REGULATORY ASSISTANCE PROJECT

One foot in the past:
The role of hybrid heat pumps in Europe

Duncan Gibb and Richard Lowes

OCTOBER 2024

Regulatory Assistance Project (RAP)®
Rue de la Science 23
B – 1040 Brussels
Belgium

+32 2 789 3012
info@raponline.org

raponline.org
linkedin.com/company/the-regulatory-assistance-project
@regassistproj.bsky.social

Cover photo: Wozzie/Shutterstock
Template design by Place Creative Company
Layout by Noble Studio

Suggested Citation

Gibb, D. & Lowes, R. (2024, October). *One foot in the past: The role of hybrid heat pumps in Europe.* Regulatory Assistance Project.

Electronic copies of this paper can be found on our website at www.raponline.org.

To be added to our distribution list, please send relevant contact information to info@raponline.org.

Contents

Acknowledgments

The authors would like to express their appreciation to Caroline Haglund Stignor (Heat Pump Centre, Technology Collaboration Programme on Heat Pumping Technologies by IEA, c/o RISE Research Institutes of Sweden), Chiara Delmastro (International Energy Agency) and Marek Miara (Fraunhofer Institute for Solar Energy Systems), as well as Dave Farnsworth, Jan Rosenow, Louise Sunderland and Monika Morawiecka for their helpful insights into early drafts of this briefing. Erica Falkenstein (Regulatory Assistance Project) provided editorial expertise.

Thanks also to Adam Chapman (Heat Geek), Andreas Graf and Steffen Verheyen (Agora Energiewende), Atse van Pelt (Natuur & Milieu), Eleonora Moschini (European Climate Foundation), Eoin Kelly and Guillaume Joly (BEUC - The European Consumer Organisation), Federico Musazzi (Assoclima), Mathias Koepke (dena), Oliver Lancaster (Institution of Gas Engineers and Managers), Silvia Rezessy and Philippe Rivière (European Commission) and Thomas Nowak (Qvantum) who gave us useful input during interviews.

Figures

Tables

Introduction

Heat pumps are predicted to play a crucial role for Europe in meeting its ambitious climate goals. According to a recent impact assessment, the European Commission expects an increase in the number of installed heat pumps from around 25 million in 2023 to 60 million by 2030.[1] Despite the growing market share of heat pumps, gas and oil boilers still dominate heating equipment stock,[2] and although future energy scenarios rely heavily on electrification with heat pumps for space and water heating in buildings, there are open questions around how to smoothly transition from a fossil-fuelled heating system to an electrified one. Hybrid heat pumps are often cited as a possible bridge between these dominant heating regimes.[3]

In this paper we discuss hybrid heat pumps, defined as heating systems that combine an air-to-water heat pump with a gas boiler, while noting that other options exist. This is because we consider the most relevant use of hybrids to be as an intermediate step from gas boiler to standalone heat pump. Under certain conditions hybrids could provide energy system benefits that smooth this transition, so it is important to explore their impact, alternatives and associated risks.

At government level, hybrid heat pumps are increasingly considered by regulators, with some countries setting them as the minimum requirement for new heating technologies and replacements, and subsidising their installation. The revised Energy Performance in Buildings Directive will end subsidies for standalone fossil fuel boilers starting 1 January 2025 – and, as there is an open question as to what constitutes a 'hybrid heat pump', the need for a more robust body of knowledge is clear.

1 European Commission. (6 February 2024). *Securing our future: Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2024%3A63%3AFIN/.

2 Duncan Gibb and Jan Rosenow. (2024, 21 May). *Guest Post: How heat pumps gained European market share in 2023 despite falling sales. Carbon Brief.* https://www.carbonbrief.org/guest-post-heat-pumps-gained-european-market-share-in-2023-despite-falling-sales/

3 This paper cites several industry studies discussing the role of hybrid heat pumps in European countries. Outside of Europe, CLASP and RAP have recommended replacing aged air conditioners with heat pumps that can cool and heat in the shoulder seasons. Malinowski, Matt, Max Dupuy, David Farnsworth, and Dara Torre. (2022). *Combating High Fuel Prices with Hybrid Heating.* https://www.clasp.ngo/research/all/ac-to-heat-pumps/.

This paper aims to fill a gap of independent analysis on hybrid systems. We offer recommendations for policymakers who are considering supporting and regulating hybrid heat pumps, ensuring that these systems contribute effectively to the broader goals of reducing emissions and transitioning to a sustainable, low-cost and equitable heating sector.

Overall, the evidence suggests that many of the possible advantages of hybrid systems are experienced by the energy system and the incumbent industry. While consumers may see some benefits from hybrids in the short term, households and policymakers may be exposed to risk, inconvenience and higher costs for uncertain benefits over the longer term. Many of these benefits can be delivered by building envelope efficiency, flexibility and other clean solutions, such as low-carbon district heating where available – technologies which are widely expected to be ramped up anyway. In addition, the possible market for hybrid heat pumps seems to be continually shrinking as wider innovation in heat pumps and clean energy increases.

Ingrid Balabanova/Shutterstock

1 What is a hybrid heat pump?

Heat pumps use energy, typically electricity, to extract ambient heat from environmental sources. They feature many advantages that make them relevant to reaching decarbonisation and clean energy goals: highly energy-efficient, they can operate with zero emissions and pollution, supply heating as well as cooling, and often provide cost savings (dependent on local energy prices). These and other benefits have led to their widespread use in many national and international decarbonisation scenarios, and to their global growth.[4]

1.1 Definition of hybrid heat pumps

Air-source heat pumps are sometimes equipped with a back-up heat source, especially in colder climates. This is because at the coldest outdoor temperatures heating demand is highest while heat pump capacity – its maximum available thermal power – will often be at its lowest. The heat pump must cover a larger temperature lift from very low outdoor temperatures to warm indoor temperatures. As a result, the heat pump's coefficient of performance (COP), the amount of heat produced for every unit of input electricity, typically falls during these periods. This means that more electricity than usual is needed for each unit of heat output, and sometimes the back-up heat source is preferred.

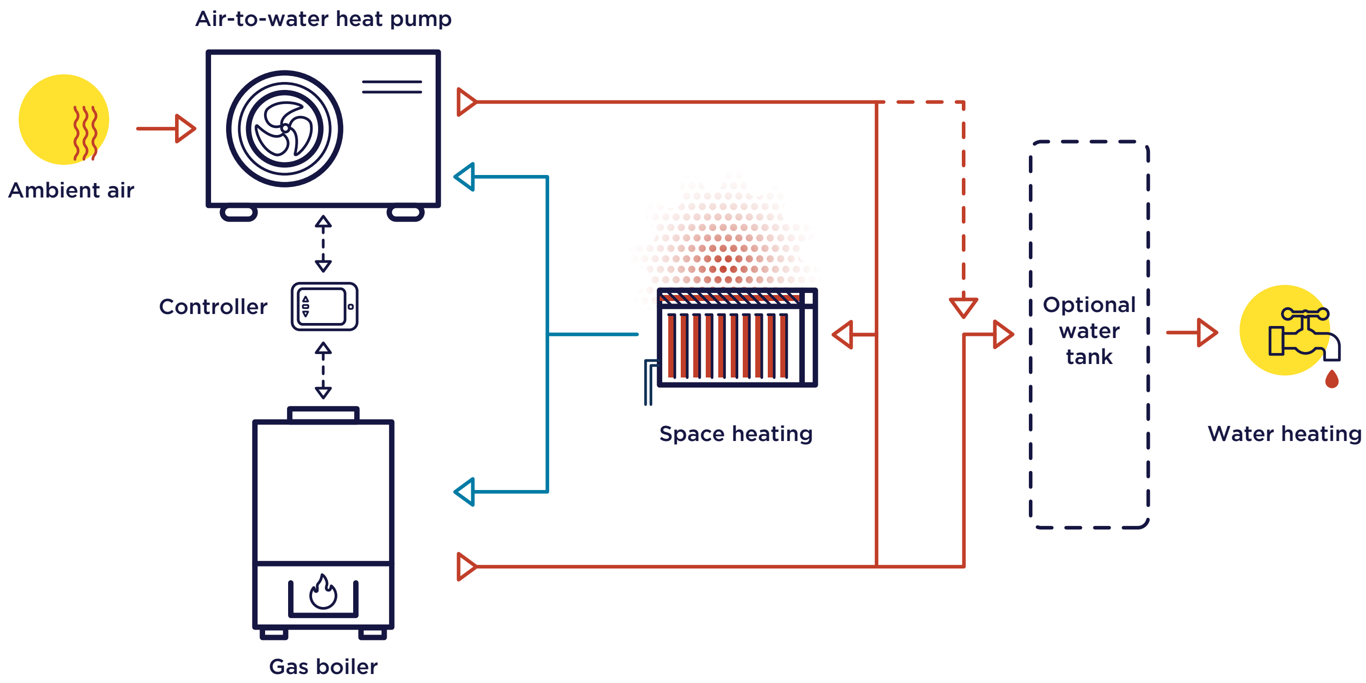
This back-up could be electric resistance heating, a biomass furnace or a fossil fuel boiler, among other possibilities. In this paper, we consider a **hybrid heat pump** as simply an air-to-water heat pump combined with a condensing gas boiler operating under an optimised control strategy. This definition is adapted from the International Energy Agency's Technology Collaboration Programme on Heat Pumping Technologies (IEA-HPT).[5] Our definition has been made more specific to focus on the technological configuration which we understand to be most relevant to decarbonising Europe's buildings: replacing gas boilers with hydronic heat pumps.[6] Many of the issues we consider would be relevant for other technological considerations, including oil/heat pump hybrids.

4 Lowes, R., Gibb, D., Rosenow, J., Thomas, S., Malinowski, M., Ross, A., & Graham, P. (2022). *A policy toolkit for global mass heat pump deployment. Regulatory Assistance Project (RAP). https://www.raponline.org/knowledge-center/policy-toolkit-global-mass-heat-pump-deployment/ and IEA. (2022).* The Future of Heat Pumps. https://www.iea.org/reports/the-future-of-heat-pumps.

5 International Energy Agency Technology collaboration Programme on Heat Pumping Technologies (IEA-HPT). (2019). *Hybrid Heat Pumps—Final Report.* https://heatpumpingtechnologies.org/publications/hybrid-heat-pumps-final-report/

6 IEA-HPT, 2019.

Figure 1. Diagram of a hybrid heat pump system



We define hybrid systems as using this specific combination because fossil gas boilers remain the dominant home heating technology in many European countries. Figure 1 shows an example configuration, where an air-to-water heat pump and gas boiler both provide space and water heating. The flow from heat pump to water tank is labelled optional, as is the water tank itself, because certain setups see the gas boiler providing domestic hot water on demand, while the heat pump meets a portion of a space heating needs. A controller optimises the functioning of both systems. Other types of hybrid heating systems are introduced in the sidebar on page 10.

It is important to ensure that the controller (with optimised control strategy) defines the performance of the hybrid heat pump. As will be discussed, a potential system benefit of hybrids is the possibility to switch between electric and gas heating in an optimised manner. That means, for example, potentially minimising peaks of the electric system load or, in the case of a smart tariff, engaging the boiler at times of high electricity prices. If the heat pump and boiler cannot be controlled jointly, these opportunities may be lost.

Hybrid heat pumps can be installed in two configurations: add-on and packaged. **Add-on hybrid systems** consist of an existing fossil fuel boiler or furnace where a smaller-sized heat pump has been appended to the overall heating system. The heat pump and boiler do not need to be located next to each other, nor do they need to be physically integrated (e.g., using the same pipework). Creating an add-on system can be as simple as installing a heat pump and new controller that governs both the boiler and heat pump with the ability to optimise their operation.

Packaged hybrid systems (also called 'factory-made' systems) are one complete unit with both components installed at the same time. These systems are specifically designed to operate as one heating system and are installed with the required controller. The European Heating Industry (EHI) definition goes further, stating that factory-made systems are made by the same manufacturer while packaged systems may not be.[7] We consider this distinction irrelevant to this paper and refer simply to packaged systems under one umbrella. Most countries do not define both add-on and packaged systems, as we show in Table 1. In France, for example, only the packaged hybrid system is considered from a regulatory perspective.

Hybrid heat pumps can be operated in three different modes: boiler mode, where the gas boiler runs alone; heat pump mode, where the heat pump runs independently; or bivalent mode, where the heat pump and gas boiler each supply a share of the space and water heating load.[8] Bivalent mode may also entail the heat pump providing space heating while the gas boiler supplies hot water.

Types of hybrid heating systems

In this paper, a 'hybrid heat pump' is considered to be an air-to-water heat pump with a condensing gas boiler. There are other types of hybrid systems, including but not limited to:

- **Air-to-air heat pump and gas or oil boiler**: These systems include an air-to-air heat pump with a gas or oil boiler providing hot water and serving as a supplementary heating source. The heat pump also can provide cooling.
- **Air- or ground-to-water heat pump and oil boiler**: These systems are expected to be less common, as in most countries oil boilers and furnaces are rarer.
- **Air- or ground-to-water heat pump and solar thermal system**: This setup integrates a hydronic heat pump with a solar thermal system, which uses solar collectors to absorb and transfer heat. The heat from the solar thermal system can preheat the water for the heat pump, improving its efficiency and reducing energy consumption, especially during sunny periods.
- **Air- or ground-to-water heat pump and biomass boiler:** An air-to-water heat pump also can be paired with a biomass boiler that burns wood pellets or chips to provide additional heating.

7 EHI. (2023). *Hybrid heat pumps: A no-regret solution for the decarbonization of buildings.* https://ehi.eu/wp-content/uploads/2023/11/2023019-Final-paper-on-hybrids-ready-for-publication.pdf.

8 EHI, 2023.

1.2 Hybrid heat pump market

Hybrid heat pumps make up a small but growing portion of the European heat pump market. In recent years, only three countries (France, Italy and the Netherlands) have reported hybrid heat pump sales to the European Heat Pump Association.[9] In 2023, these totalled nearly 90,000 units sold, and hybrids currently make up around 50% of the hydronic heat pump market in Italy and the Netherlands.[10] Although France has been reporting the longest (around 4,000 units per year since 2017), these sales have been eclipsed by Italy and the Netherlands. Italy reported almost 130,000 sales in 2022; however, this collapsed to around 30,000 in 2023 following the severe decline of its total hydronic heat pump market.[11] Sales in the Netherlands have grown from fewer than 10,000 units in 2021 to more than 50,000 in 2023. According to EHI, the Dutch industry is aiming for 2 million units to be installed by 2030.[12]

It should be noted that these sales figures include only factory-made packaged systems and not add-on systems, although – according to our interviews and industry studies – the most common case for hybrid heat pumps involves fitting them in an add-on configuration. This is important, as current regulatory definitions and sales figures address packaged systems only, yet we can expect add-on heat pumps to comprise an unknown yet significant portion of the market. It is also unclear if the heat pumps in add-on configurations are fitted with heating system controls allowing both components to be controlled jointly. We have summarised some of these regulatory definitions in Table 1.

Finally, this paper discusses flexibility at great length as an alternative to hybrid heat pumps. We define flexibility as the ability to adjust to the variability of energy generation and consumption patterns and grid availability across relevant timeframes.[13] For example, an energy system could harness flexibility through energy storage by charging a storage system during times of high generation and discharging during times of high demand. A household could decide to run their appliances, such as a heat pump, during periods of low electricity prices, such as the nighttime.

Ingrid Balabanova/Shutterstock

9 European Heat Pump Association. (2024). *2024 market report.* https://www.ehpa.org/product/2024-market-report/. The United Kingdom reports hybrid heat pump sales in an aggregated "other" category alongside exhaust air heat pumps and sanitary hot water heat pumps. No other countries submit hybrid statistics to EHPA, whereas 21 countries submit general heat pump statistics.

10 Federico Musazzi, Assotermica, personal communication with RAP, 22 May 2024 and Atse van Pelt, Natuur & Milieu, personal communication with RAP, 18 April 2024.

11 The removal of Italy's superbonus and revision of its tax credit were largely responsible. See EHPA. (2024). *Pump it down: Why heat pump sales dropped in 2023.* https://www.ehpa.org/news-and-resources/press-releases/pump-it-down-why-heat-pump-sales-dropped-in-2023/

12 EHI, 2023.

13 Yule-Bennett, S., & Sunderland, L. (2024). *Flex-ability for all: Pursuing socially inclusive demand-side flexibility in Europe.* RAP. https://www.raponline.org/knowledge-center/flex-ability-for-all-pursuing-socially-inclusive-demand-side-flexibility-europe/

Table 1. Regulatory classifications of hybrid heat pumps by jurisdiction

	Characteristics of a hybrid heat pump
France[14]	To qualify for financial support via France's White Certificate programme, a new hybrid heat pump must have a seasonal energy efficiency of at least 111%. The 'coverage rate' of the standalone heat pump must also be 70% or higher. This is defined as the ratio between the amount of thermal energy provided by the heat pump without the gas boiler and the annual heating needs of the home.
Germany[15]	The Building Energy Law (Gebäudeenergiegesetz) requires that hybrid heat pumps are operated by a centralised controller and that the heat pump component is given priority. The back-up system can only be operated during periods where the heat pump cannot technically meet the heating load.
Italy[16]	Italy's general definition says that hybrids are a 'factory-made' solution and smart, intelligent combination of condensing gas or oil boiler and a heat pump. At the time of writing there was no further definition, although the government was working on specific standards which would define different forms of hybridisation.
Netherlands[17]	A new 'hybrid heat pump standard' requires that homeowners replace an existing boiler with (at minimum) a hybrid heat pump. The new heating system's minimum energy performance must be 1.31, which measures the ratio of fossil energy used to the building's heat demand. This requirement will gradually be reduced to 0.7. It is understood that a hybrid heat pump can meet this target if it operates 68% of the time with a COP of 3.8.
United Kingdom[18]	Microgeneration Certification Scheme (MCS) requirements, those needed for the accreditation of heat pumps for them to receive most public subsidies, currently state that a heat pump should be selected that will provide at least 100% of the calculated heat loss unless reasonable justification can be given. MCS launched a consultation in early 2024 to consider a definition for heat pumps. The draft stated that the heat pump component of the system shall be selected so it will provide at least 55% of the calculated heat loss (in kilowatts) at the rated condition of 55°C flow at the specified external temperature. The UK government is not currently planning on expanding policy to support hybrid heat pumps, however.
European Union	Ecodesign defines a hybrid heat pump as an encased assembly or assemblies designed as a unit consisting of an electric heat pump, a boiler and a hybrid master controller providing an optimised operation of the heat generators for space heating and possibly water heating. At the time of writing, it was under discussion whether to increase the minimum efficiency standard for space heating appliances to 115%, effectively making hybrid heat pumps the minimum standard for new heating appliances.

14 Government of France, Ministry of the Energy Transition. (n.d.). *Certificats d'économies d'énergie* [Energy savings certificates]. https://www.ecologie.gouv.fr/sites/default/files/BAR-TH-159%20vA50-4%20%C3%A0%20compter%20du%2001-04-2023.pdf

15 Government of Germany, Federal Ministry of Justice. (July 2019). *Gebäudeenenergiegesetz* [Building energy act – GEG]. https://www.gesetze-im-internet.de/geg/__71h.html and Mathias Koepke, Germany Energy Agency, personal communication with RAP, 8 June 2024.

16 Gestore dei Servizi Energetici, *Regole Applicative Del D.M. 16 Febbraio 2016* [Application rules of the D.M. 16 February 2016]. p. 99. https://www.gse.it/documenti_site/Documenti%20GSE/Servizi%20per%20te/CONTO%20TERMICO/REGOLE%20APPLICATIVE/REGOLE_APPLICATIVE_CT.pdf and Federico Musazzi, Assotermica, personal communication with RAP, 22 May 2024.

17 Government of the Netherlands. (2023, 17 July). *Questions and answers: hybrid heat pump the standard in 2026*. https://www.rijksoverheid.nl/documenten/publicaties/2022/05/23/qena-hybride-warmtepomp-standaard-in-2026 and Government of the Netherlands. (2023, 1 May). *Letter to Parliament on the scope of heating installation standards*. https://www.rijksoverheid.nl/documenten/kamerstukken/2023/05/01/kamerbrief-over-reikwijdte-normering-verwarmingsinstallaties.

18 Microgeneration Certification Scheme. (2024, 12 February). *Consultation: MIS 3005-D: The Heat Pump Design Standard*. https://mcscertified.com/consultation-mis-3005-d-the-heat-pump-design-standard/

2 Stepping stone: The potential benefits of hybrid heat pumps

Hybrid heat pumps could provide several benefits during the transition to a fully decarbonised energy system. These benefits appear conditional, as they depend on several pre-existing issues and their relevance can vary between countries based on a host of factors. Many of them also only apply to existing buildings, as new buildings are subject to efficiency standards that limit the benefits of hybrid heat pumps. The key arguments for hybrids are:

- Hybrids could be useful to Europe's worst-performing buildings, where the installation of a standalone heat pump would require upgrades to the building envelope and heat distribution system.[19] Installing a hybrid system can delay these renovation measures and provide immediate and large-scale emissions savings. This includes buildings with limited technical options for improving building envelope efficiency, such as historical buildings, and is especially true where electric resistance would otherwise be used as back-up.[20]
- EHI points out that a hybrid does not require building envelope or heat distribution upgrades – and, in the case of an add-on system, is simply a case of installing a small heat pump and smart controller alongside an existing boiler.[21] However, as noted by IEA-HPT, installing a new hybrid system with a full-capacity boiler and smaller heat pump can be, depending on local circumstances, more expensive than installing a standalone heat pump. In all cases, a large degree of upfront cost uncertainty exists as the European heat pump industry matures.
- In cold climates, hybrids can be beneficial in certain existing buildings which require high heat distribution temperatures during extreme cold periods, which a standalone heat pump might struggle to meet. In addition, during longer stretches of cold weather and/or low renewable electricity generation the boiler component can provide a source of non-electric flexibility.
- Hybrid systems may benefit a congested electric grid as they can significantly reduce peak power demand. Analysis of the UK energy system reveals that hybrid heating scenarios require only 16% to 50% of the transmission and distribution costs needed for all-electric systems, stemming from lower investments in reinforcing the distribution network.[22]

19 EHI, 2023.

20 IEA-HPT, 2019. and Renaud, A., Lucas, C., & Gruet, Q. (2022). *Externalités positives des PAC hybrides* [Positive externalities of hybrid heat pumps]. Gaz Rézeau Distribution France. https://www.artelys.com/app/uploads/2022/06/Externalites-positives-des-PAC-hybrides-vf.pdf.

21 EHI, 2023.

22 Hybrid Heating Europe & Guidehouse. (2021). *Vision Paper: Unlocking the the hybrid heating potential in European buildings.* https://hybridheatingeurope.eu/wp-content/uploads/2021/03/hhe_vision-paper_final.pdf

Additionally, the existing capacity of the electricity grid might be insufficient to support the load of widespread all-electric heat pumps, while hybrid systems could enable extensive use of renewable energy with minimal grid load peaks.[23]

- Hybrid heat pumps can contribute to consumer acceptance and understanding of heat pump technologies. Homeowners see immediate reductions in emissions and local air pollution while staying with their familiar heating system. As hybrids have a range of suitable applications, their use may give a boost to industry experience that facilitates wider standalone heat pump deployment.[24]
- Installing a packaged hybrid heat pump may lead to lower upfront costs than a standalone heat pump. The amount of heat provided by the heat pump will govern the size of the required unit, and thus the cost of the system. Sometimes, the heat pump covers the continuous 'baseload' heating demand throughout the year. The boiler is then expected to take over during the coldest periods where a low-capacity heat pump might struggle or experience lower performance, which also coincides with times of peak heating demand. This means that the heat pump component can be sized smaller than if it were to cover the full peak heating load. In many cases, this has proven to be around 70-80% of the total annual heating demand delivered by the heat pump, with the remainder from the other heating source.[25] A hybrid system may also lower the upfront cost by postponing building envelope upgrades.
- Hybrid heat pumps may also result in lower running costs than a standalone heat pump, but that depends heavily on local energy prices and the chosen control strategy.
- In cases where space is a limitation, hybrid heat pumps provide an advantage. Standalone air-to-water heat pumps typically serve both space heating and domestic hot water needs, often requiring a tank to store hot water for later use. Some boiler systems, so-called combi boilers, can provide instantaneous domestic hot water, removing the need for a large household tank. In smaller homes where space is at a premium, this can be an advantage. Hybrids can also be configured in such a way that the boiler component provides domestic hot water while also contributing to space heating demand. However, this would decrease the total share of overall heat from the heat pump, resulting in higher lifetime emissions from the system.

The possible advantages of hybrid heating systems are summarised in Table 2, but many of these benefits can be achieved via alternative means. In addition, supportive actions, such as electricity grid upgrades and the delivery of building envelope measures, are likely to occur regardless of the heating system concerned.

Hybrid systems could provide short-term help in reaching longer-term decarbonisation goals, but electrification and low-carbon district heating remain the main technological pathways for decarbonising heat in buildings in all main energy scenarios.

23 IEA-HPT, 2019 and Renaud, A., et al., 2022.

24 IEA-HPT, 2019.

25 IEA-HPT, 2019.

Table 2. Benefits of hybrid heat pumps to address specific issues in existing buildings

Issue to address	Hybrid heat pump solution	Other alternatives
Very low building envelope efficiency	• Removes or defers need to upgrade heat distribution system and/or add insulation	• Improve building envelope efficiency and install standalone heat pump • District heating and bioenergy • Radiator upgrades
Extreme cold climates (less than -15°C)	• Higher performance because of lower COP at low temperatures • Lower running costs (dependent on energy prices)	• Improve fabric efficiency and install standalone heat pump • District heating • Radiator upgrades • Electric heating back-up • Install a larger or cold-climate heat pump
Congested electric grids	• Reduces risk of grid congestion • Provides source of non-electric flexibility • Provides time buffer to upgrade grids before full electrification	• Improve building envelope • Optimise use of existing capacity and expand grids faster • Heat pump flexibility • Energy storage
Limited physical space	• Boiler component can provide hot water on demand meaning there is no need for a water tank	• District heating • Innovative hot water solutions and storage tanks (e.g., small phase-change storage)
Low consumer confidence	• Can introduce households to heat pumps while keeping much of their familiar heating system in place	• Communication campaigns • Public workshops • "Visit a heat pump" and consumer-installer forums
Lowering upfront cost	• Packaged systems may, in some circumstances, be cheaper than standalone heat pumps • Add-on systems are most likely cheaper than standalone heat pumps	• Grants and financing • Operating cost savings may lead to a reasonable payback period • Invest in installer training and manufacturing to bring down upfront costs
Immediately reducing emissions from existing gas boiler	• Emissions can be quickly reduced with heat pump component taking over bulk of load	• Replace full heating system with standalone heat pump for greater emissions reduction • Building envelope (if applicable)
Lowering energy system costs	• If building envelope efficiency is not pursued, hybrid heat pumps may lead to lower energy system costs	• Improve building envelope efficiency • Grid expansion • Heat pump flexibility • Self-generation with solar PV

In the following sections of this paper we explore the benefits in more detail, evaluating what possible risks they may entail and what alternatives exist. First, we investigate the importance of an optimised control strategy and its relevance to unlocking any benefits. Next, we consider in which circumstances the potential value of hybrid heat pumps may be relevant and in which it may be overstated. This discussion begins with a chapter focusing on the energy system followed by the household perspective.

2.1 Load to nowhere: The importance of an optimised control strategy

All possible benefits of hybrid heat pumps rely on the implementation of an optimised control strategy. Such a control strategy works by dynamically managing the operation of both the heat pump and the gas boiler. Several combinations are possible: the heat pump runs alone, the heat pump and gas boiler run in parallel, or the gas boiler runs alone.

The control strategy can optimise based on different criteria, the most common being cost, emissions and fixed switchover temperature.[26] For example, if optimised for cost a controller might run the heat pump component during periods of low electricity prices. If optimised for emissions, it might monitor the carbon intensity of the electricity supply and the unit's COP, turning on the gas boiler if the emissions from the heat pump are greater (although this is only likely in areas with a very fossil-based electricity grid or extremely low temperatures that reduce the heat pump's COP). These are two examples of an optimised control strategy.

A poor control strategy would mean that the heat pump component is rarely engaged, or the gas boiler is unsuitably operated. A fixed switchover temperature could lead to this situation. Certain hybrid systems have controls that set a switchover temperature, above which the heat pump runs and below which the gas boiler runs. This switchover temperature is often set between -5°C and 0°C. This control strategy is problematic for several reasons, however. One, heat pumps are perfectly capable of providing full heating well below these temperatures. There is no technical reason to turn off the heat pump at this point, and the heat pump components should be sized to provide heating below this range. Two, the system may switch to the gas boiler due to this arbitrary set point, leading to unnecessary emissions. Depending on energy prices, that could have negative cost implications for the homeowner.

Regulatory definitions also play a crucial role, as they dictate how these control strategies should be implemented or set boundaries for which units can run at a certain time. In Germany's Building Energy Law, the heat pump is given priority and the gas boiler may only run in one of three 'bivalent' modes. A control strategy within a home would optimise for this.

This is why our definition of hybrid heat pumps includes a controller that can optimise the operation of the two units. It is a key part of unlocking any potential benefits of hybrid heat pump systems if they exist, depending on the local climate, energy prices, and the specific building concerned.

26 Other control strategy criteria exist, such as primary energy, external price signals (e.g., congestion tariff), avoiding excessive switching on and off, and forced shutdown of either the gas boiler or the heat pump. See IEA-HPT, 2019.

3 Short-term gain, long-term pain? The energy system perspective

Many claims about the importance of hybrid heat pumps concern the overall optimisation of the energy system. They suggest that the existing energy system is not prepared to absorb widespread electrification with standalone heat pumps, as they will place strain on the grid, especially during cold spells, possibly leading to higher emissions. In this section, we explore these arguments.

3.1 Impact on the electricity grid

Certain studies have suggested that widespread deployment of heat pumps will harm electric grid reliability and necessitate massive grid expansions, while hybrid heat pumps (by using a share of non-electric heating, particularly at peak times) could allow heat pump installations to grow while permitting grid capacity to be increased more slowly.[27]

This argument has merit, as replacing all non-electric sources of heat with an (efficient) electric source will necessarily contribute to a rise in electricity demand. For example, adding a heat pump can nearly triple a household's peak winter demand.[28] Also importantly, if heat pumps are installed in low-performing buildings in cold climates and use electric resistance heat as back-up on the coldest days, this could lead to a significant increase in peak electric load.

Both flexibility and building envelope efficiency can play key roles to minimise this effect. Tapping into sources of flexibility for the power grid, such as storage (both electric and thermal) and interconnections, will lead to a much more efficient and reliable system.[29] The International Energy Agency calculates that the EU's building flexibility should more than triple to nearly 40 GW by 2030, with heat pumps contributing around 12% (4.5 GW).[30] These sources of flexibility will be important for absorbing fluctuations in energy supply, increasingly provided by variable renewables, and energy demand, increasingly adjusted dynamically by consumers.

Successful examples of widespread demand flexibility exist. In 2022, the UK launched a Demand Flexibility Service, which allowed consumers to reduce their electricity demand as a source of grid flexibility. During the winter of 2022-23, 1.6 million households participated, achieving more than 3.3 GWh of demand

27 Catapult Energy Systems. (2024). *Innovating to Net Zero 2024.* https://es.catapult.org.uk/report/innovating-to-net-zero-2024/ and Clegg S, Mancarella P. (2019, 1 October). *Integrated electricity-heat-gas modelling and assessment, with applications to the Great Britain system. Part II: transmission network analysis and low carbon technology and resilience case studies. Energy 2018;184:191e203.* https://doi.org/10.1016/j.energy.2018.02.078

28 IEA, 2022.

29 RAP. *Power System Blueprint: Ensure Efficient Reliability.* https://blueprint.raponline.org/ensure-efficient-reliability/.

30 IEA, 2022.

reductions.[31] The following winter achieved 3.7 GWh of demand reductions, with more than 2.6 million homes and businesses taking part.[32] National Grid found that on average 91% of household demand reduction was less than 1 kW and concluded that these actions were due to manual intervention, rather than being automated by larger loads like heat pumps and electric vehicles. While these manual reductions are significant, it is important that household flexibility does not come at the expense of comfort, especially for low-income households.[33]

Improving the efficiency of the building envelope, the heat distribution system and the heat generation device (e.g., a heat pump) may mitigate the need for overall grid expansion. Improving a home's efficiency rating by two energy performance grades (e.g., from D to B in Denmark) can halve the heating energy demand, lowering the peak by one-third.[34]

France's transmission system operator RTE conducted an in-depth analysis on future heat pump deployment scenarios in the country.[35] It noted that massively increasing heat pump deployment to reduce fossil gas use will lead to a growth in peak electricity demand of about 4 GW in 2035 compared to 2019. France currently sees a winter electricity consumption peak of around 80-90 GW, with average levels at 70-80 GW.[36] RTE concludes that this 4 GW increase will not jeopardise the electricity supply if building envelope efficiency is accelerated (leading to demand reductions), heat pump performance optimised, and many electric resistance heaters replaced by heat pumps. In countries such as France, where electric resistance heaters currently supply about 20% of its heating, there are massive potential efficiency gains which will help soften the impact of widespread heat pump use.

While these examples demonstrate that grid management strategies can support successful, widespread heat pump deployment, what is true in one part of the world may not be true in another. Countries with a higher share of fossil heating and weaker electric grids, such as the Netherlands and Germany, may need to place an additional emphasis on transmission and distribution expansion.

3.2 Impact on energy system costs

Studies have suggested that the widespread utilisation of hybrid heat pumps may lead to cheaper overall energy system costs than using standalone heat pumps. In these scenarios, savings may be made through a reduction in the need for additional electricity network capacity and 'firm' electric generation capacity, e.g. nuclear power.[37]

European energy system models have shown the cost reductions of back-up gas boilers, i.e. hybrid systems, to be limited if significant building envelope efficiency gains are achieved. In a study by Zeyen, Hagenmeyer and Brown, building renovations are by far the largest energy system cost reduction lever, saving up to 50%

31 ESO. (2023, 9 May). *Demand Flexibility Service delivers electricity to power 10 million households.* https://www.nationalgrideso.com/news/demand-flexibility-service-delivers-electricity-power-10-million-households

32 ESO. (June 2024). *Demand Flexibility Service Winter 2023 – 2024 End of Year Report.* https://www.nationalgrideso.com/document/319876/download. p. 25

33 Yule-Bennett, S., & Sunderland, L., 2024.

34 IEA, 2022.

35 RTE. (2023). *Bilan Prévisionnel 2023-2035.* http://www.rte-france.com/actualites/bilan-previsionnel-transformation-systeme-electrique-2023-2035.

36 RTE. (n.d.). *Consumption.* https://analysesetdonnees.rte-france.com/consommation/synthese

37 Guidehouse Germany GmbH. (2022, 15 July). Decarbonisation pathway for the European building sector. ehi. https://ehi.eu/wp-content/uploads/2022/10/Decarbonisation-pathways-for-the-EU-building-sector_full-study-1.pdf; Imperial College London. (August 2018). Analysis of alternative UK heat decarbonisation pathways. https://www.theccc.org.uk/wp-content/uploads/2018/06/Imperial-College-2018-Analysis-of-Alternative-UK-Heat-Decarbonisation-Pathways.pdf

by helping to minimise heat demand peaks. These renovations make the potential cost benefit of hybrid systems low, at around 1-2%.[38] In Germany, 10% of electricity demand could be reduced, lowering power system costs by almost EUR 5 billion, by the use of dynamic tariffs that encourage flexibility.[39] Other studies have shown that power system costs can be reduced by around 25% through heat pump flexibility by minimising extensive grid upgrades, among other factors.[40]

Ultimately, we conclude that hybrids could have an energy system cost benefit only in situations of very low-performing buildings and a lack of energy system flexibility, resulting in expensive grid upgrades. To meet zero carbon emissions goals, however, all fossil fuel combustion will need to be removed eventually.

3.3 Impact on greenhouse gas emissions

Hybrid heat pump proponents claim that replacing or augmenting a gas boiler with an add-on heat pump will lead to lower emissions.[41] This is clearly true in the short term, as the heat pump component immediately reduces gas consumption. But how does it compare against replacing the gas boiler with a standalone heat pump alternative?

When heat pumps are at their lowest performance, using more electricity to produce each unit of heat, emissions per unit of heat are likely to be higher. This can be compounded by the fact that at the coldest times of the year demand for heating rises sharply and electricity systems may be at their most carbon-intensive, leading to particularly high emissions. At such times, burning fossil fuels directly in a hybrid rather than using the heat pump could lower carbon emissions.

Whether or not direct combustion will lead to lower emissions than the heat pump will depend on the carbon intensity of the power grid and the performance of the heat pump. To get a sense of the scale, Figure 2 shows the average annual and maximum monthly carbon intensities of several European power grids: Poland, Germany, the United Kingdom and France.

Based on COPs from real-world performance testing, we applied a heat pump performance curve depending on the outside temperature ranging from a COP of 1.82 (at -20°C) to 4.40 (15°C).[42] In the EU-27 (not shown), UK and France, we calculated that the average grid carbon intensity in 2023 was so low that a standalone heat pump will be the more climate-friendly option well below -20°C. This holds true even when considering the highest monthly carbon intensity in 2023. In the Netherlands (not shown), the switchover points are below -30°C (2023 average) and -21°C (highest monthly average). These calculations are further explored in the Annex of this paper.

38 Zeyen, E., Hagenmeyer, V., & Brown, T. (2021). *Mitigating heat demand peaks in buildings in a highly renewable European energy system.* Energy, 231, 120784. https://doi.org/10.1016/j.energy.2021.120784

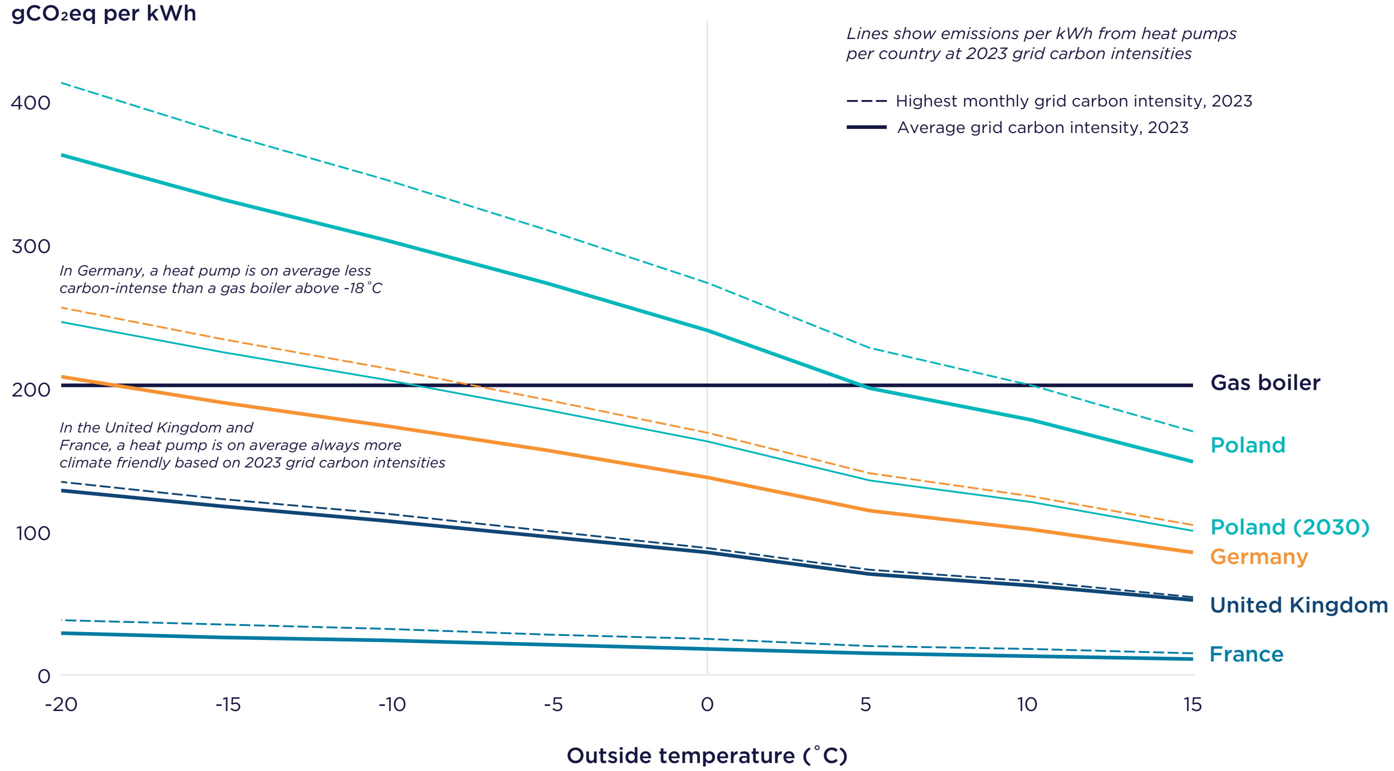
39 Agora Energiewende und Forschungsstelle für Energiewirtschaft e. V. (2023). *Haushaltsnahe Flexibilitäten nutzen.* https://www.agora-energiewende.de/fileadmin/Projekte/2023/2023-14_DE_Flex_heben/A-EW_315_Flex_heben_WEB.pdf

40 ZVEI. (2024, 19 March). *Mehrwert dezentraler Flexibilität* [Added value of decentralised flexibility]. https://www.zvei.org/presse-medien/publikationen/kurzstudie-mehrwert-dezentraler-flexibilitaet

41 EHI, 2023.

42 Gibb, D., Rosenow, J., Lowes, R., & Hewitt, N. J. (2023). *Coming in from the cold: Heat pump efficiency at low temperatures. Joule, 0(0). https://doi.org/10.1016/j.joule.2023.08.005*

Figure 2. Emissions from heat pumps at average 2023 grid carbon intensities



Note: Electric grid carbon intensities can vary widely depending on the given fuel mix. This chart does not aim to show marginal emissions at any given carbon intensity, but an average to assess the overall annual impact of heat pumps on emissions compared to a gas boiler. Marginal emissions can decrease or increase quickly, for example falling during periods of high wind energy production or rising during cold periods where heat pump performance is lower. Emissions at various temperatures were calculated by applying a heat pump performance curve and dividing by chosen carbon intensity.

Source: Carbon intensities from Ember, 2023 Global Electricity Review. Heat pump performance curve at various temperatures based on data from Gibb et al., Coming in from the cold: Heat pump efficiency at low temperatures.

For Germany and Poland, countries with significant levels of coal power on their grids, the picture is more nuanced. Taking the average 2023 carbon intensity (381 gCO_2eq/kWh), a heat pump in Germany would have fewer operational emissions above -18°C.[43] Yet this crossover point increases to -8°C when considering the highest monthly carbon intensity. This story is similar in Poland, where 6°C and 16°C are the switchover points.

However, Poland is on the path to power sector decarbonisation, with its coal power share falling from 84% in 2013 to 61% in 2023 – and, while heat pumps may today generate more emissions than a gas boiler when Poland's grid is at its most carbon-intense, that will no longer be the case in several years. The government is expected to aim for about 250 gCO_2eq/kWh by 2030, roughly the level of the Netherlands today.[44] In general, it should be kept in mind that power grids have significantly reduced their emissions over the

43 Ember, Electricity Data Explorer, https://ember-climate.org/data/data-tools/data-explorer/.

44 Government of Poland, Ministry of Climate and Environment. *Prekonsultacje w zakresie aktualizacji dokumentów strategicznych – KPEiK/PEP2040.* [Pre-consultations on updating strategic documents – KPEiK/PEP2040.] https://www.gov.pl/web/klimat/prekonsultacje-w-zkresie-aktualizacji-dokumentow-strategicznych-kpeikpep2040

last five years, and the European Union's goal is for a fully decarbonised grid by 2035. The EU's Green Deal also implies an increasingly cleaner electricity supply.[45]

The assertion that hybrid heat pumps lead to lower energy system emissions depends heavily on a given country's electric grid carbon intensity. There is potentially the argument that the gas boiler could be run only when the marginal energy system emissions surpass a certain level (this is a possible control strategy discussed later). As Europe transitions to lower-carbon electric grids, however, we do not expect this to be a meaningful benefit of hybrid systems in the medium to long term.

3.4 Heat pump performance in cold climates

The challenge of air-source heat pumps in cold climates is that not only does their COP decrease with sub-zero temperatures, but it is also a time of the highest heating needs and often lower heat pump capacity, i.e. maximum thermal power. Performance statistics from heat pumps have shown that they can operate effectively down to very low outside temperatures, however. Some cold climate models function with a COP above 2 down to -30°C.[46] Even in some of the coldest parts of the United States, heat pumps are relied on as a primary heating device.[47] 'Standard' heat pumps, which aren't necessarily equipped or designed for colder climates, can provide full efficient heating down to -15°C. Thus, in these mild cold climates, the necessity for a 'back-up' gas boiler is overexaggerated. Certainly, in places where minimum temperatures do not fall below -15°C, heat pumps can comfortably provide full heating over winter, subject to correct sizing and installation.

In extreme cold climates where temperatures fall below -15°C, hybrid systems may be justified for providing back-up heating. In mild cold climates, where minimum temperatures are between -5°C and -15°C, they are borderline cases which would depend on the building's building envelope efficiency and the heat pump performance. In warmer climates, hybrid heat pumps are not necessary from a local climate standpoint and standard heat pumps can be expected to provide full heating and, in some cases, cooling.

IMS Heat Pumps

45 European Commission. (n.d.). *The European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en*

46 Gibb, D., et al., 2023.

47 Valainis, Andrew. (2024, May 31). What's the Buzz? Ground-Truthing Cold-Climate Heat Pump Performance. RAP. https://www.raponline.org/blog/whats-the-buzz-ground-truthing-cold-climate-heat-pump-performance/

3.5 Section summary

Hybrid heat pumps may, under certain conditions, relieve some short-term energy system challenges such as managing peak electric load and immediately reducing greenhouse gas emissions, and may possibly lead to lower energy system costs. However, this could result in a lock-in effect for hybrid technologies, delaying or avoiding full decarbonisation. In addition, as many countries plan to limit gas use in buildings by 2040, this raises questions about whether hybrids installed by 2030 will realistically be replaced before that deadline. Hybrid systems also mean a longer period for maintaining the gas grid with fewer customers and higher per-capita decommissioning costs. Likewise, they may lead to higher overall energy consumption by postponing retrofitting and maintaining reliance on gas heating during the coldest periods. It is important to remember that many of the arguments in favour of hybrids also are reasons to improve building envelope efficiency and pursue energy system flexibility.

As will be discussed in the next section, promoting hybrid heat pumps entails certain risks to households. If they are responding to energy system needs that can also be met with efficiency and flexibility, then these options must be considered as well.

IMS Heat Pumps

4 Don't you forget about me: The household perspective

Households are the bedrock of the transition to cleaner heating systems. These decision-makers choose which heating system to use, whether to insulate, and how to engage with new flexibility offerings. The journey of each European household will influence the feasibility and practicality of any country's plan to install hybrid systems.

As all benefits of hybrids depend on low building envelope efficiency, they are only relevant to Europe's existing buildings. Apart from cold climates, hybrids provide no value to new builds which are already subject to high building envelope efficiency standards. Existing leaky buildings may benefit from hybrid systems in terms of performance and cost, although, as shown in the previous section, likely not in terms of emissions reductions.

Hybrids may only be an appropriate choice in multi-family buildings where a lack of space could make it challenging to install an individual air-to-water heat pump, especially one equipped with a hot water tank. Centralised heating options with standalone heat pumps and hot water distribution can overcome even this situation, however. From a household perspective, hybrids could potentially provide benefits to existing and low-performing buildings, but outside of these conditions their advantages weaken.

4.1 Limiting the need for heat distribution system upgrades

For heat pumps to work most efficiently, they require lower outlet temperatures than are typical for combustion heating technologies such as boilers and furnaces.[48] Moving from a combustion technology to a heat pump may therefore require changes to the heat emitter system in the form of larger diameter pipes and ducts, and an increase in output radiators in number or size. Such upgrades can be disruptive and expensive, particularly if pipework and ducts are buried in walls.

A hybrid heat pump could remove the need for immediate changes to the emitter system as the heat pump could run for some of the time, but when higher outlet temperatures are needed the back-up boiler could be used.

48 "Outlet temperatures" refers to the flow temperature in radiators and underfloor or the air temperature in the case of blown air systems. Lowes, R. (2022, 30 November). *Good COP/Bad COP: Balancing fabric efficiency, flow temperatures and heat pumps.* RAP. https://www.raponline.org/knowledge-center/good-cop-bad-cop-balancing-fabric-efficiency-flow-temperatures-heat-pumps/; Pehnt, M., Lawrenz, J., Mellwig, P, Oxenaar, S., & Sunderland, L. (2023, 27 June). *Lowering flow temperatures is key in the switch to efficient clean heat.* ifeu, RAP. https://www.raponline.org/knowledge-center/lowering-flow-temperatures-key-switch-to-efficient-clean-heat/

While this value is obvious, there are a few issues to bear in mind. First, the required upgrades may not be that disruptive, particularly if pipe- or ductwork changes are not needed. Emitter systems may already be oversized, meaning that the heat output may be more than adequate for the existing combustion technology. This effectively gives headroom in the existing system that allows flow temperatures to be lowered.

Second, for combustion heating systems to operate most efficiently, flow temperatures must be relatively low; the flow temperatures of a properly installed boiler would not vary widely from a heat pump's: around 55°C with a return temperature of around 40°C, to achieve 92% efficiency.[49] This difference would be further narrowed by around 5°C since heat pumps utilise higher flow rates, i.e. the speed of water or air circulating in the system.[50]

Newer heat pumps using propane as a refrigerant can produce higher outlet temperatures (up to 75°C) than older models, meaning that the physical emitter upgrades that were previously required may no longer be needed.[51] While lower flow temperatures can always increase heat pump performance, general heat pump performance has improved over time, meaning that a new heat pump running at a higher flow temperature today may be just as efficient as an older heat pump running at lower flow temperatures.[52]

4.2 Removing the need for a domestic hot water storage tank

Compared to boilers the instantaneous energy output of heat pumps tends to be lower, and hot water cannot be produced by the heat pump on demand. As such, heat pump systems typically produce and store hot water for later use. This hot water storage tank requires space, which may be unavailable. In these cases, hybrid heat pumps can use the boiler component to provide instantaneous hot water and eliminate the need for storage. In this scenario, add-on systems often require more space than packaged systems, as the existing boiler is being augmented by a smaller heat pump, whereas the packaged system is designed as one unit and optimised for space.

While space is needed for any form of storage, products are available which can store heat for hot water production using less space, such as appliances using phase change material or small thermal energy storage systems.[53] Hot water storage also can be placed in a wide range of convenient places, such as lofts.

There are also other options for hot water production, including instantaneous showers and hot water taps. Although these may be suitable for smaller properties with lower heat or hot water demand, direct electric technologies have lower efficiency than heat pumps and would lead to higher running costs.

Providing instantaneous hot water with a hybrid heat pump comes with disadvantages as well. First, hot water can be a significant proportion of building heating demand and emissions. Second,

49 Heat Geek, (16 November 2018), Condensing Theory - How Do Condensing Boilers Add Efficiency?, https://www.heatgeek.com/condensing-boilers-efficiency.

50 Adam Chapman, Heat Geek, personal communication RAP, June 2024.

51 Green Match, High Temperature Heat Pump: Costs & Benefits (August 2024), https://www.greenmatch.co.uk/heat-pumps/high-temperature.

52 Energy Systems Catapult Ltd. (2023). *Interim Insights from Heat Pump Performance Data.* https://es.catapult.org.uk/news/heat-pumps-shown-to-be-three-times-more-efficient-than-gas-boilers/

53 IEA Energy Conservation through Energy Storage, (September 2018), Applications of Thermal Energy Storage in the Energy Transition: Benchmarks and Developments, https://iea-es.org/wp-content/uploads/public/Applications-of-Thermal-Energy-Storage-in-the-Energy-Trenasition-Annex-30_Public-Report.pdf.

the efficiency of instantaneous combustion-based hot water heating is often low, reducing the potential benefit of a hybrid. Third, with a storage tank, hot water can be produced at off-peak times and stored for later use, a flexibility which is lost if there is no hot water storage.

4.3 Improving consumer confidence

The availability of a 'back-up' source of heating could, in theory, provide consumers with increased confidence in heat pumps by allowing them to keep their familiar heating system, potentially increasing heat pump uptake. In the Netherlands in 2023, where around half of the air-to-water heat pumps installed were hybrid systems, evidence suggests that this has been the case.[54]

However, this potential value may be pure perception, especially as many Dutch hybrid heat pump installations use the combustion element solely for hot water production. There is also the risk that the promotion of hybrid heat pumps supports a public narrative that standalone heat pumps are simply not suitable for the replacement of fossil fuel heating systems.

Consumer confidence could be improved with clear government communication, stakeholder workshops and consumer protection measures. When building up its heat pump industry in the 1990s, Sweden dedicated half of its procurement budget to communications to build consumer confidence in a relatively new technology. In Finland, discussion boards for users to access advice and share experiences helped improve public acceptance of heat pumps.

54 Atse van Pelt, Natuur & Milieu, personal communication with RAP, 18 April 2024.

These cases are explored further in *A policy toolkit for global mass heat pump deployment.*[55]

4.4 Evaluating running costs

The COP of heat pumps is lower with higher temperature differentials between source temperatures and outlet temperatures. The lowest COP will be on colder days when the heating demand is highest and elevated flow temperatures are required, and, in the case of air-source heat pumps, when the air temperature is at its minimum. When COPs are lowest, the heat pump will be using more electricity to produce each unit of heat and therefore each unit will be more expensive. At these times, it may be the case that these units of heat can be provided more cheaply using a combustion technology.

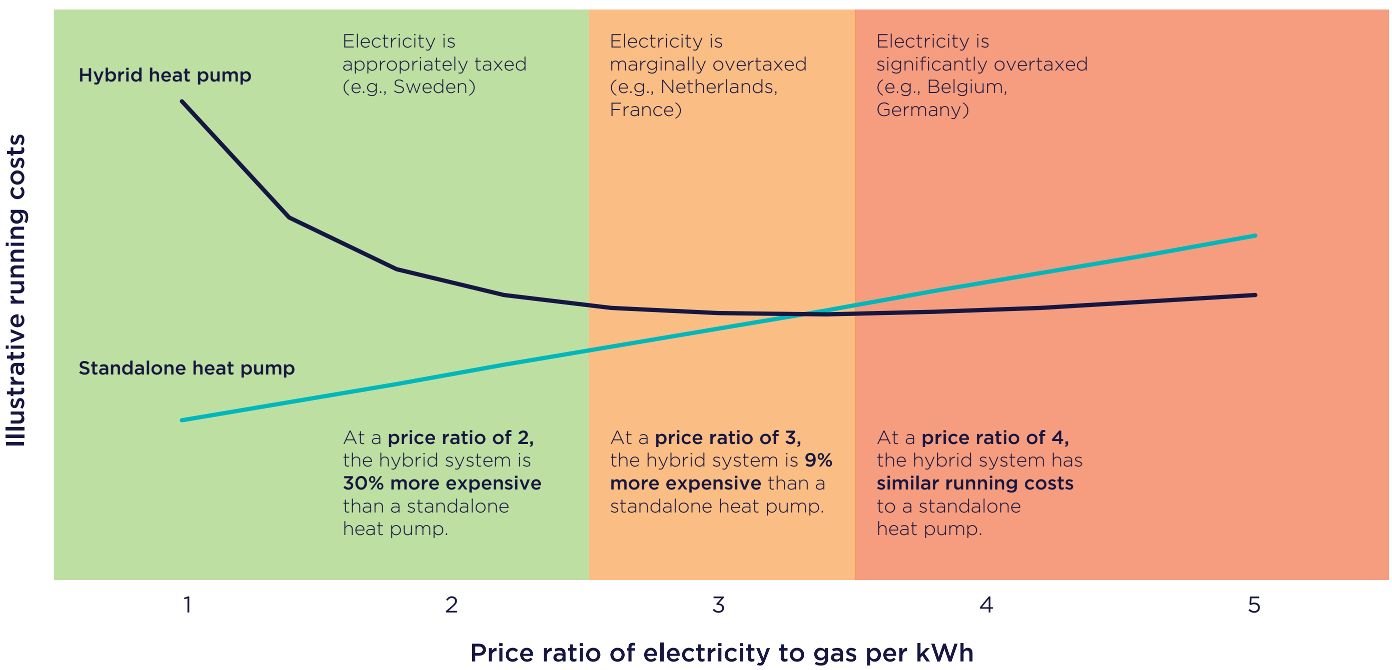
Heat pump performance has steadily improved, however, including in cold conditions. While running costs may be lower at times, the overall heating system costs of hybrids include additional capital expenses for the combustion element (which may only be used very infrequently). It may be cheaper to absorb the occasional performance reduction of the standalone heat pump. In jurisdictions where the gap between fossil fuel and electricity prices is smaller, there will be fewer occasions where running the combustion element makes financial sense. These times would be further offset by savings from running the heat pump throughout the rest of the year.

55 Lowes, R., Gibb, D., Rosenow, J., Thomas, S., Malinowski, M., Ross, A., & Graham, P. (2022). A policy toolkit for global mass heat pump deployment. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/policy-toolkit-global-mass-heat-pump-deployment/. Sovacool, B. K., & Martiskainen, M. (2020). Hot transformations: Governing rapid and deep household heating transitions in China, Denmark, Finland and the United Kingdom. Energy Policy, 139, 111330. https://doi.org/10.1016/j.enpol.2020.111330.

Figure 3 shows the running costs of a standalone heat pump compared to a hybrid system. With an assumed COP of 3.5, boiler efficiency of 90% and heat pump covering 70% of annual heat production, it shows hybrid systems do not make financial sense unless the price ratio of electricity to fossil gas is very high. Electricity would have to be more than four times as expensive as fossil gas before the hybrid system was cheaper. In almost all European countries, electricity is 'only' two to three times more expensive per kWh than fossil gas or fuel oil. That means that in these nations, a hybrid system would entail higher running costs over the course of the year.

This analysis does not consider a lower COP during cold periods, which would affect the economics. However, even in the worst case where COP falls to 2 during the coldest periods, the hybrid system is only 8% cheaper during those limited timeframes. The rest of the heating season, when temperatures are milder and COP is up to 3.5, the heat pump would be the more economic choice.

Figure 3. Running costs for hybrid and standalone heat pumps for varying price ratios



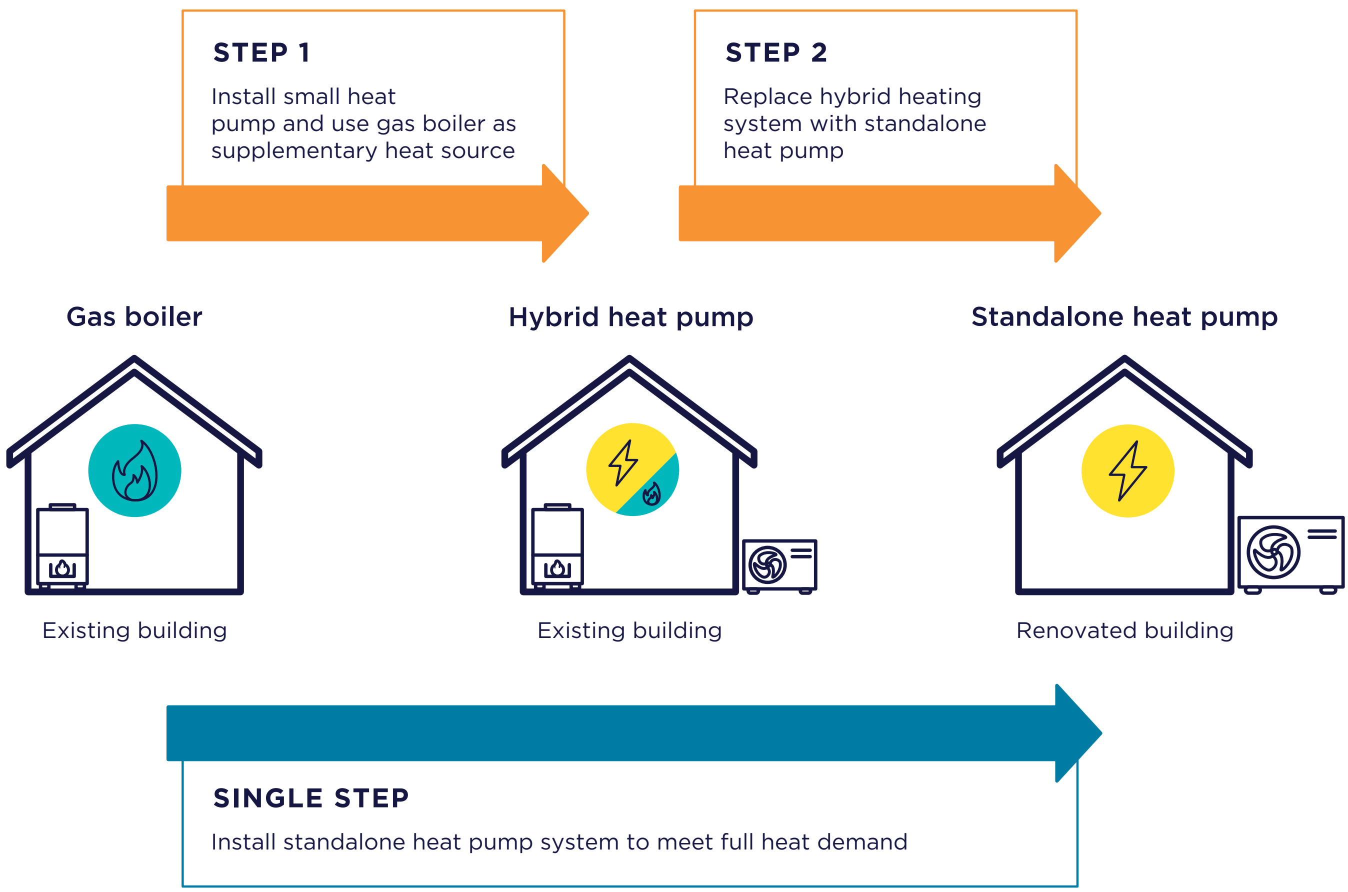
Note: This analysis assumes a heat pump COP of 3.5, a gas boiler efficiency of 90%, and that the heat pump component meets 70% of the annual heat demand.

4.5 A complex and expensive household journey?

Proponents of hybrid heat pumps describe their intermediate role in a stepwise electrification plan. A household would transition from fossil gas to a hybrid heating system as a first step, followed by purchasing a standalone heat pump as a second step. Here we evaluate the convenience of such an approach, as outlined in Figure 5.

We consider the below graphic to be the most relevant scenario to evaluate, as it checks several boxes where hybrid heat pumps may have an advantage: an existing and aging gas boiler providing space and water heating and a space-restricted and unrenovated home with a very low standard of insulation where the homeowner is potentially facing costs for insulation and upgrading the heat distribution system (radiators etc.) before fully replacing the gas boiler.

Figure 4. Proposed household journey from gas boiler to heat pump via hybrid heating



This will not be the case in many buildings. If the building envelope efficiency is higher, the climate warmer and space is less of an issue (or the house has an electric water heater), then the arguments in favour of a hybrid heat pump are less relevant.

In this example, a homeowner could postpone a retrofit and instead install an add-on heat pump with a controller. This has the advantage of a lower upfront cost, both by avoiding the upgrades and by purchasing a smaller heat pump. The heat pump component would be sized to cover 70% of the house's space heating needs over the course of the year.[56] The heat pump would likely not be powerful enough to meet peak winter heating demand and would not provide domestic hot water. The controls optimise the operation of the hybrid system by choosing the heat source that is most economical based on electricity and gas tariffs.

In this scenario, homeowners are faced with several inconveniences. First, they are now responsible for the maintenance and servicing of two heating appliances, as well as two energy bills. Second, they are continuing to pay network charges for the gas grid, which have risen in recent years as more customers disconnect from the gas network and gas in Europe has become increasingly expensive.[57]

The running costs also could be problematic. Even if the system is configured to optimise on cost, a low-performing building might be too leaky for the small heat pump to provide full heating throughout the winter. If this person lives in a country where the price ratio between electricity and gas is favourable, it means they need to turn to gas even if it is to their financial disadvantage.

The point of the add-on system, according to proponents, is to eventually replace it with a standalone heat pump. When the gas boiler needs replacing – an opportune time to switch to a standalone heat pump – perhaps the small add-on heat pump component has not reached its end-of-life. It is also unlikely to be large enough to provide full winter heating, even in the case of a building envelope retrofit, and a homeowner would need to consider replacing the full heating system. In the case of a packaged hybrid heat pump perhaps the boiler and heat pump components will have a similar life, but they could see technical faults at different times.

The household journey from gas boiler to hybrid heat pump to full electrification is not a simple one. The homeowner must change their heating system twice, and likely before the end-of-life of one of the system components. This is expensive and can be disruptive for a household, as they are effectively purchasing and installing two heat pumps during this journey, as well as paying for two network charges and maintenance of two appliances while they own the hybrid system. For policymakers, an additional risk is that households may need to be subsidised twice: once for the hybrid system and once again to switch to a standalone heat pump.

While purchasing a hybrid system may allow households to postpone retrofit expenses by several years, that cost will nevertheless come in due course – and, in the meantime, the household is faced with maintaining two parallel systems and will be responsible for a decade of emissions that could have been avoided by renovating and replacing with a standalone heat pump in step one. Overall, the hybrid heat pump appears to provide some benefits to the energy system and is simple for the consumer in the short term, but over the medium term it risks becoming an inconvenient and expensive option.

56 According to our expert interviews, this is the most common case. We recommend sizing the heat pump to meet a future heating demand once the retrofit is complete.

57 Renaud, A., Lucas, C., & Gruet, Q. (2022). Externalités positives des PAC hybrides, https://www.artelys.com/app/uploads/2022/06/Externalites-positives-des-PAC-hybrides-vf.pdf.

IMS Heat Pumps

4.6 Section summary

Hybrid heat pumps may offer some benefits to households, such as delaying building envelope upgrades, optimising space allocation, and allowing for the retention of their existing heating system. Their exact cost impact remains uncertain, as upfront costs depend on the configuration and running costs are dictated by local energy prices. Volatile fossil fuel prices may result in significant financial risks to households. The hybrid heat pump proposition exposes consumers to significant risk, and many of its benefits can also be achieved by improving building envelope efficiency, flexibility and other heating options, such as low-carbon district heating if available.

5 Principles for policymakers

While hybrids may offer some benefits, such as potentially allowing the early partial decarbonisation of heating systems and a slower expansion of the electricity grid, they also bring risks and may deliver only limited benefits compared to standalone heat pump systems.

These risks include:

- A complex and expensive consumer journey involving two heating system interventions and possibly the need for additional subsidy.
- Higher overall energy transition costs.
- Not delivering reductions in emissions savings and fossil fuel use as claimed.
- Unnecessarily locking building owners into fossil fuels and gas grids.

As such, we propose the following principles for policymakers looking to drive heat pump uptake who may be considering hybrids:

ThomsonD/Shutterstock

1. Develop a clear regulatory definition of a hybrid heat pump for policy support.

- Without this definition, it is not easy to understand which systems or components are supported. Defining and regulating add-on systems as well as packaged systems will be important. This definition should include a minimum share of thermal energy covered by the heat pump component and required hybrid system efficiency.

2. Decide whether the fossil fuel component of a hybrid heat pump should deliver space heating and/or hot water.

This will determine what future retrofits will be needed, such as eventual emitter upgrade or installation of water storage.

- Parameters governing the control strategy of hybrid systems should be considered, including how optimal performance can be delivered and how frequently the control strategy should be evaluated to ensure it is optimised.

3. Ensure financial and regulatory support for hybrid heat pumps is reflective of their value.

noting that this is likely to be less than for standalone heat pumps.

- If capital support for hybrids is too high compared to standalone heat pumps, this could lead to sub-optimal technology deployment and related risks and legacy issues for governments.
- Funding mechanisms should cater to the fact that further retrofitting may be necessary.
- Support should reflect that emissions reductions from hybrids may only be partial compared to standalone heat pumps.
- This principle can be applied to all hybrid heat pump-related grants and 'clean heat standard' type policies.

4. Regulate and monitor hybrid systems

to ensure that the heat pump component is used effectively, an optimised control strategy is in place, and emissions reductions are realised.

- Without such regulation, hybrid systems could operate in fossil fuel mode for most of the time, lowering their value.
- Detailed policy design may need to consider the appropriate ratio of fossil fuel boiler compared to heat pump capacity, or, in the case of an add-on system, require that the heat pump component be sized for a future heat demand of the building.
- Certain controls or control strategies, such as optimising for cost or emissions, can ensure that the heat pump is used and works optimally.

5. Develop a 'needs case' for hybrids.

- To limit the risk of unnecessary consequences and minimise public expenditures, niche subsidy support rather than broad support for hybrid heat pumps may make sense.
- Such a needs case may outline circumstances for hybrid deployment, such as where additional electricity capacity is needed or where a hot water tank is not present.
- Such a needs case should include geographic considerations, such as low temperature extremes, and wider energy strategy.

6. Account for infrastructure implications

(both gas and electricity) regarding a switch to hybrid systems.

7. Determine whether the electricity grid (and any planned expansion and optimisation) can cope with standalone heat pumps,

and what other flexibility options are in place to support the integration of standalone heat pumps.

- Evaluate the expected impact on gas network charges for customers left behind on a sparse gas network. Assess the costs and benefits of both the continued use of the gas grid (including per-unit distribution costs for consumers) and network decommissioning.

8. Consider any support for hybrids as part of a policy package for clean heating.

- Wider market reforms should support clean heating more broadly and limit the risks of unintended consequences and perverse incentives. Specifically for hybrids, energy costs should ensure that the ratio between gas and electricity reflects externalities and doesn't encourage fossil fuel use.

9. Temporal variability in energy market prices needs to be reflected at the billing level

to ensure the flexible value of hybrid heat pumps can be achieved and that fossil fuels are used only when they will limit costs and/or emissions. Dynamic tariffs, offers and services should be widely encouraged to maximise flexibility options.

- Cost-reflective gas and electricity network regulation can reflect likely increases in electricity demand and decreases in gas network use, managing risks of stranding and decommissioning.
  The costs of electricity network upgrades to support heat pumps should be appropriate to support electrification and should not inadvertently promote emissions-producing solutions.

6 Conclusions: One foot in the past?

If policymakers wish to plan the energy systems of the future, they should avoid keeping a foot in the past. In European climates the benefits of hybrid systems are conditional and uncertain at best, while being risky to households and the environment at worst.

The reductions in the cost of renewable electricity and innovations in heat pump efficiency mean that heat pumps are increasingly demonstrating improved performance and cost-effectiveness. As such, technology trends mean that the case for hybrids is more limited than it once was.

Based on current electricity grids, only in extremely fossil fuel-heavy power systems do hybrid heat pumps potentially outperform standalone heat pumps on emissions. Europe's power grids are rapidly greening, lessening this potential benefit. What's more, standalone heat pumps can function efficiently even in the cold and, given improvements in building envelope efficiency, their system costs are expected to be lower.

At an energy system level, numerous studies conclude that building envelope efficiency is the critical lever for lowering emissions and enabling the uptake of heat pumps in Europe's buildings. Improving envelopes can reduce the size of heat pumps required and increase opportunities for heat pumps to be used efficiently and flexibly. Even during peak winter events, an efficient building stock can level off power system peaks in heating systems with vast heat pump usage.

Only in situations where the building stock remains particularly leaky and the electricity grid inadequate would hybrid heat pumps provide some value to the energy system. This value is conditional, however, and the consumer experience necessary to facilitate it is potentially complex and costly, while providing uncertain household value in return.

If hybrid heat pumps are supported by policy, we recommend that they be clearly regulated, with definitions that concern both packaged systems and add-on configurations. All hybrid system installations should be accompanied by an optimised control strategy that maximises any benefits, ensuring adequate efficiency and share of heat delivered by the heat pump. Finally, the emphasis in policymaking should be on protecting households while providing the energy system with the resources it needs to reach full decarbonisation of heating.

Annex

About Figure 2

We calculated the carbon intensity of heating with a gas boiler and a heat pump for various countries. Annual average and monthly grid carbon intensities were taken from Ember.[58] The emissions factor for the gas boiler was taken from the UK government and the gas boiler was assumed to be 90% efficient.[59] A heat pump performance curve was calculated from the in-field COP measurements from Gibb et al.[60] It calculated an average COP at each temperature, ranging from 1.82 at -20°C to 4.4 at 15°C.

The carbon intensity of a heat pump for each country was calculated by taking the grid carbon intensity and dividing it by the COP at each temperature point. That results in the following table for the average carbon intensities in 2023. A similar table was produced for the range of highest monthly emissions in 2023.

Carbon intensity	gCO_2eq/kWh	-20	-15	-10	-5	0	5	10	15
Poland	662	363	332	304	274	241	201	179	150
Germany	381	209	191	175	158	139	116	103	87
Netherlands (not shown)	268	147	134	123	111	98	81	72	61
EU-27 (not shown)	244	134	122	112	101	89	74	66	55
United Kingdom	238	130	119	109	98	87	72	64	54
France	56	31	28	26	23	20	17	15	13
Gas boiler (90% efficient)	***183***	***203***	***203***	***203***	***203***	***203***	***203***	***203***	***203***

A summary table showing emissions crossover points is shown below. A heat pump has fewer operational emissions above this temperature.

Carbon intensity	2023 average	Highest monthly in 2023
France	Less than -30°C	Less than -30°C
United Kingdom	Less than -30°C	Less than -30°C
EU-27	Less than -30°C	-22°C
Netherlands	Less than -30°C	-21°C
Germany	-18°C	-8°C
Poland	+6°C	+10°C

58 Ember, Electricity Data Explorer, accessed April and May 2024, https://ember-climate.org/data/data-tools/data-explorer/.

59 GOV.UK, Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal.

60 Gibb, D., Rosenow, J., Lowes, R., & Hewitt, N. J. (2023). *Coming in from the cold: Heat pump efficiency at low temperatures.* Joule, 0(0). https://doi.org/10.1016/j.joule.2023.08.005

About Figure 3

We wanted to investigate the running cost of a hybrid heat pump compared to a standalone heat pump at different electricity-to-gas price ratios. To do so, we assumed a COP of 3.5 for the heat pump, a gas boiler efficiency of 90%, and that the heat pump provided 70% of the heat demand.

The running costs are for comparison purposes only, so they are essentially dimensionless. We assumed a heat demand of 1 and an electricity price starting at 100 and increasing by 5 until 150. In the row where the price ratio is 1, the prices of electricity and gas are 100. In the row where the price ratio is 5, the price of electricity is 140 and the price of gas is 28.

The running cost is then calculated with the following, explained below:

$$Running\ cost = E_{heat} * P_{elec} * (\frac{E_{HP}}{COP} + \frac{1 - E_{HP}}{P_{ratio} * \eta_{GB}})$$

Symbol	Meaning	Value
COP	Coefficient of performance of heat pump	3.5
η_{GB}	Gas boiler efficiency	0.9
E_{heat}	Heat demand	1
P_{elec}	Price of electricity	100-150
E_{HP}	Share of heat demand from heat pump	0.70 (hybrid) / 1.00 (standalone heat pump)
P_{ratio}	Ratio of electricity-to-gas prices	Variable

Price ratio	Hybrid heat pump running costs	Standalone heat pump running costs
1	53	29
1.5	44	30
2	40	31
2.5	38	33
3	37	34
3.5	37	36
4	37	37
4.5	37	39
5	37	40
5.5	38	41
6	38	43

REGULATORY ASSISTANCE PROJECT

Regulatory Assistance Project (RAP)®
Belgium / China · 德国 / Germany / India / United States

Belgium
Rue de la Science 23
B – 1040 Brussels
Belgium

+32 2 789 3012

Germany
Anna-Louisa-Karsch-Straße 2
D – 10178 Berlin
Germany

+49 30 700 1435 421

info@raponline.org
raponline.org

Energizing
CHANGE