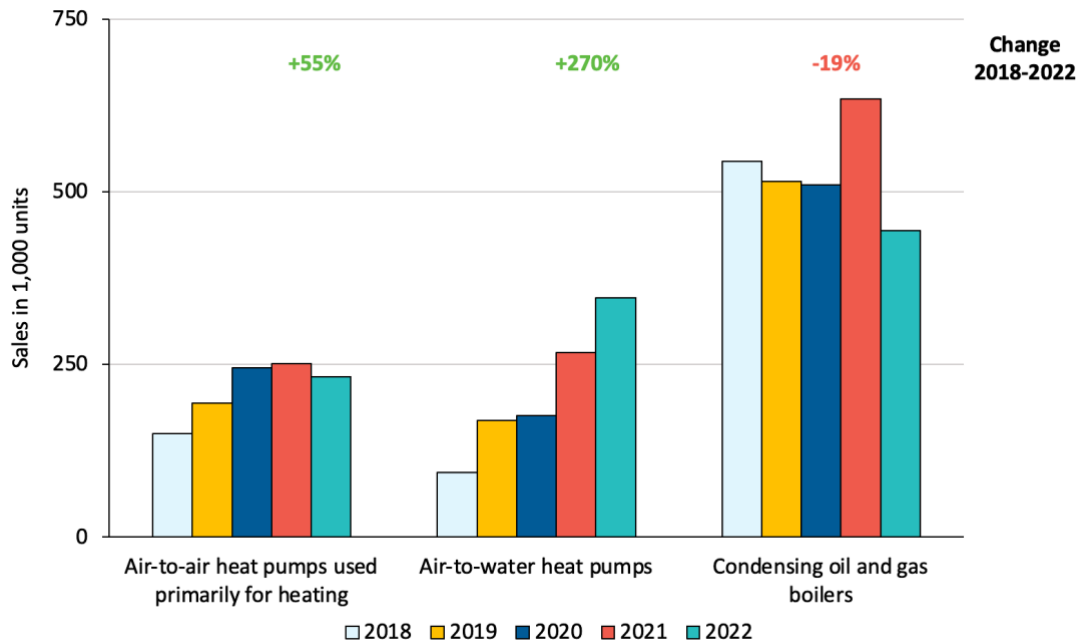
¹¹ The French Heat Pump Association, AFPAC, estimates that only around 30% of these devices are primarily used for heating, while the remainder are just for cooling. Air-to-air heat pumps used for heating thus account for around 14% of the market.

¹² Observ'ER. (2023, May). *Suivi du marché 2022 des pompes à chaleur individuelles* [Monitoring the 2022 market for heat pumps]. <https://energies-renouvelables.org/etudes-observer>

¹³ Uniclimate. (2023, 2 February). *Bilan 2022 et Perspectives 2023 des Industries Thermiques, Aérauliques et Frigorifiques* [2022 assessment and 2023 outlook for the heat, air and refrigeration industries]. https://www.uniclimate.fr/presse_51_dossier-de-presse-bilan-2022-et-perspectives-2023-des-industries-thermiques-aerauliques-et-frigorifiques.html

¹⁴ Uniclimate. (2023, 2 February). *Bilan 2022 et Perspectives 2023 des Industries Thermiques, Aérauliques et Frigorifiques* [2022 assessment and 2023 outlook for the heat, air and refrigeration industries]. https://www.uniclimate.fr/presse_51_dossier-de-presse-bilan-2022-et-perspectives-2023-des-industries-thermiques-aerauliques-et-frigorifiques.html

¹⁵ Uniclimate. (2023, 2 February). *Bilan 2022 et Perspectives 2023 des Industries Thermiques, Aérauliques et Frigorifiques* [2022 assessment and 2023 outlook for the heat, air and refrigeration industries]. https://www.uniclimate.fr/presse_51_dossier-de-presse-bilan-2022-et-perspectives-2023-des-industries-thermiques-aerauliques-et-frigorifiques.html

Figure 5. Sales of heating systems in France, 2018-2022

Note: Sales of air-to-air heat pumps have been adjusted to include only devices used primarily for heating.

Source: Uniclimate. (2023). *2022 assessment and 2023 outlook for the heat, air and refrigeration industries.*

The growth in heat pump installations is not limited to new buildings. This is true for both air-to-water heat pumps and air-to-air heat pumps. More than 89% of air-to-water heat pumps were installed in existing buildings in 2022.¹⁶

As a result of surging market demand, the price of installing an air-to-water heat pump is increasing in France. Since 2017, average equipment prices for a 7-8 kW heat pump have risen from around €7,550 to €9,770 in 2022, or around 5% per year as shown in Figure 6.¹⁷ Notably, nominal prices for this equipment increased 10% in 2022 and 2021 compared to the previous year.

According to an industry survey conducted by Observ'ER, a key reason for this rising cost is the increasingly long lead times for equipment availability as the supply of parts and materials has become expensive and tight.¹⁸ This lag has progressed to the point where component suppliers are asking heat pump manufacturers to order well in advance, causing these effects to cascade through the entire supply chain to the installation companies. The average price of the installation has also been gradually

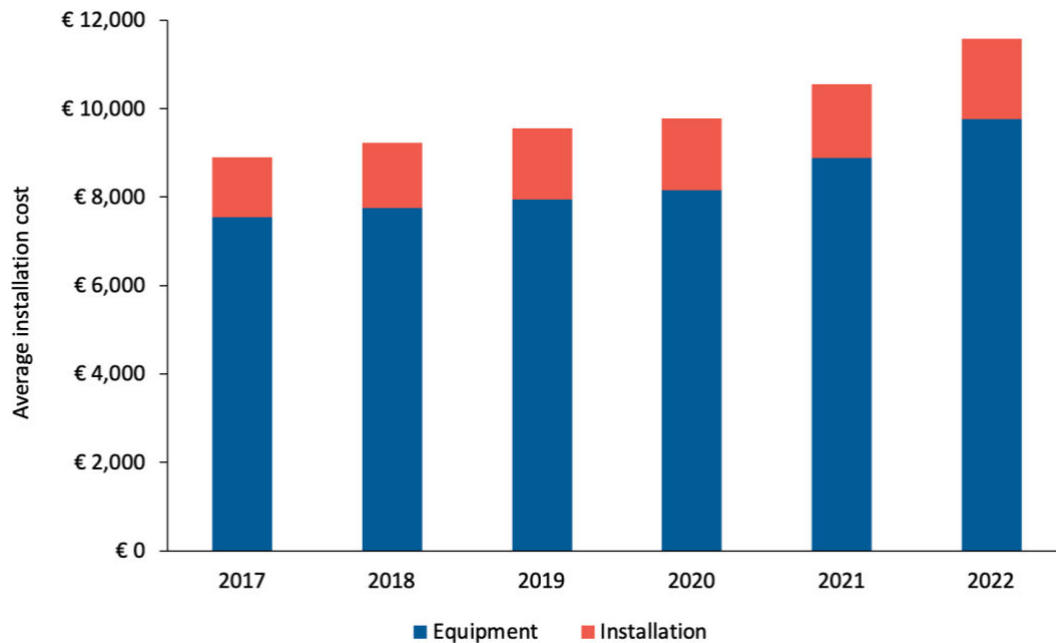
¹⁶ Observ'ER, 2023

¹⁷ Equipment price includes the heat pump, hot water cylinder, circulating pump and more. These are nominal prices and have not been adjusted for inflation. Observ'ER, 2023.

¹⁸ Observ'ER, 2023

rising. Counterintuitively, subsidy schemes may also be in part responsible for rising prices, as demand for heat pumps has increased while suppliers and installers have not yet caught up.

Figure 6. Average price of installing a 7-8 kW air-to-water heat pump in France, 2017-2022



Note: 'Equipment' includes heat pump, 200 L hot water cylinder, thermostat and control accessories, expansion vessel, valves and hydraulic connections, and circulating pump. Prices are nominal and have not been adjusted for inflation.

Source: Observ'ER. (2023). *Monitoring the 2022 market for heat pumps.*

Review of heat pump policy in France

High-level frameworks and regulation

Framed by the SNBC and PPE, France has a strategic framework that mandates the phaseout of fossil fuel boilers and the use of clean heating sources, notably heat pumps. Its environmental regulation of 2020, *Réglementation Environnementale 2020*,¹⁹ aims at decarbonising and reducing the energy consumption of new buildings. Its scope includes environmental standards for heating equipment in new buildings. Since it came into force in January 2022, standalone gas boilers must not be installed in new individual homes. Collective housing will be subject to the restriction starting in 2025. Gas boilers will be permitted only when installed in a hybrid format alongside an

¹⁹ Ministère de la Transition écologique et de la Cohésion des territoires & Ministère de la Transition énergétique [French Ministry for the Ecological Transition and Territorial Cohesion & French Ministry of the Energy Transition]. (2023, 17 February). *Réglementation environnementale RE2020* [Environmental regulations 2020 RE2020]. <https://www.ecologie.gouv.fr/reglementation-environnementale-re2020>

electric heat pump or similar. This may, however, have unintended consequences (see text box on hybrid heat pumps on page 15).

This restriction does not apply, however, to existing buildings. To address this sector, France launched a consultation in June 2023 to explore its options for banning the installation of gas boilers in existing individual homes and collective housing. The consultation closed on 28 July 2023, and the French government decided against restricting gas boiler installations in existing buildings. In place of the ban, it announced changes to the subsidy scheme and a target to manufacture 1 million heat pumps by 2027.

Economic instruments

In terms of economic instruments, France introduced a carbon price in 2014 that applies to all sectors of the economy, including buildings. Originally set at €7 per tonne of carbon emitted (tCO₂), the price gradually rose to €44.6/tCO₂ in 2018, where it has remained ever since.²⁰ In terms of the cost of gas heating, the carbon price translates to €9 per megawatt-hour (MWh), roughly 16% of France's average price of fossil gas in 2021 before taxes (€57/MWh).²¹ The price of carbon is clearly a significant tool for improving the economics of heat pumps versus gas boilers. As an economic instrument, however, it applies to the running costs only and does not impact infrastructure costs. Consequently, gas usage may eventually be reduced, but it will not be the most cost-efficient way of doing so.

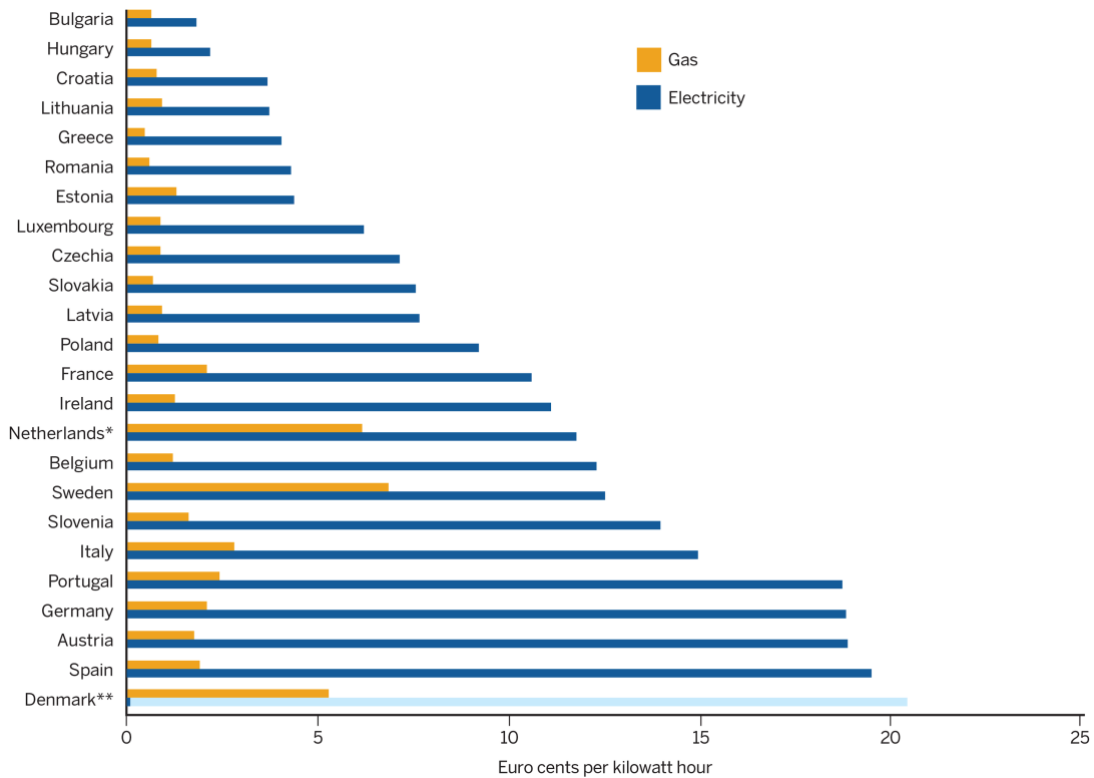
Notably, taxes and levies placed on energy are another key lever to improve the economics of heat pumps. These economic tools are often imposed on energy carriers to help build energy infrastructure, fund various energy programmes or (dis)incentivise the use of a certain fuel. If taxes and levies are too high on electricity or too low on gas and heating oil, this can negatively affect the economic rationale for electric heating. Finding a suitable balance is key.

In most European countries, however, electricity faces more than three times more tax per unit of energy than fossil gas, as illustrated in Figure 7.²²

²⁰ Ministère de la Transition écologique [French Ministry for the Ecological Transition] (2023). *Guide 2023 sur la Fiscalité ses Énergies* [2023 Energy tax guide]. <https://www.ecologie.gouv.fr/sites/default/files/guide%20fiscalit%C3%A9%20energie%202021.pdf>

²¹ Eurostat. (2023). *Gas prices for household consumers – Bi-annual data*. https://ec.europa.eu/eurostat/databrowser/view/NRG_PC_202/default/table?lang=en

²² Rosenow, J., Thomas, S., Gibb, D., Baetens, R., De Brouwer, A. & Cornillie, J. (2022). *Levelling the playing field: Aligning heating energy taxes and levies in Europe with climate goals*. Regulatory Assistance Project & 3E. <https://www.raponline.org/knowledge-center/aligning-heating-energy-taxes-levies-europe-climate-goals>

Figure 7. Taxes and levies on electricity and gas in EU Member States, average, in 2021

* The taxes and levies on electricity in the Netherlands do not include the lump sum rebate given to residential electricity consumers, as this is not directly related to electricity consumption.

** The taxes and levies on residential electricity consumption over 4,000 kWh per year for residential consumers registered as using electricity for space heating in Denmark are the lowest in the EU. All other residential electricity consumption is subject to the highest rate in the EU.

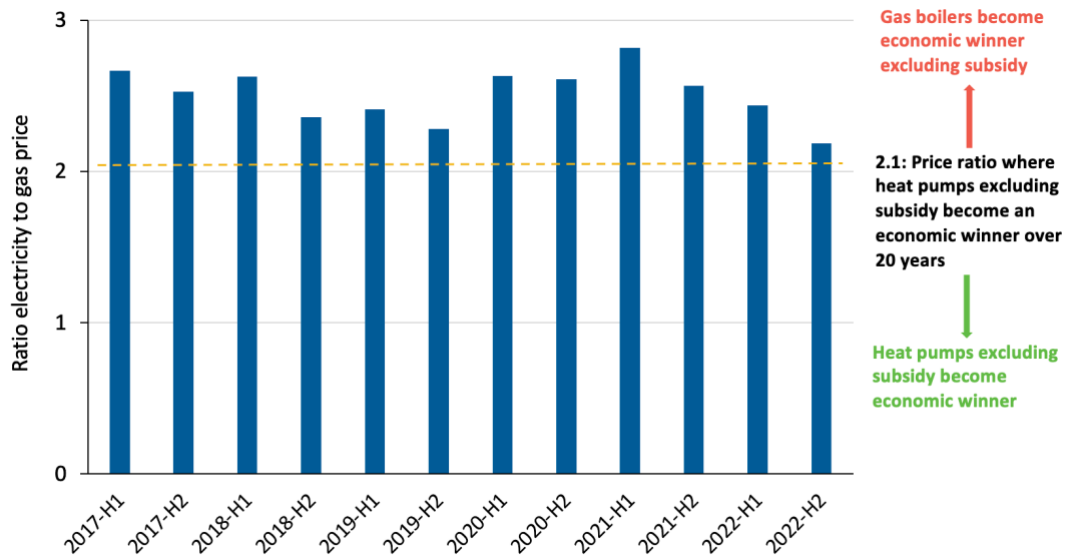
Source: Regulatory Assistance Project & 3E. (2022).
Levelling the playing field: Aligning heating energy taxes and levies in Europe with climate goals.

On average, a heat pump needs about three times less input energy than a boiler to produce the same amount of heat — and, in France, costs roughly twice as much upfront. A simple calculation, assuming a boiler efficiency of 95% and heat pump coefficient of performance of 3, shows that electricity must be less than 2.1 times as expensive as fossil gas for heat pumps to be economically advantageous over the device lifetime. In the second half of 2022, electricity cost around 2.2 times as much as fossil gas, as illustrated in Figure 8.²³ By further rebalancing taxes and levies away from

²³ RAP calculations based on Eurostat. (2023). *Disaggregated final energy consumption in households* [Data set]. Accessed 7 September 2023. https://ec.europa.eu/eurostat/databrowser/view/nrg_d_hhq/default/table?lang=en; Eurostat. (2023). *Number of households by household composition, number of children and age of youngest child* [Data set]. Accessed 7 September 2023. https://ec.europa.eu/eurostat/databrowser/view/lfst_hhnhtych/default/table?lang=en

electricity, heat pumps can provide even more lifetime savings. Many EU Member States have begun taking steps towards this, such as the Netherlands and Germany.²⁴

Figure 8. Ratio of average electricity and gas prices in France, 2017-2022



Note: For this simple calculation, for a gas boiler the capital expenditure is assumed at €5,000, and for a heat pump at €10,000. Gas boiler efficiency is 95% and heat pump coefficient of performance is 3, a conservative estimate. The prices include all taxes.

Source: Eurostat. (2023). *Disaggregated final energy consumption in households*; Eurostat. (2023). *Number of households by household composition, number of children and age of youngest child*.

Regulation

France's White Certificate programme — *Certificats d'Économies d'Énergie (CEE)* — is an energy efficiency obligation scheme that requires most energy suppliers to meet energy saving targets, achieved through energy efficiency actions among end users. Each eligible energy efficiency action generates credits — white certificates — depending on its scale and expected longevity. Suppliers are free to carry out their own actions, contract with third parties, or buy credits bilaterally or on the spot market. Obligated or third parties can use any combination of financial incentives, information provision and other supporting activities to bring about the end-use energy efficiency actions.

²⁴ Rosenow, J., Thomas, S., Gibb, D., Baetens, R., De Brouwer, A. & Cornillie, J. (2023). Clean heating: Reforming taxes and levies on heating fuels in Europe. *Energy Policy* 173, 113367. <https://doi.org/10.1016/j.enpol.2022.113367>

The level of the obligation in the current, fifth phase of the scheme (2022-2025) was increased by 25%²⁵ and is expected to mobilise around €20 billion in investment.²⁶ It includes a requirement for at least 33% of white certificates to be delivered among low-income households, and bonuses (called “*coups de pouce*”) for actions focused on decarbonisation, such as replacing fossil fuel heating with clean heating systems. Another revision is planned to gradually increase the obligation in 2025 before the sixth phase.²⁷

The white certificate programme sets a quantitative target for energy savings and allows actions funded by other programmes to be combined, effectively setting the ambition level for end-use energy savings.²⁸ The extent to which heat pumps will deliver the targeted energy savings depends on their relative cost-effectiveness for obligated parties, which in turn depends in part on the deemed savings allocated to heat pumps, the bonuses available for decarbonisation actions, and the strength of other related policy instruments such as grants, heating system and building regulations, and energy and carbon taxation.

The cost-effectiveness of heat pumps in meeting obligated parties’ targets is reflected in the measures carried out in the current phase of the white certificate programme. Over the course of the first 15 months of this phase beginning in January 2022, heat pump installations were responsible for a higher share of white certificates (31%) than any other standardised action.²⁹ Among the other standardised actions, various forms of building insulation generated 24% and individual biomass boilers 4%. These percentages include bonus white certificates, as described above.³⁰

The white certificate programme has had a large impact on the heat pump market, particularly among low-income households. Yet it has also played a role in market swings, as target setting, banking and borrowing rules, as well as changes to bonuses,

²⁵ Banque de Territoires. (2022). *Certificats d'économies d'énergie: un décret augmente de 25% le niveau d'obligation* [Energy saving certificates: decree increases obligation by 25%]. <https://www.banquedesterritoires.fr/certificats-deconomies-denergie-un-decret-augmente-de-25-le-niveau-dobligation>

²⁶ Batinfo.com. (2021, 3 February). *The government is preparing the 5th period of the Energy Saving Certificates (EEC) system*. <https://batinfo.com/en/actuality/the-government-is-preparing-the-5th-period-of-the-energy-savings-certificate-system-cee-17442>

²⁷ Ministère de la Transition Écologique [French Ministry for the Ecological Transition]. (2023). *Consultation sur la 6e période CEE et la fin de la 5e période* [Consultation on the 6th EWC period and the end of the 5th period]. <https://www.ecologie.gouv.fr/sites/default/files/CEE-Consultation.pdf>

²⁸ The actual level of energy savings is likely to be affected by several factors. The availability of bonuses enables obligated parties to meet their obligations using priority measures, such as those focused on decarbonisation, which generate more certificates than their energy savings would otherwise have created. Other certificates are also available for actions by third parties that help obligated parties target measures at those in energy poverty. In addition, most of the energy savings from measures installed in buildings are ‘deemed savings,’ based on historic evidence on their effectiveness. The actual energy savings, although impossible to measure, could be more accurately estimated using meter data, albeit at greater cost. Energy savings among low-income groups are likely to be lower than the deemed savings owing to those households being less able to afford to pay for a standard level of thermal comfort and therefore overheating their living spaces. On the other hand, obligations are expressed in cumulative terms, whereby the energy savings over the expected lifetimes of the measures are discounted at a rate of 4% per year; the metric is known as ‘cumac.’

²⁹ Standardised actions are commonly carried out actions for which a fixed value of white certificates has been defined. For more details, see Ministère de la Transition Écologique [French Ministry for the Ecological Transition]. (2023). *Opérations standardisées d'économies d'énergie* [Standardised energy saving operations]. Accessed 11 September 2023. <https://www.ecologie.gouv.fr/operations-standardisees-deconomies-denergie>

³⁰ Ministère de la transition énergétique [French Ministry of the Energy Transition]. (2023, May). *Lettre d'information 'Certificats d'économies d'énergie'* [Newsletter ‘Energy savings certificates’]. <https://www.ecologie.gouv.fr/sites/default/files/2023-05%20lettre%20d%27infos%20CEE%20vf.pdf>

affected supply chains.³¹ The programme will continue to be a major driver of French policy as it advances further towards delivering emissions reductions. Longer-term certainty about targets would be helpful to provide a basis for supply chain investment.

Financial support

France provides an array of financial support programmes to facilitate the deployment of heat pumps, among other clean heating technologies.

The flagship grant scheme for renovations — *MaPrimeRénov'* — is a tiered government support scheme based on household income. The lowest-income households (below €39,500 for a three-person household in Ile-de-France), are eligible for a grant of up to €5,000 towards an air-to-water heat pump, an amount falling to €3,000 for moderate-income households (below €67,500).³²

Although high-income households with a total annual income greater than €67,500 are not eligible for heat pump subsidies in *MaPrimeRénov'*, they can benefit from one of the bonus schemes in the white certificate programme, *Coup de pouce chauffage*.³³ This bonus is linked to the value of the white certificate generated through installation of a heat pump. It provides minimum levels of support of €4,000 for the lowest-income households, and €2,500 — which is not dependent on household income — to replace a gas boiler with an air-to-water heat pump or a hybrid heat pump.

Replacing a fuel oil boiler also qualifies for €4,000 or €2,500 in support, respectively. As mentioned, these grant schemes are cumulative, so a lowest-income household would theoretically have access to €9,000 in funding, while a high-income French household would receive €2,500.³⁴ Considering average air-to-water heat pump prices rose in 2022 to nearly €12,000 for an 8-kW air-to-water system, this financial support would be inadequate to overcome upfront cost barriers for the average consumer. The timing of the support is also key, especially for low-income households, who would struggle to pay the upfront cost and wait for reimbursement.

To bridge that gap, since 2009 France has also provided zero-interest loans — *L'éco-prêt à taux zero* — that can be used to install heat pumps. Some banks propose financing the remaining cost of energy-efficient renovations, including heat pumps, with the zero-interest loans.³⁵ Household income does not play a role in qualifying for the loan.³⁶ With a mere 20,000 to 30,000 zero-interest loans granted annually,

³¹ Osso, D., Rolland A., & Chatagnon, N. (2020). *The ups and downs of the French EEO scheme: Positive and negative impacts on the building renovation market*. <https://edf.hal.science/hal-03070247/document>

³² France Rénov. (2023). *Les Aides Financières en 2023* [Financial Aid in 2023]. <https://france-renov.gouv.fr/sites/default/files/2023-01/Guide-des-aides-financieres-2023.pdf>

³³ Ministère de la Transition Écologique [French Ministry for the Ecological Transition]. (2022). *Coup de pouce 'Chauffage' et 'Isolation'* ['Helping hand' for heating and insulation]. <https://www.ecologie.gouv.fr/coup-pouce-chauffage-et-isolation>

³⁴ The government announced in October 2023 upcoming changes to the French subsidy programme, with several billion euros allocated towards energy-efficient home renovation and heating systems. The change is expected in January 2024 and details were not available at the time of publication.

³⁵ Republic of France. (2022, 25 November). *Service Public, Rénovation énergétique: comment cumuler l'éco-PTZ avec MaPrimeRénov'?* [Public service announcement: Energy renovation: how to combine the zero interest eco-loan with MaPrimeRénov?]. <https://www.service-public.fr/particuliers/vosdroits/F36448>

³⁶ Republic of France. (2022, 6 October). *Service Public, Éco-prêt à taux zéro (éco-PTZ)* [Public service announcement: zero interest eco-loan]. <https://www.service-public.fr/particuliers/vosdroits/F19905>

however, the results fall well below the programme's objective of 400,000 per year. This has led analysts to conclude that banks have not properly promoted the loans, even though they are attractive to the banks — thus, households are simply not aware or interested.³⁷

As a further measure, France provides a lower value-added tax (VAT) rate of 5.5% for an air-to-water heat pump.³⁸ It is worth noting that air-to-water heat pumps are eligible for many of France's support schemes, such as MaPrimeRénov', zero-interest loans and reduced VAT, but not air-to-air heat pumps. This is largely because France does not wish to incentivise the use of air-conditioning in warmer months, as it is generally viewed as energy-intensive and runs counter to the country's principles of '*sobriété énergétique*,' or restraint in energy overconsumption. In addition, air-to-air heat pumps tend to be cheaper, so they may not require support, and benefit from a growing market due in part to their attractiveness to consumers as a cooling device.

The role of hybrid heat pumps in building decarbonisation

Hybrid heat pumps typically combine an electric heat pump with a condensing gas boiler. Homeowners often consider this combination because they fear that their heat pump alone will not be able to provide full heating during cold periods. In addition, hybrid systems may also lessen concerns about electric grid capacity during cold spikes.

However, field testing and consumer experience have shown that in all European countries, standard air-source heat pumps can provide efficient heating, even at the coldest temperatures.³⁹ Hybrid heat pumps may also be more expensive to install and operate than electric heat pumps (see Annex). The use of a hybrid heat pump can potentially raise energy bills (as the consumer must sign up with both energy services), pays for the upkeep of the existing gas network and remains vulnerable to fluctuating prices. Notably, the French transmission system operator RTE found that even if the number of homes heated by heat pumps increased seven-fold, pushing up peak demand on the grid by 6 gigawatts (GW), the current system could manage the change.⁴⁰

Hybrid heat pumps may have a role to play in existing buildings where it is technically challenging or expensive to replace a gas boiler with an electric solution. However, in most conditions, an electric heat pump or district heating would be suitable, especially in new buildings that adhere to modern fabric efficiency standards.

The levels of these support schemes, especially for low-income households, can make heat pumps an increasingly economic option. When the upfront cost is amortised annually over the device lifetime of 18 years, high-income households can expect an

³⁷ Giraudet, L.-G. (2021). Pourquoi le recours à l'éco-prêt à taux zéro est-il si faible? [Why is take-up of the zero-rate eco-loan so low?]. *Transitions. Les nouvelles Annales des Ponts et Chaussées* [The new annals of Ponts et Chaussées]. 1. pp.128-133. <https://enpc.hal.science/hal-03278386/document>

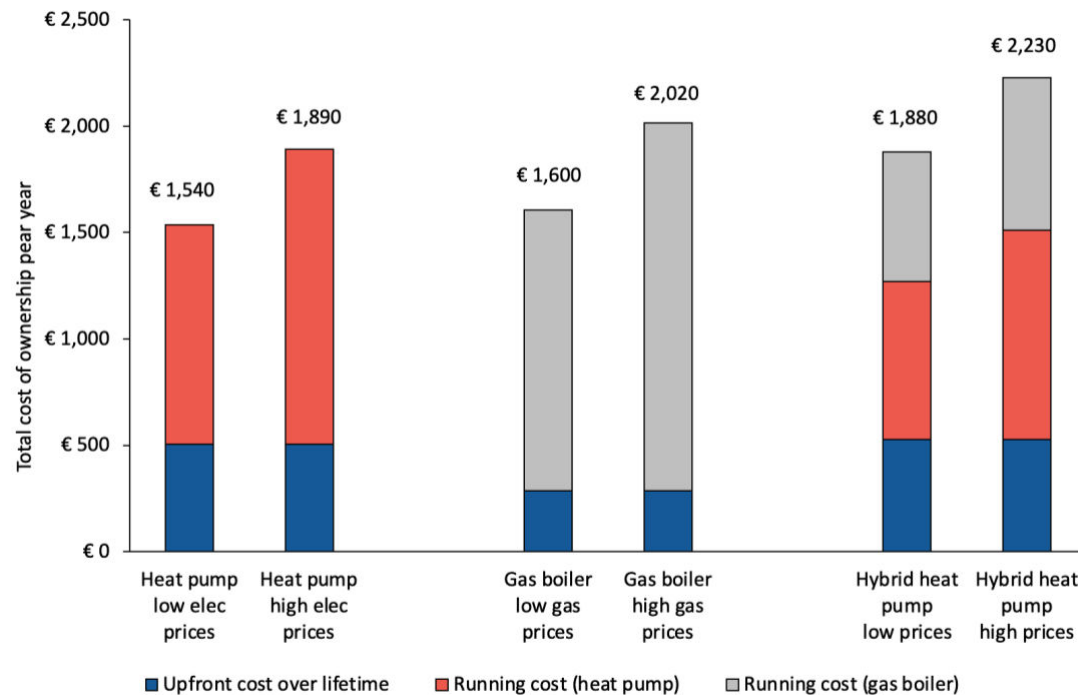
³⁸ France Rénov, 2023.

³⁹ Gibb, D., Rosenow, J., Lowes, R., & Hewitt, N.J. (2023, 11 September). Coming in from the cold: Heat pump efficiency at low temperatures. *Joule* 7(9). <https://doi.org/10.1016/j.joule.2023.08.005>

⁴⁰ RTE. (2023). *Bilan Prévisionnel 2023-2035* [Balance forecast 2023-2035]. <http://www.rte-france.com/actualites/bilan-previsionnel-transformation-systeme-electrique-2023-2035>

annual total cost of ownership of around €1,500 per year for a heat pump, €1,600 for a gas boiler and €1,900 for a hybrid heat pump under 2021 price conditions, as shown in Figure 9.⁴¹ For details on the methodology, see Annex.

Figure 9. Yearly total cost of ownership of a heat pump, gas boiler and hybrid heat pump in France, high-income household



Note: Electricity prices are set at €176/MWh and fossil gas prices are at €72/MWh (both 2021 averages after VAT, left columns) and prices 50% higher (right columns). Subsidy of €2,500 included for heat pump and hybrid heat pump. See Annex for more details.

Source: Please see Annex for full list of data sources.

This translates to annual savings in running costs of €280 for an air-to-water heat pump compared to a gas boiler and €320 compared to a hybrid heat pump. If fossil gas prices double again, the respective savings become €700 and €430. Here we can see how the hybrid heat pump mitigates the gas price risk compared to using only a gas boiler. However, in times of high gas *and* electricity prices, an air-to-water heat pump would still be more economical. In addition to the issue of gas prices rising, system costs will continue to increase as users leave the gas network and costs are spread across fewer customers. Heating with fossil gas will likely become more expensive as a result, increasing the cost disparity.

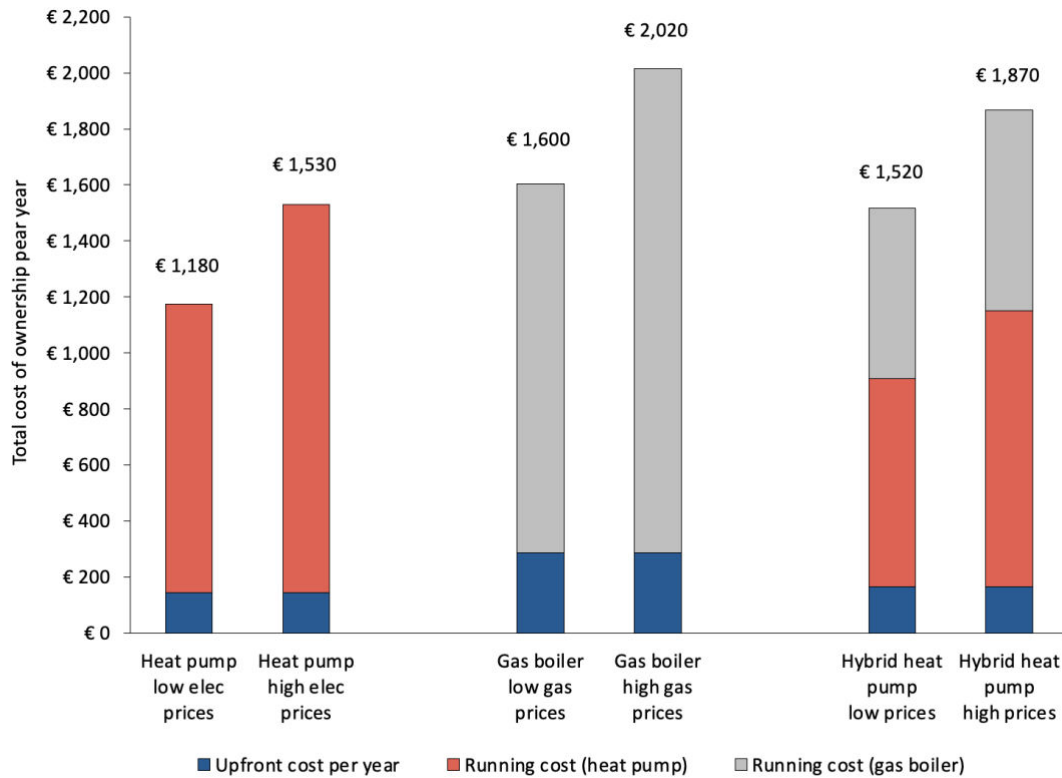
For the lowest-income households, which have access to a maximum subsidy of €9,000 for air-to-water and hybrid heat pumps, the investment makes even more sense. Figure 10⁴² illustrates that lowest-income households can expect a total cost of ownership of around €1,200 per year for a heat pump, €1,600 for a gas boiler and

⁴¹ Please see Annex for full list of assumptions and data sources.

⁴² Please see Annex for full list of assumptions and data sources.

€1,500 for a hybrid heat pump under 2021 gas prices. The operating cost savings are the same as for a high-income household because only the upfront subsidy is adjusted based on income levels. Even in the unlikely occurrence of high electricity and low gas prices, an air-to-water heat pump would still see cost savings of €210 and €70 compared to a gas boiler and hybrid heat pump, respectively.

Figure 10. Yearly total cost of ownership of a heat pump, gas boiler and hybrid heat pump in France, low-income household



Note: Electricity prices are set at €176/MWh and fossil gas prices are at €72/MWh (both 2021 averages after VAT, left columns) and prices 50% higher (right columns). Subsidy of €9,000 included for heat pump and hybrid heat pump. See Annex for more details.

Source: Please see Annex for full list of data sources.

Although France's clean heat subsidies are further advanced and offer greater support than many other EU countries, the programme still contains pitfalls. French households, especially low-income households, face a complex subsidy programme that is difficult to access. Despite the generous amounts available, homeowners can struggle to understand the different options and how to receive funding. In addition, in most cases⁴³ they only have access to the subsidies after installation, meaning they must usually provide capital upfront. To address this, the French government relies on the public service FranceRénov', which provides transparent consumer advice for individuals, businesses, and communities.⁴⁴

⁴³ In some cases, homeowners can access the CEE subsidy upfront via the installers and may request up to 70% of the MaPrimeRénov' subsidy prior to installation. This process, however, is more complicated.

⁴⁴ More information at France Rénov, <https://france-renov.gouv.fr>

Remaining challenges of decarbonising French buildings

France's approach to decarbonising buildings is built on three key pillars:

- Incentivising energy efficiency, especially in low-income households, and decarbonising through white certificates and carbon pricing.
- Subsidising clean heating alternatives.
- Regulating buildings for efficiency.

This approach seems to have contributed to growing the market for clean heating technologies, especially air-to-water heat pumps in recent years, and providing support to low-income households. Notably, it is one of the only countries in Europe to provide long-term support to the poorest households with a dedicated budget.⁴⁵

However, France has experienced setbacks and faces unique challenges that slow its progress towards renewable heat in buildings. First and foremost, the country has around 5.2 million primary residences with very poor levels of insulation, with energy performance certificates of F and G.⁴⁶ Around 2.9 million buildings, or 40%, are heated with fossil gas and fuel oil. Even worse, 1.2 million, or more than half of those heated with fuel oil, are the country's worst-performing buildings.

Regardless of the heat source used, it is important that these 5.2 million inefficient buildings undergo some level of renovation. However, the current rate at which France's worst buildings are being renovated to a high level of energy performance, an A or B certificate, is at less than half of the government's target: around 60,000 to 90,000 homes are renovated each year, compared to an objective of 200,000.⁴⁷ Overall, in 2022 more than 700,000 homes were partially renovated with €3.4 billion of funding.⁴⁸

France faces significant technical barriers to spurring the uptake of air-to-water heat pumps, especially in renovation. Although fossil gas represents the highest share of energy consumed for heating, electric resistance heaters are proportionally more common in buildings, especially in apartments. These structures may not yet have a

⁴⁵ Sunderland, L. & Gibb, D. (2022). *Taking the burn out of heating for low-income households*. Regulatory Assistance Project. <https://www.raonline.org/knowledge-center/taking-burn-out-of-heating-low-income-households>

⁴⁶ Ministère de la Transition Écologique [French Ministry for the Ecological Transition]. (2022). *Le parc de logements par classe de performance énergétique au 1er janvier 2022* [Housing stock by energy performance class as of January 1, 2022]. <https://www.statistiques.developpement-durable.gouv.fr/le-parc-de-logements-par-classe-de-performance-energetique-au-1er-janvier-2022-0>

⁴⁷ Rüdiger, A. & Gaspard, A. (2022, May). *Réussir le pari de la rénovation énergétique: Rapport de la plateforme d'experts pour la rénovation énergétique des logements en France* [Making the energy renovation challenge a success: Report from the platform of experts for the energy renovation of housing in France]. Iddri & Ademe. <https://www.iddri.org/fr/publications-et-evenements/etude/reussir-le-pari-de-la-renovation-energetique>

⁴⁸ Republic of France. Agence nationale de l'habitat (Anah) [National Housing Agency]. (2023, 23 January). *Plus de 700 000 logements rénovés en 2022: l'activité de l'Anah se poursuit à un très haut niveau et confirme la tendance engagée en 2021* [More than 700,000 homes renovated in 2022: Anah's activity continues at a very high level, confirming the trend begun in 2021]. [Press release]. <https://www.anah.fr/presse/detail/actualite/plus-de-700-000-logements-renoves-en-2022-lactivite-de-lanah-se-poursuit-a-un-tres-haut-niveau-et-confirme-la-tendance-engagee-en-2021>

hydronic heating system based on radiators or underfloor heating. Small apartments may also bump up against significant space issues when considering installation of a hot water tank. Local authorities such as cities and regions have a key role in providing guidance to their constituents to determine the best technical option, whether it is a district heating connection, an air-to-water heat pump, a hybrid heat pump or another alternative.

What's more, the renovation and heating sector in France was the subject of complaints over poor administration and fraud. MaPrimeRénov', for example, received approximately 1,400 complaints, primarily related to administrative and technical problems. These issues disproportionately affect the lowest-income households, which rely heavily on subsidies to fund their renovation projects and heat pump installations.^{49,50} Frequent acts of fraud included companies using deceptive names, misrepresenting their services and posing as official sustainability and energy efficiency agencies. Such practices misled consumers, leading some to purchase or upgrade heat pumps, and created confusion around tax credits. A 2018 study revealed that over half of the 469 companies audited exhibited anomalies, indicating the persistence of unfair practices.⁵¹

The government took action to address these issues, including by making telemarketing and cold calling for energy renovation services or heating system replacements illegal. It also strengthened a certification standard known as 'label RGE' in 2020, increased communication efforts to guide consumers towards its one-stop-shop network FranceRénov', and published detailed information to help individuals identify and avoid fraudulent practices.^{52,53} These actions aimed to protect consumers and improve the overall integrity of the renovation and heating sector in France. In addition, France provides support for training and certifying installers in energy efficiency and heat pump installation.⁵⁴ Despite these experiences, 84% of French homeowners surveyed in a 2021 study stated their confidence in heat pumps.⁵⁵

⁴⁹ Reporterre. (2023, 21 April). *Rénovation: 1 400 réclamations contre MaPrimeRénov'* [Renovation: 1,400 claims against MaPrimeRénov']. <https://reporterre.net/Renovation-1-400-reclamations-contre-MaPrimeRenov-article>

⁵⁰ Les Echos-Études. (2019, 18 November). *Le label RGE renforcé pour lutter contre les arnaques à la rénovation énergétique* [RGE label strengthened to combat energy renovation scams]. <https://www.lesechos-etudes.fr/blog/actualites-21/le-label-rge-renforce-pour-lutter-contre-les-arnaques-a-la-renovation-energetique-9517>

⁵¹ Republic of France, Ministère de L'Économie des Finances et de la Souveraineté Industrielle et Numérique, Direction générale de la concurrence, de la consommation et de la répression des fraudes [Ministry of the Economy, Finance and Industrial and Digital Sovereignty, General Directorate for Competition, Consumer Affairs and Fraud Control]. (2019, 3 October). *Pratiques déloyales et trompeuses dans le secteur des énergies renouvelables et de la rénovation thermique* [Unfair and deceptive practices in the renewable energies and thermal renovation sector]. <https://www.economie.gouv.fr/dgccrf/pratiques-deloyses-et-trompeuses-dans-le-secteur-des-energies-renouvelables-et-de-la>

⁵² Ministère de L'Économie des Finances et de la Souveraineté Industrielle et Numérique [Ministry of the Economy, Finance and Industrial and Digital Sovereignty]. (2023, 15 June). *Professionnels du bâtiment: comment obtenir la mention « reconnu garant de l'environnement* [Building professionals: how to obtain the "recognised environmental guarantor" label]. <https://www.economie.gouv.fr/entreprises/batiment-label-rge>

⁵³ Republic of France, France Rénov'. (n.d.). *Se prémunir contre les fraudes* [Protecting yourself against fraud]. <https://france-renov.gouv.fr/fraudes>

⁵⁴ For example, the FEEBAT initiative subsidises a 5-day training for installers, preparing them to apply for the qualification exam that would allow them to install heat pumps supported by the subsidy programmes. FEEBAT. (n.d.). *Les certificats d'économies d'énergie: FEEBAT conçoit pour vous des formations à la rénovation énergétique* [Energy savings certificates: FEEBAT designs energy renovation training courses for you]. <https://www.feebat.org/>

⁵⁵ Association Promotelec. (2021, May). *La pompe à chaleur: L'outil par excellence de la transition énergétique* [Heat pumps: the ideal tool for the energy transition]. <https://www.promotelec.com/app/uploads/2021/05/Synthese-etude-Promotelec-Pompes-a-chaleur.pdf>

Conclusions

When it comes to decarbonising its buildings with heat pumps, France may be leading the way in Europe, but it has a long road ahead. Its air-to-water heat pump sales have grown to around 350,000 units per year, but still lag behind gas and oil boiler sales, which continue to hover around 500,000 units. A faster uptake of heat pumps is needed if the country wants to meet its target of 38% renewables in heating by 2030.

However, France has put in place several exemplary policies that have made it Europe's heat pump leader. The country's generous tiered subsidy schemes make heat pumps affordable for most, and notably for the lowest-income households. These policies are expected to be strengthened in 2023. Policymakers have removed financial support for individual gas boilers and restricted their installation in new buildings, further boosting the prospects for clean heating. Finally, France's public communications following the fraudulent practices improved accessibility to information for its consumers. Its carbon price on heating fuels also appears largely effective.

Yet, France still faces challenges. Countries in earlier stages of the transition to clean heat in buildings may learn valuable lessons from the French experience. The support framework may be generous, but it remains complicated for consumers, leading them to identify it as a major barrier: only 21% believe it is easy to navigate France's subsidy framework.⁵⁷ Moreover, a lower price ratio between gas and electricity would make heat pumps even more economically advantageous to operate. It would also lessen the cost hurdle posed by the high initial investment by shortening the payback time.

Finally, the road ahead for gas boilers remains unclear. Although the government has announced a massive scale-up of heat pump manufacturing by 2027 and will not ban the installation of boilers in existing buildings, there remains little guidance on the suitability of hybrid heating solutions. In some situations, such as extreme weather locations, collective housing or buildings with difficult-to-renovate structures, hybrid

Policy toolkit for global mass heat pump deployment

In 2022, RAP alongside its partners CLASP and Global Buildings Performance Network published the first edition of its *Policy toolkit for global mass heat pump deployment*.⁵⁶ The toolkit describes a comprehensive policy framework for rapid expansion of heat pumps that breaks the policy tools into three main categories: economic instruments, financial support, and regulation. Communication and coordination, as well as the important considerations of equity, round out these tools.

⁵⁶ Lowes, R., Gibb, D., Rosenow, J., Thomas, S., Malinowski, M., Ross, A., & Graham, P. (2022). *A policy toolkit for global heat pump deployment*. Regulatory Assistance Project, CLASP & Global Buildings Performance Network. <https://www.raonline.org/knowledge-center/policy-toolkit-global-mass-heat-pump-deployment/>

⁵⁷ France Bleu. (2023, 23 February). *SONDAGE – Rénovation énergétique: plus de la moitié des propriétaires renoncent en raison du coût* [SURVEY – Energy renovation: more than half of homeowners give up because of cost]. <https://www.francebleu.fr/infos/environnement/renovation-energetique-plus-de-la-moitie-des-proprietaires-prets-a-se-lancer-renoncent-en-raison-du-budget-4912683>

heating might be justified. However, there is a risk that homeowners may opt for a hybrid solution even when it is not in their best interest or does not provide real value. Consumers need clear direction to help them understand the conditions requiring hybrid solutions. The use of this hybrid technology also requires holistic planning to avoid driving up system costs and perpetuating networks that will eventually become obsolete. Vulnerable energy users in particular are at risk of being stuck on those networks. Making financial support for installing a hybrid heat pump contingent on a technical review by an expert could help reduce this risk.

France has made great strides towards decarbonising its buildings with heat pumps. Its policy decisions can help guide other European countries. Challenges remain, and this paper provides the following recommendations.

Recommendations:

- **Streamline the grant application process** and simplify the wide variety of technology categories.
- **Provide comprehensive and clear technical guidance to consumers,** including identifying cost-effective solutions and defining the necessary conditions for a hybrid heat pump system.
- **Focus technology-specific financial support on air-source heat pumps.** Make support for hybrid heat pumps contingent on a technical review by an energy expert and their recommendation in heating and cooling plans from the local government.

Annex: Yearly total cost of ownership methodology

Calculations presented in this paper show the annual total cost of ownership for an air-to-water heat pump, a gas boiler and a hybrid heat pump (heat pump and gas boiler combination). These calculations are shown for both a high-income and low-income household in Figures 9 and 10. This annex explains the methodology behind the calculations and the numbers chosen.

We took the residential space and water heating demand in 2021 numbers from the Eurostat database *Household final energy consumption disaggregated*.⁵⁸ We then divided the average space heating demand per country by the number of households to reach an average space and water heating demand per household.⁵⁹

Device characteristics

For each technology, we assumed the following average seasonal conversion efficiencies:

- Air-to-water heat pump with a seasonal coefficient of performance (SCOP) of 3.1.
- Condensing gas boiler with an efficiency of 95%.

These efficiencies are largely accepted as industry standards and may even downplay the performance of heat pumps. For example, the Sustainable Energy Authority of Ireland reported a median SCOP of 3.95 in 2020, and Croatia, Denmark and the Netherlands have seen SCOP reach above 4.⁶⁰

The efficiency value we used in this study also may be generous towards the gas boilers, considering it corresponds to the minimum as defined by Appendix X in the European Commission's Energy Efficiency Directive guidance note.⁶¹ The existing fleet of boilers in France is not comprised exclusively of the most energy-efficient options and would therefore operate at a fleet efficiency much lower than 95%.

For the hybrid heat pump, we assumed, based on work by the Danish Energy Agency, that the heat pump efficiency would be slightly higher than in standalone applications because it is not heating at the lowest temperatures.⁶² Likewise, the gas boiler efficiency

⁵⁸ Eurostat. (2023). *Disaggregated final energy consumption in households* [Data set]. Accessed 7 September 2023. https://ec.europa.eu/eurostat/databrowser/view/nrq_d_hhq/default/table?lang=en

⁵⁹ Eurostat. (2023). *Number of households by household composition, number of children and age of youngest child* [Data set]. Accessed 7 September 2023. https://ec.europa.eu/eurostat/databrowser/view/lfst_hhnhtych/default/table?lang=en

⁶⁰ International Renewable Energy Agency (IRENA). (2022). *Renewable Solutions in End-Uses: Heat Pump Costs and Markets*. <https://www.irena.org/Publications/2022/Nov/Renewable-solutions-in-end-uses-Heat-pump-costs-and-markets>

⁶¹ European Commission. (2019, 25 September). Annex to the European Commission Recommendation (EU) 2019/1658 of 25 September 2019 on transposing the energy savings obligations under the Energy Efficiency Directive. <https://eur-lex.europa.eu/eli/reco/2019/1658>

⁶² Danish Energy Agency. (2022). *Technology Data: Heating Installations*. <https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-individual-heating-plants>

would be lower than in standalone applications as it is primarily used for hot water supply, which has a lower efficiency than space heating.⁶³ The values used were:

- Hybrid heat pump:
 - Heat pump SCOP of 3.4
 - Gas boiler efficiency of 91%

In terms of the hybrid system's heating load, our research has shown that the share of the total heating load met by the heat pump in a hybrid system is around 70%-90%. To differentiate this case from a standalone heat pump application, we assumed that 75% of the heating load would be supplied by the heat pump and the remainder by the gas boiler.

Capital costs

For each technology, our calculation consists of a capital cost component and an operating cost component. For upfront costs, we used the cost of installing an air-to-water heat pump in Observ'ER's *Suivi du marché 2022 des pompes à chaleur individuelles* as the average price for a 7-8 kW air-to-water heat pump, including all components and installation in 2022.⁶⁴

The cost of a hybrid heat pump is highly uncertain. The authors assume a brand-new replacement or newly installed heating system, for which all components need to be installed. If an undersized heat pump was being installed to augment an existing gas boiler, the price would clearly be lower. For our case, we assumed the hybrid heat pump price was slightly more expensive than an equivalent air-to-water heat pump, as advised by experts at the French Heat Pump Association AFPAC and outlined in the Danish Energy Agency's *Technology Data: Heating Installations, 208 hybrid gas and electric heat pumps*.⁶⁵ More real-world data on hybrid heat pump installations would help improve the accuracy of the modelling used here.

As described in detail in the paper, subsidies are available, either through MaPrimeRénov' or France's White Certificate programme, for up to €2,500 for high-income households and up to €9,000 for low-income households. The upfront costs used in the model are as follows:

- Air-to-water heat pump, low-income: €11,580 (upfront) - €9,000 (subsidy) = €2,580
- Air-to-water heat pump, high-income: €11,580 (upfront) - €2,500 (subsidy) = €9,080
- Hybrid heat pump, low-income: €12,000 (upfront) - €9,000 (subsidy) = €3,000
- Hybrid heat pump, high-income: €12,000 (upfront) - €2,500 (subsidy) = €9,500
- Gas boiler: €5,170

⁶³ Danish Energy Agency, 2022.

⁶⁴ Observ'ER, 2023.

⁶⁵ Danish Energy Agency, 2022.

Operating costs

In terms of operating costs, the price of fuel plays the greatest role. We used fuel prices from Eurostat. The electricity prices used are 2021 averages (€167/MWh before VAT) and a rate 50% higher than the 2021 averages. Fossil gas prices are 2021 averages (€59/MWh before VAT) and a rate 50% higher than the 2021 averages.

Prices (€/MWh)		Scenario 1 (normal price)	Scenario 2 (high price)
Electricity	<i>Before VAT</i>	€166.90	€250.35
	<i>After VAT</i>	€176.08	€264.12
Gas	<i>Before VAT</i>	€59.30	€88.90
	<i>After VAT</i>	€72.06	€103.35

We assumed the carbon price on fossil gas to be €9/MWh. That value is calculated from a price of €44.60 per tonne of CO₂ emitted.⁶⁶

Maintenance costs for the heat pump were assumed at €178/year and for the gas boiler at €120/year. For the hybrid heat pump, we assumed maintenance costs of €223/year, as the Danish Energy Agency suggests the costs run 25% higher than for standard heat pumps.⁶⁷ Network costs for the electricity system were assumed at €144/year and for gas €250/year.

Finally, we used the following parameters to calculate capital costs and operating costs:

- Weighted average cost of capital: 5%
- Device lifetime (all devices): 18 years
- VAT: 5.5%

⁶⁶ Ministère de la Transition écologique [French Ministry for the Ecological Transition]. (2023). *Guide 2023 sur la Fiscalité ses Énergies* [2023 Energy tax guide]. <https://www.ecologie.gouv.fr/sites/default/files/guide%20fiscalit%C3%A9%20energie%202021.pdf>.

⁶⁷ Danish Energy Agency, 2022.

Reference cost table for high-income households

	Heat pump		Gas boiler		Hybrid heat pump	
	<i>Low prices</i>	<i>High prices</i>	<i>Low prices</i>	<i>High prices</i>	<i>Low prices</i>	<i>High prices</i>
Annualised upfront cost	€ 504	€ 504	€ 287	€ 287	€ 640	€ 640
Running cost, heat pump	€ 1,032	€ 1,387	€ 0	€ 0	€ 741	€ 983
Running cost, gas boiler	€ 0	€ 0	€ 1,317	€ 1,729	€ 609	€ 716
Total cost (rounded)	€ 1,540	€ 1,890	€ 1,600	€ 2,020	€ 1,990	€ 2,340

Reference cost table for low-income households

	Heat pump		Gas boiler		Hybrid heat pump	
	<i>Low prices</i>	<i>High prices</i>	<i>Low prices</i>	<i>High prices</i>	<i>Low prices</i>	<i>High prices</i>
Annualised upfront cost	€ 143	€ 143	€ 287	€ 287	€ 278	€ 278
Running cost, heat pump	€ 1,032	€ 1,387	€ 0	€ 0	€ 741	€ 983
Running cost, gas boiler	€ 0	€ 0	€ 1,317	€ 1,729	€ 609	€ 716
Total cost (rounded)	€ 1,180	€ 1,530	€ 1,600	€ 2,020	€ 1,630	€ 1,980



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