Vision paper | 2021

Hybrid Heating EUROPE

Unlocking the hybrid heating potential in European buildings

Hybrid heating solutions accelerate the EU's energy and climate agenda

Imprint

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2050
net zero emissions in Europe

The building sector is responsible for more than **⅓** of the EU's emissions.

Energy renovations only reduce building energy consumption by **1%** per year. Effective action is crucial to meet the EU targets of **60%** emission reduction by 2030 (compared to 2015) and climate neutrality by 2050.

Currently, **¾** of the building stock is energy inefficient, yet around **90%** of today's buildings will still be in use in 2050.

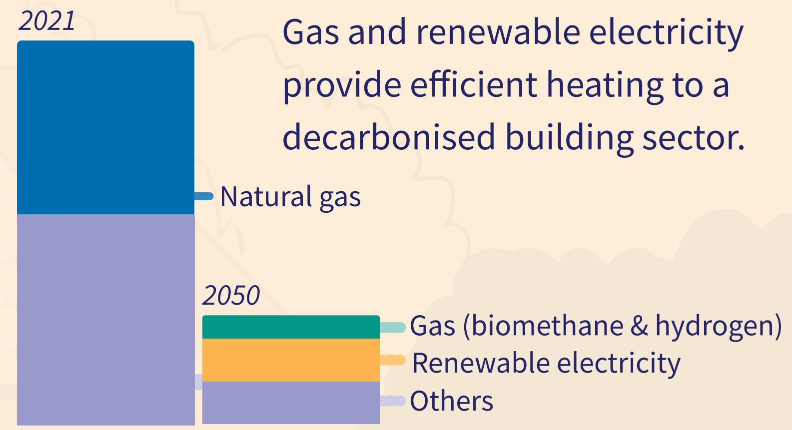
Consumer benefits

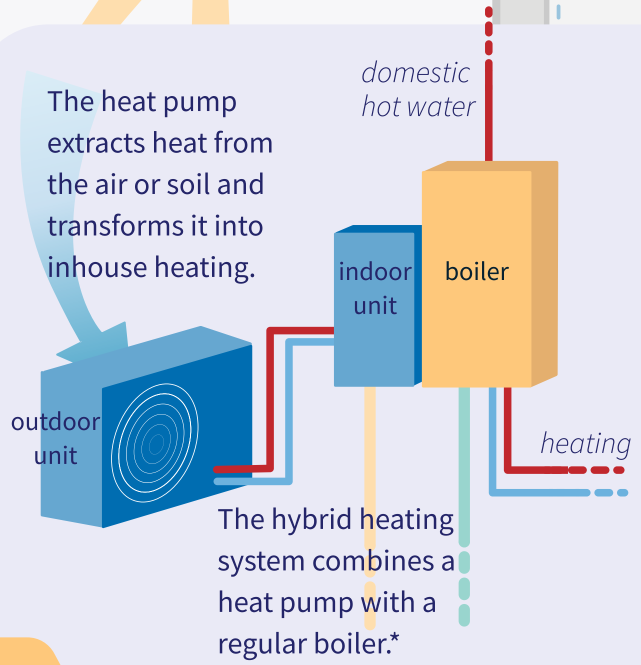
The benefits of hybrid heat pumps over alternative low-carbon solutions:

- **Up to 50% reduction in energy bill.**
- **Easy installation.**
- **No immediate building renovation needed.**

2050 end-vision

Gas and renewable electricity provide efficient heating to a decarbonised building sector.





Climate benefits

Accelerated carbon emission reduction through:

- **Wide applicability, easy installation.**
- **Immediate emission reduction through reduced fossil fuel consumption.**
- **An efficient and smart grid compatible system.**

Energy system benefits

The fuel switching capability of hybrid heat pump supports local energy system integration:

- **Reduces peak power demand.**
- **Increases system resilience.**
- **Reduces system investment cost by making use of existing gas infrastructure.**

Hybrid Heating
offers a solution

** See page 8 of our report for more information on hybrid heating system use cases.*

Executive summary

The heating of buildings is a major and complex part of the European energy transition, as acknowledged by the European Commission in its recent Renovation Wave Communication. Electric heat pumps are seen as an important part of the solution, together with renewable district heating and green gas. However, the shift to heat pumps has to be compatible with the speed at which existing buildings can be renovated to enable their heating systems to operate at lower temperatures and by the speed at which local, and even regional and national, electricity grids can be upgraded to handle their combined peak demand. Hybrid heating solutions, combining an electric heat pump with a boiler, offer a future-proof way to accelerate the role that heat pumps can play by addressing both of these constraints at the same time. In this way they can support the objectives of the European Green Deal and its Fit for 55 package by facilitating:

- accelerated CO_2 emission reduction – this is key to achieve the EC target of 60% CO_2 reduction in buildings by 2030, compared to 2015
- accelerated renewable energy uptake in heating – increase of ambient heat and optimised system integration of renewable electricity
- future-proof initial step of staged deep renovations - peace of mind for people to cope with the challenge for decarbonising homes
- affordable upfront investments for households - "leaving no one behind" on the road to a climate-neutral building stock by 2050.

When implementing hybrid heating solutions, consumers benefit from lower costs and the ability to spread out investments in home insulation, while maintaining comfort levels. The energy system benefits from the local integration of gas and electricity and energy infrastructures enabled by hybrid heating solutions. This integration reduces peak power demand and thus reduces immediate need for investments in grid reinforcement compared to alternatives. With the ability to switch between gas and electricity adding further flexibility, system resilience is also increased. The continued use of existing gas infrastructure avoids the more expensive rollout of new district heating systems where applicable.

Hybrid heating solutions fit in a net-zero energy system by mid-century, when supplied with renewable electricity, biomethane and renewable and low-carbon hydrogen.

The companies united in Hybrid Heating Europe are convinced that Europe should scale up hybrid solutions. This requires action from hybrid system manufacturers, energy providers and policy makers.

1. Introduction and scope

1.1 Carbon emissions in European buildings need to decline fast

Reducing carbon emissions in public and private buildings is key to meeting Europe's climate goals: at least -55% by 2030 and climate neutrality by 2050. The European Green Deal singled out building renovation as a key initiative to drive energy efficiency in the sector and deliver on objectives. With around 90% of buildings today expected to still be in place by 2050, this is a sizeable challenge. The current rate of 1% energy renovation annually is not fast enough. [1]

The European Commission’s [2] Renovation Wave agenda aims to address this challenge and calls for accelerating deep renovation with high energy efficiency levels while respecting affordability, integration of renewables, and life cycle thinking.

1.2 Hybrid heating solutions can support the EU climate energy agenda and energy system integration

Hybrid heating solutions show the promise to deliver on these goals. Such systems offer immediate real-world emission reductions and renewable heat uptake, without causing electricity resource adequacy concerns. The benefits can be higher than those offered by alternative options with more limited applicability and higher costs for users and burden on the electricity system. Deployed at the individual building level, hybrid heating solutions support local energy system integration because they can combine electricity consumption at times of abundant renewables with (low carbon) gas consumption at times of low renewable electricity availability or peak heat demand.

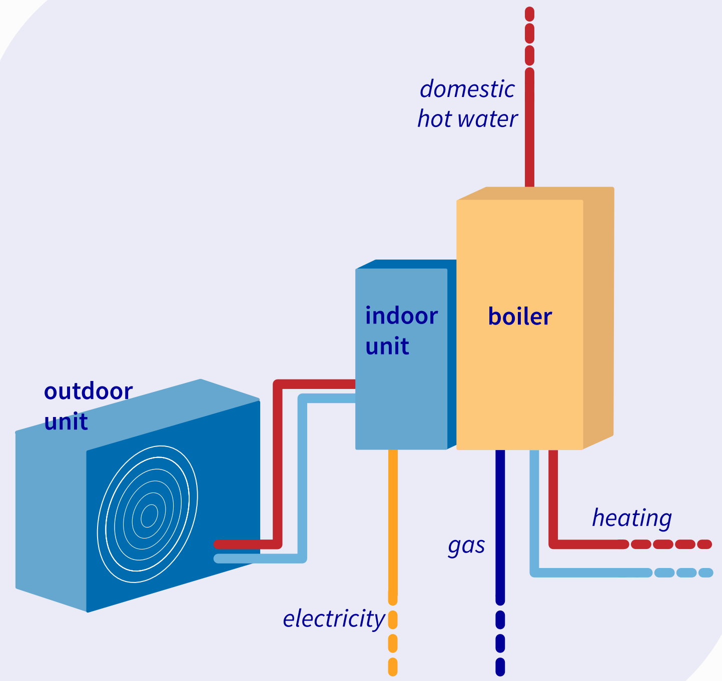
Hybrid heating solutions that combine gaseous fuel-fired boilers with electric heat pumps, are a mature technology. In 2019, 32,000 units were installed in Italy, Germany, France, the Netherlands and the UK and significant growth is projected over the next several years [3]. They can save cost and reduce emissions from buildings that have not undergone deep renovation yet, supporting a building decarbonisation pathway “that leaves nobody behind”. This complements electrification by all-electric heat pumps, decarbonisation of gaseous fuels, and renewable district heating. As the building insulation is improved over time, the emission reduction by its hybrid heating and the share of renewable energy it uses further increase. Because of their wide immediate applicability and modest up-front cost, hybrid heat pumps are a no-regret option that can accelerate the speed of adoption of low carbon heating systems and so speed up the decarbonisation of the built environment.

1.3 Hybrid Heating Europe: a broad coalition

Twelve companies, active in gas and electricity infrastructure and in manufacturing of heating equipment, joined forces to address this challenge in a unique coalition, reflecting the need to work on optimal energy system solutions across the sectors.

1.4 This paper

This vision paper shows that hybrid heating solutions can contribute significantly to the energy transition by bringing benefits to consumers, the climate and the energy system. Specifically, it examines how hybrid systems could accelerate the adoption of heat pumps by limiting immediate investment needs. The paper includes recommendations on how to support a faster, easier and more affordable transition through the deployment of hybrid heating solutions.



Hybrid Heating Solutions (HHS)

We define hybrid heating solutions as systems deployable at the individual building or household level that combine existing or new gaseous or liquid fuel-based boilers with an electric heat pump for space heating or domestic hot water.

1.4 Where in the EU building stock can hybrid heat pumps play a role?

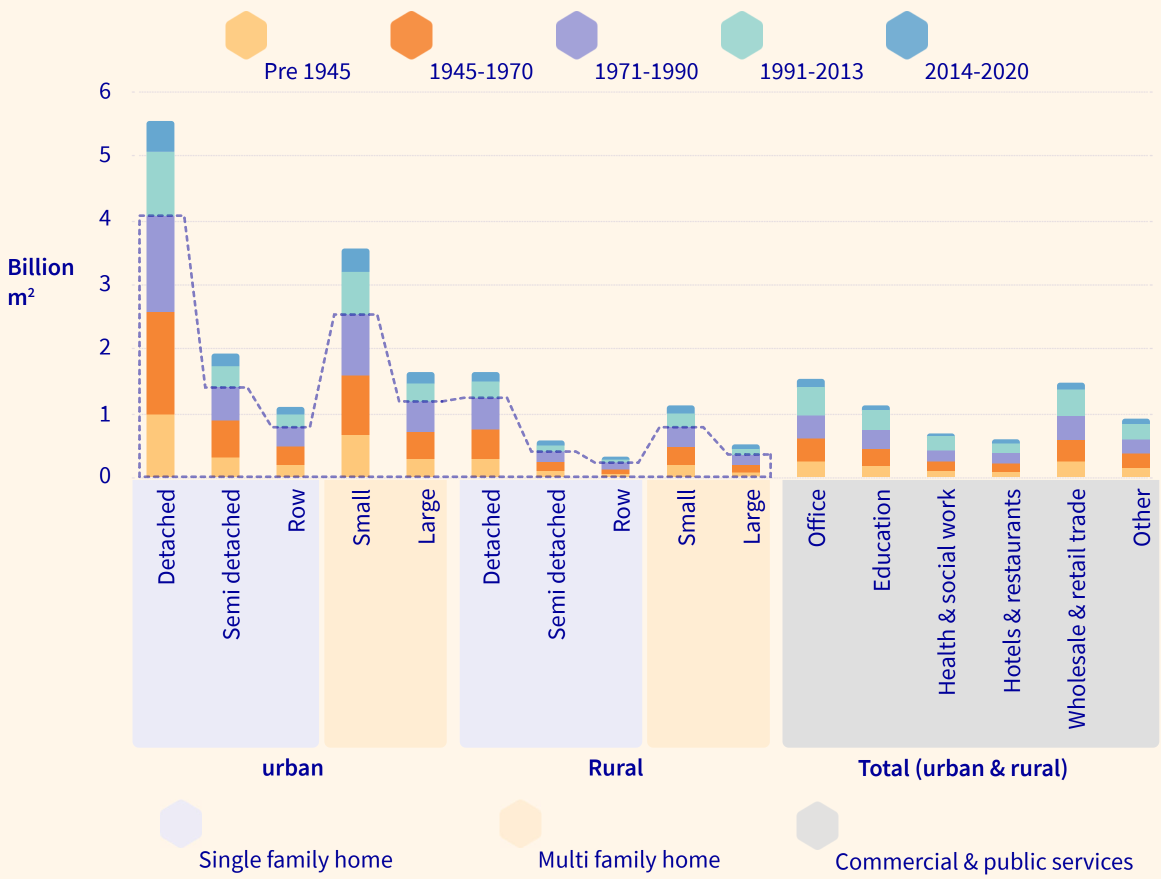
Determining in which parts of the building sector hybrid heat pumps should be used requires the consideration of various aspects.

First, the building needs to have the access to the gas grid[1], without which a hybrid pump is not possible. Hybrid heat pumps are best suited to buildings where the overall building shell efficiency has not yet reached a sufficient level to use only electric heat pumps. The hybrid heat pump can reduce CO_2 emissions immediately compared to a gas or oil boiler, and its operation mode can gradually be shifted to more electric heat pump share when the building envelope is renovated over time. Most of these cases can be found in the urban areas for single-family and multifamily buildings, as figure 1 shows. This is the first focus area for hybrid heat pumps, since a high share of these buildings have a gas grid nearby.

Residential buildings in rural areas – especially the ones not able to connect to a gas grid, which can continue to use existing liquid fuel tanks – are another area to consider for hybrid heat pump use. In these cases, a hybrid solution may even be the only short-term solution to reduce CO_2 emissions. Development of biomethane production and connection to the local gas grids would provide an opportunity to serve the local communities with renewable energy produced from local biowastes and residues.

Commercial and public sector buildings could also be an option, but they vary much more in size (and system power required) and only have partial gas-grid connectivity.

Figure 1. Overview on EU building stock 2020 (in billion m²) and applicability of hybrid heat pumps.



[1] Although a hybrid system using liquid based fuel can also be installed, this paper focuses the analysis on gaseous fuel based boilers.

2. Consumer benefits

Hybrid heating solutions are a mature technology providing consumer benefits and additional options for low carbon heating. Consumers benefit from lower costs and the ability to spread out building renovations, while comfort levels can be assured. Especially in older buildings with modest insulation levels, the consumer may not consider an all-electric heat pump solution due to the potential comfort risk (in case of insufficient capacity on the coldest days) or the high cost of bringing insulation to the necessary level to avoid this. Hybrid heating solutions provide additional options for adapting the decarbonisation of buildings to individual needs and financial capacity – this is key for success, as millions of EU households with a largely heterogenic building stock must buy in.

2.1 Lower and more spread out investment cost and a lower heating bill

In such buildings, hybrid heat pumps would have a number of cost benefits for consumers:

A. **The investment in a hybrid heating system can be relatively modest**, as it consists of an electric heat pump sized to cover the frequently occurring heat demand combined with a gas-fired boiler to cover infrequent peak demand. Consumers with a recent high-performance boiler can reduce their investments by simply adding a small heat pump and a control system.

B. Hybrid systems require **no immediate (deep) renovation measures** to save emissions and energy. Even on particularly cold days, comfort is guaranteed as the gas boiler can kick in when the heat pump cannot cope. Hybrid systems do not necessarily need a retrofit to low-temperature space heaters. Additional renovation measures should be undertaken to save on the energy bill, but this can be done later to spread out costs in line with regular renovation cycles. Consumers can install a hybrid system when it is convenient for them, for example when they need to replace their existing boiler.

C. The consumer's **energy bill can be reduced significantly** with smart controls because of the high efficiency of the heat pump and the ability to switch to the lowest cost energy vector (gas or electricity) at any time when using a smart system which can respond to energy price signals.

The following sections describe each of the three cost advantages in more detail.

A. Modest investment in the hybrid heating system itself

The investment in a hybrid heating system can be relatively modest, as it consists of an electric heat pump sized to cover the frequently occurring heat demand combined with a gas-fired boiler to cover infrequent peak demand. Consumers with a recent high-performance boiler can further reduce their investments by simply adding a small heat pump and a control system.

The required outdoor unit (ODU), or ground heat exchanger, for this hybrid solution is modest in size, making it viable even for houses with limited outdoor area. A low capacity pump could even be placed in the boiler installation room and in this way the noise emission to neighbours can be lowered or avoided altogether. Such solutions enable higher customer acceptance and wide applicability.

B. Hybrid heat pumps enable more gradual building renovation

The Renovation Wave sets a path towards deep decarbonisation of the European building stock by putting energy efficiency first. However, renovation speeds are not fast enough today and there are building types that are difficult to renovate soon[2].

Extensive field testing [7] demonstrates that hybrid solutions can be applied effectively to virtually any building, independent of envelope and heat distribution system characteristics, without immediate additional insulation measures. Such systems accelerate the take up of renewables in heating, providing additional options with a lower cost when considering the replacement of an old boiler.

Subsequent staged investments into improved insulation of the building envelope will further improve the building efficiency and lower the energy bill. In an increasingly renovated building, the share of heat provided by the heat pump will increase [7]. Seen this way, a hybrid heating system is a no-regret investment and it will continue to serve in an increasingly renovated building. However, it has the additional advantage of being more widely applicable from day one.

Such pathway benefits allow homeowners to decide when to invest and renovate, ideally in line with regular renovation or replacement cycles of existing heating systems and according to individual renovation roadmaps. In many cases, hybrid systems can increase the uptake of heat pumps by avoiding the need to undertake a major home energy renovation at the same time.

C. Lower heating energy bill

Even with the present tariff structure, a heat pump's efficiency can reduce a building's energy bill once a hybrid heating system is installed (with higher average coefficient of performance compared to an all-electric heat pump). The energy bill is also reduced by the heat pump's high operating time and the possibility to make smart use of price signals. For the UK, savings of up to 50% were found

[2] E.g. heritage buildings or relatively young buildings where renovations on the building shell are economically not feasible yet.

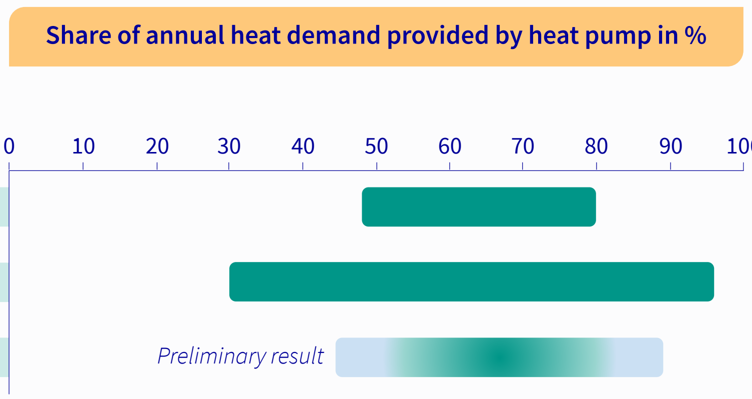
[8], but the effect will vary significantly among countries depending on local energy prices, regulations and the presence of additional incentives. For the Netherlands, recent testing data shows potential energy bill savings of up €600 annually[3].

Field tests and meta-analyses, as figure 2 illustrates, show that the heat pump part of hybrid systems can cover from 30% to 96% of the annual heat demand [4], depending on building properties, local climate and chosen control strategy (e.g. price optimised or CO_2 optimised). With these operating hours, the heat pump's efficiency translates directly into lower energy bills; the typically more expensive use of electricity compared to gas can be more than offset by the high efficiency of the heat pump.

Figure 2. Share of heat supply from the heat pump part of hybrid systems varies. Data sources: [4], [9].

Pilot studies on hybrid systems

Country	Building sample	Year
UK	4	2014-2015
UK	9	2014-2015
NL	420	2020



Key take-away
Larger share of heat produced by heat pump in hybrid systems, but varies over building types, energyprice regimes, climate and chosen control strategy.

[3] https://www.consumentenbond.nl/warmtepomp/beste-warmtepomp

Hybrid systems connected to smart meters will amplify this effect. Where individual consumers or prosumers can respond to short-term price signals from the grid, they stand to benefit by always choosing the cheaper option.

This effect will be enhanced further if future energy price developments are considered; as more renewables are introduced into the system, the difference in electricity prices between cheap and expensive hours will increase. Electricity prices will likely be lower during hours of abundant renewables and conversely higher when renewables are not available, but also when demand peaks, like in windless winter weeks. In this price environment, hybrid systems can effectively reduce costs for homeowners as they allow for switching out of the most expensive electricity hours in favour of gas.

Hybrid heating solutions enable and support energy system integration. An integrated energy system will minimise the costs of transition towards climate neutrality for consumers and open new opportunities for reducing their energy bills and active participation in the market, as the European Commission envisions. [10]

2.2 Easy installation, less disruption and wider applicability

Hybrid systems can be installed irrespective of the heat delivery systems, such as underfloor heating. Existing radiators can be retained if required, which greatly reduces the cost and disruption of moving to a hybrid heating system, although the overall performance can improve by increasing the heat distribution surface area.

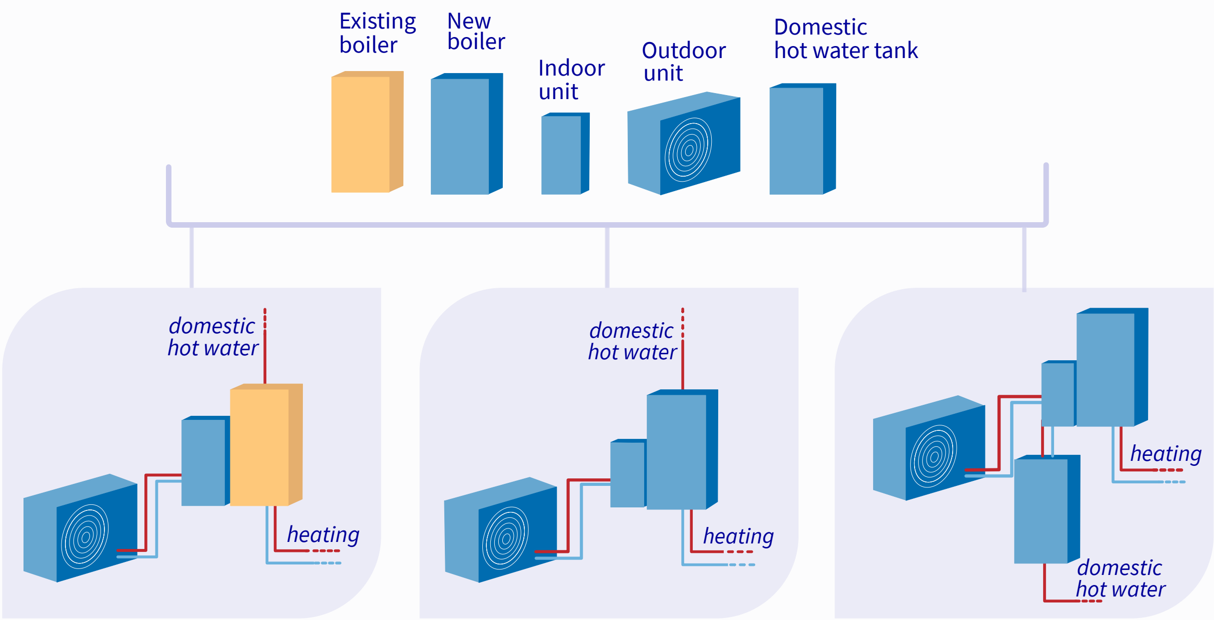
Hybrid heating solutions can thus improve energy efficiency even in relatively poorly insulated buildings, requiring higher heating system temperatures, showing the wide applicability over various building types and energy labels.

Hybrid systems come in various shapes and sizes, as figure 3 shows. Installation can take place as an add-on to an existing boiler, extending its operational life. A hybrid heating system can also be installed as a single package when it is time to replace the conventional boiler.

Hybrid heating systems can also provide domestic hot water, further extending their applicability. On average, domestic hot water needs higher temperatures than space heating, the boiler part of the hybrid heat pump can efficiently supply this.

Hybrid heating systems are designed to look and operate like conventional boiler systems. They are designed to connect straight into legacy heating systems, delivering like for like performance and maintaining comfort levels in buildings. Hybrid heating systems can make use of existing natural gas-fired boilers, allowing for an eventual switch to zero-carbon biomethane, when this is available. If a hydrogen-ready boiler is used, switching to hydrogen is an option as well.

Figure 3. Three categories of hybrid heating system use cases.



Type 1 Retrofit hybrid use case

A heat pump is added to an existing boiler, hot water is provided by the boiler.

- For systems with a good existing boiler.
- Lowest upfront cost option.
- Allows staged investments.
- Master control of the heat pump decides to activate boiler control. Two user interfaces available.
- Low space requirement.

Type 2 Heating hybrid use case

Existing system is replaced by hybrid system, where hot water is provided by boiler the boiler only, without hot water tank. .

- Good cost/efficiency ratio.
- Lower investment need.
- Master control of the heat pump decides to activate boiler control. One or two user interfaces available.
- Low space requirement

Type 3 Heating and hot water hybrid use case

Existing system is replaced by hybrid, where the heat pump contributes to both heating and hot water, with the boiler as backup/support.

- Highest upfront cost, highest hot water comfort.
- Intelligent communication between heat sources.
- Single system control and interface.
- Tank for hot water is required.

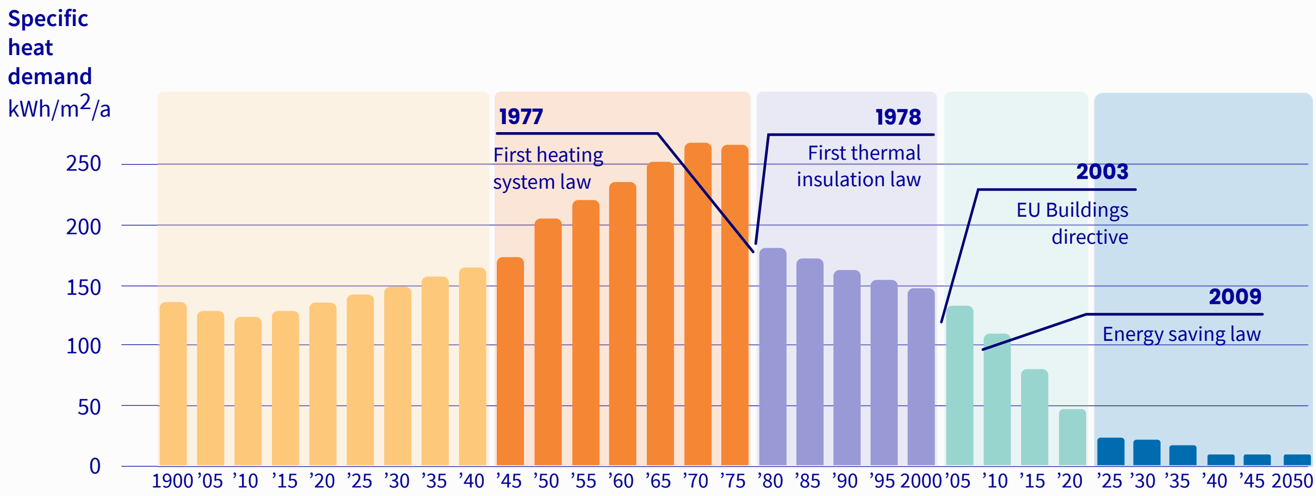
Installation, operation and maintenance of hybrid systems: messaging to installers

From field experience, coalition members recognise hesitation among installation companies to adopt hybrid systems and recommend hybrid heating solutions to their customers. More communication is needed to demonstrate that:

- Installation, commissioning and service is similar to traditional gas or oil boilers. Being able to build on existing boilers is an added advantage.
- The operating menu and thermostat unit operate in similarly to traditional systems.
- The system is guaranteed to deliver heat comparable to the predecessor (availability of central heating and domestic hot water) leading to less customer complaints.
- Backup heat source available (heat pump backs up boiler and vice versa when there is a failure of one of the heat sources)..
- Opportunity to make the best of the variable energy tariff.

Hybrid heating solutions are largely applicable over various building types, energy labels [7] and areas where the electricity grid does not (yet) have sufficient capacity for all-electric options. This makes hybrid heating systems a complementary solution to scaling up all-electric heat pump deployment and district heating. Combined, these options cover a much wider range of buildings sooner than each solution could by itself. Figure 4 shows an example from Germany which illustrates that hybrid heat pumps could be applicable in older buildings which represent almost 50% of the building stock with the highest heating demand and where an all-electric solution would not be appropriate.

Figure 4. Illustrative applicability of hybrid heating systems in German building stock.



Share stock* (%)	26	46	21	7	
Heat demand (kWh/a)	20.000-25.000	30.000-40.000	20.000-25.000	10.000-20.000	
Heat load (kW)**	13-16	19-25	13-16	6-12	
Radiators share*** (%)	85.5	85.5	76-55	Not available	
Average surface (m^3)	170	160	150	150	

*Source: Destatis, Umweltbundesamt; number of buildings
**Assumption: 1600 h/a full load equivalent hours
***Source: IWU Darmstadt

The combination of applicability in less well-insulated, typically older buildings and the flexibility that hybrid heating systems provide in spreading out the cost of renovation measures is especially important in tackling energy poverty. Energy poor and vulnerable households should be included in the transition and engaged with, and should not be disproportionally burdened with the associated cost, as the Citizens' Energy Forum recently stated. [11]

3. Energy system benefits

The fuel switching capability of hybrid heating solutions brings energy system benefits. Hybrid systems have a limited peak power demand, avoiding the need for heavy electric infrastructure just to cope with infrequent cold spells. They increase system resilience by allowing for take up of renewable electricity on days with lots of wind and sun, being able to switch between gas and electricity networks and lowering power outage risk so also reducing the immediate need for investments in grid reinforcement. Finally, they use existing gas infrastructure, preventing more expensive rollout of new district heating systems in areas with a lower building density. Hybrid heating solutions are a no-regret option from an infrastructure perspective.

3.1 **Peak power demand reduction**

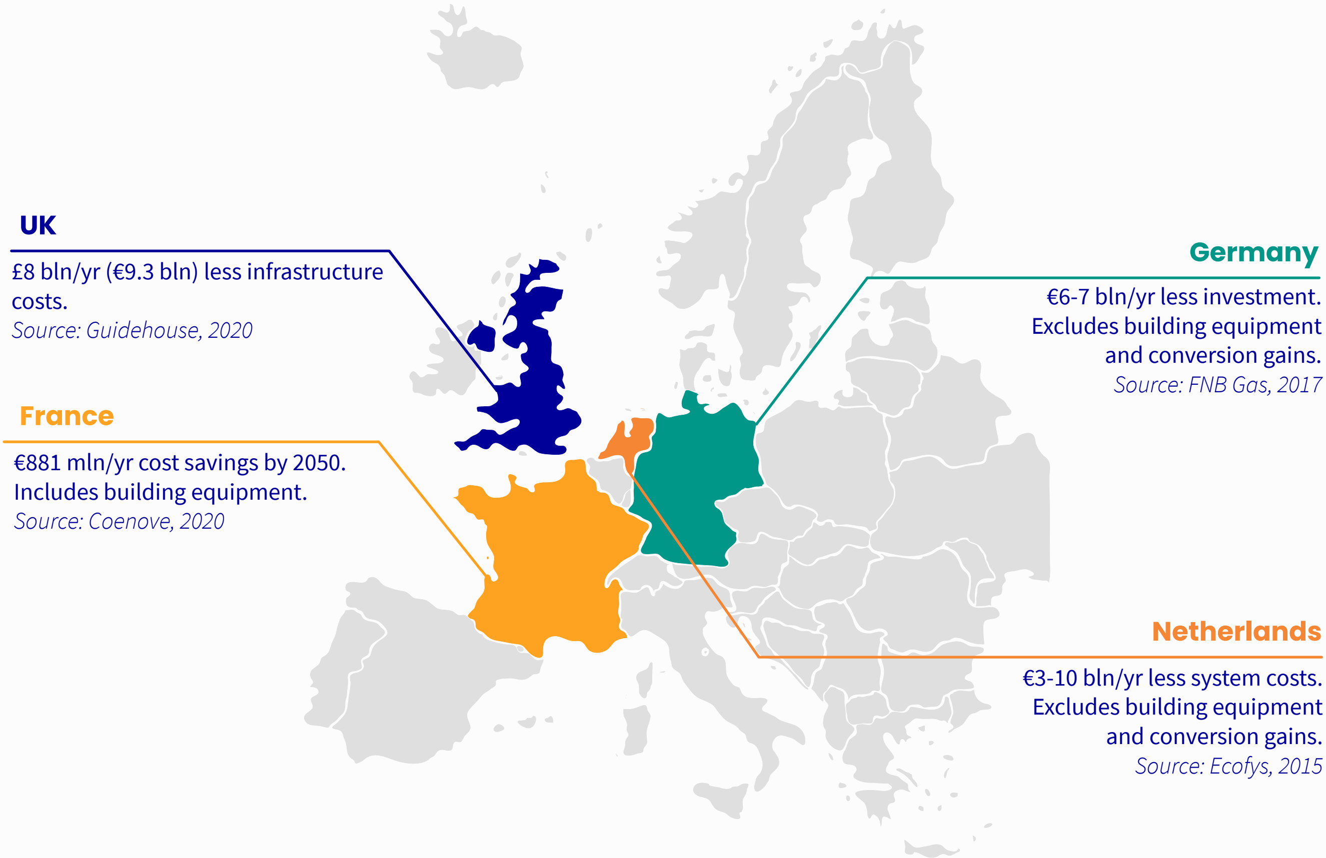
Typical cold spells in Europe occur only a few times per year, and the coldest ones, determining the capacity of our heating systems, only once every decade or so. Where all-electric systems are installed at scale, they require the electricity grid to be dimensioned in a way that enables meeting power demand during the worst cold spells. This means that the existing electric infrastructure, at all levels, needs to be expanded to allow the delivery of sufficient electricity in these peak demand moments, which is expensive and will require many years to complete.

At the low voltage level, a higher capacity connection may already be required for solar PV panels or an electric car charger so the cost difference for the additional capacity for a heat pump can be relatively modest if added at the same time. However, considering the overall electricity grid and reserve capacity, the sum of all such additional capacity requirements leads to considerable investments.

Hybrid heating solutions have a lower capacity heat pump and can so rely on gas grid capacity to deliver peak heat demand. Peak power demand can be as much as 5 times [12], [4], [13], [14] lower compared to all-electric systems. This demand reduction has immediate consequences for grid dimensions (the amount of copper, the size of transformers, the number and size of peaker plants) and, as a result, greatly reduces investments needed in the electricity system. Analysis shows that this investment reduction may amount to €6-€7 billion per year for Germany [15] with estimates varying by country, as figure 5 illustrates.

The costs of operating and maintaining the existing gas grid, on the other hand, are generally low. As long as other building and applications in a distribution grid still need the gas grid, the marginal cost of operating and maintaining it for a building in that area is very low indeed.

Figure 5. Existing literature shows significant cost savings associated with lower electricity grid investments but assumptions differ widely and a direct comparison is complex. Sources: [12], [15], [19], [20]



The overall societal cost savings in the EU could be significant. Based on existing literature, heating technology costs in the range of €5-47 billion per year could be saved [[16], [17], [15] [12], [18], [8]]. On top of this, insulation costs of up to €21 billion per year could be avoided in the optimal case, and energy infrastructure costs in the range of €10-€17 billion per year.

For electricity costs, some studies show additional costs of up to €4 billion per year, others show savings of up to €18 billion per year. Since the underlying studies differ regarding energy system design and quantification methodology, it is unlikely that the maximum savings per category are realistic. The ranges shown instead give an impression of the order of magnitude. Adding the individual cost savings (and potential additional costs) to an overall bandwidth is not considered as reasonable.

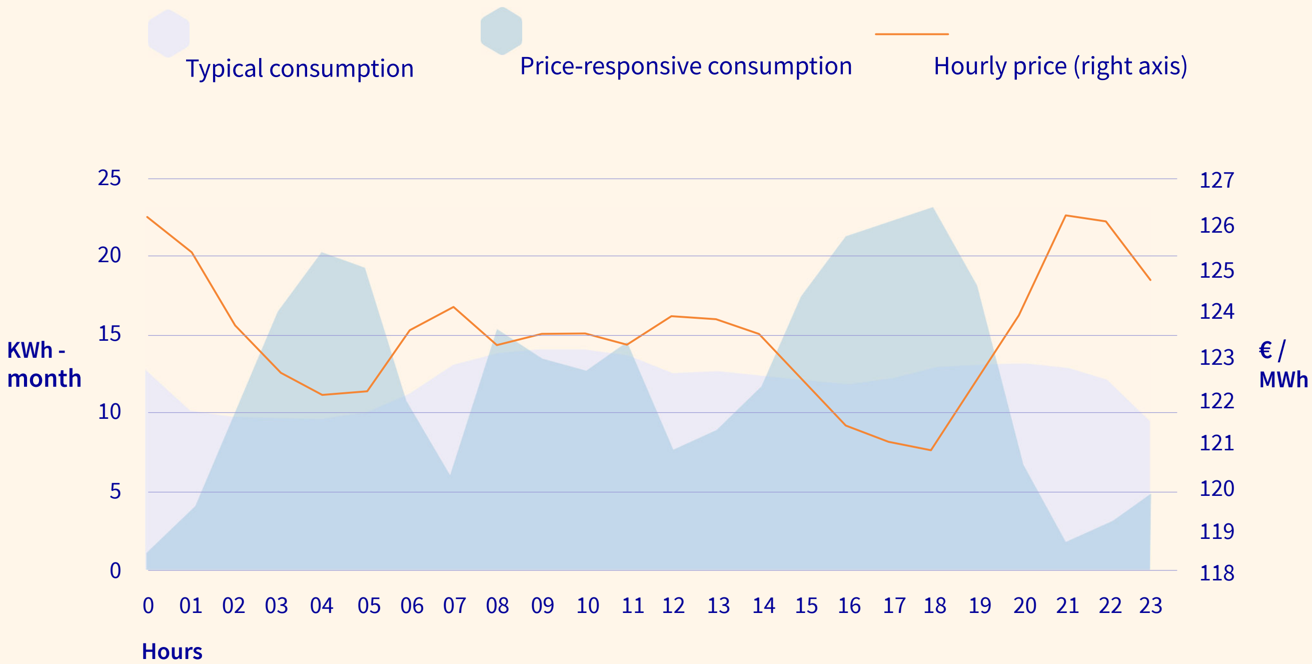
If winter peak demand is met with gas, existing gas storage can be used for flexibility. Biomethane produced in summer can be stored safely in underground gas storage systems that are today already used for seasonal storage of natural gas. This can be supplemented with hydrogen storage in salt caverns, for instance, as the recent European Hydrogen Backbone paper discusses [21]. Hydrogen produced from excess renewable power could be used in hybrid heat pumps for heating buildings, avoiding the need to convert it back to electricity, with associated losses. The use of biomethane or hydrogen should be considered in relation to other potential uses in the transition towards a net-zero European economy.

3.2 Increased energy system resilience and seasonal flexibility

Hybrid heating systems in the built environment increase energy system resilience and flexibility by reducing the need for renewable power curtailment and the risk of power outage in times of insufficient power supply. This way, hybrid heating solutions enable energy system integration and a smoother transition away from fossil fuels towards a decarbonised energy system.

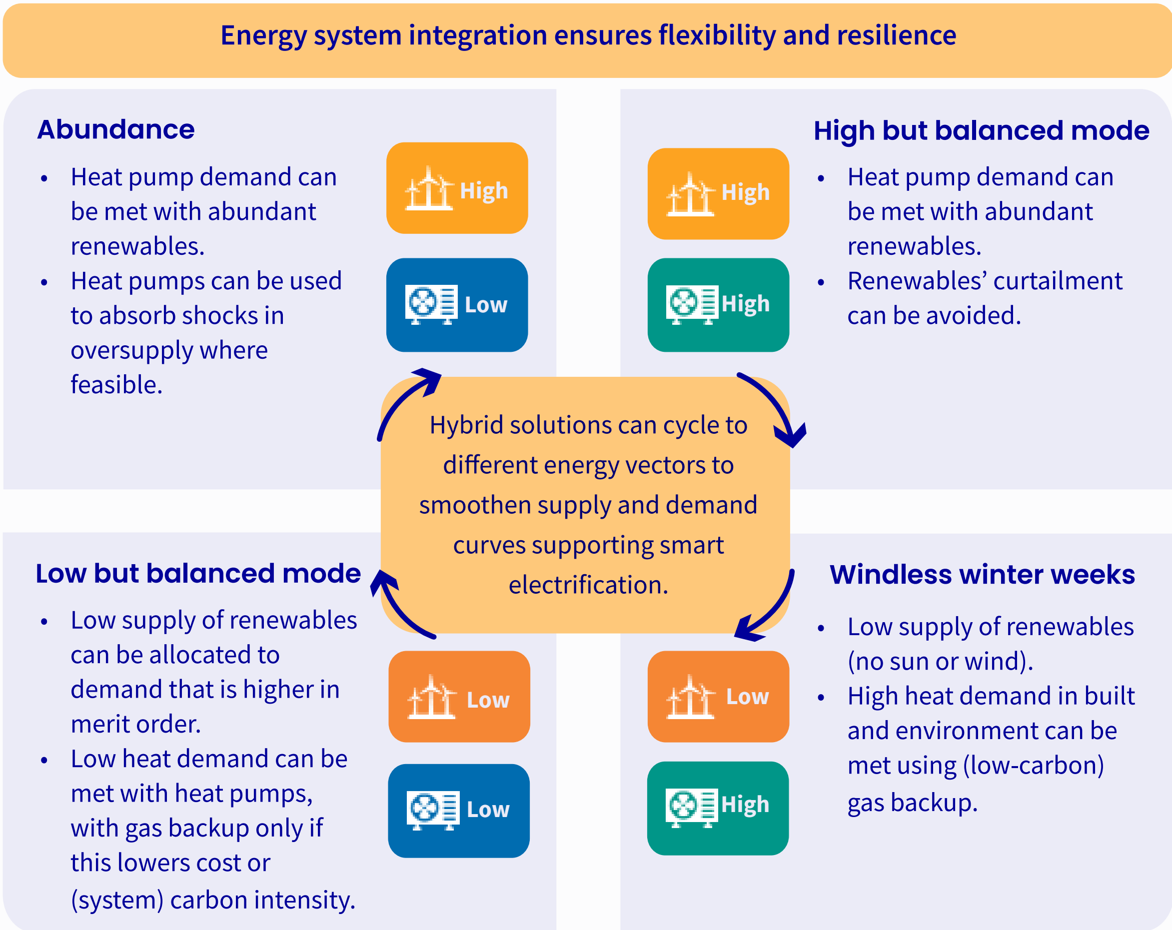
The EU's ambition is to have at least 32% renewables in the EU energy mix by 2030 [22]. For electricity alone, this share will already surpass 50% by that time frame. The increasing penetration of renewables at the (relative) expense of dispatchable power introduces more volatility in power supply. When hybrid heating solutions are introduced at scale, an additional "switch" becomes available to the energy system as Figure 6 shows. This switch can absorb peak power supply in times of a lot of wind or solar entering the system, preventing curtailment.

Figure 6. Illustrative effect of time-variable tariffs on electricity consumption.



This switch also works the other way around. In times of low renewable power supply or peak demand, the hybrid systems can respond to power or carbon intensity signals and switch to gas to facilitate system stability. The Freedom Project in the UK demonstrated that a network of hybrid systems can respond to carbon intensity signals as well [8]. This capability facilitates the lowest emission intensity of the energy system at all times.

Figure 7. Energy system integration of gas and electricity in buildings ensures flexibility and resilience.



Most hybrid heating systems delivered today allow the user to set energy tariff- or efficiency-related switch points. Increasingly, such systems come with built-in smart systems that allow the homeowner to choose between responding to dynamic price signals or carbon signals – provided they are part of a smart grid that provides consumers with such signals. Product labels are explored or rolled out to help consumers recognise this functionality [23]. At the same time, residential energy management systems, including smart thermostats, see rapid expansion [24].

The building blocks to boost this development are being implemented. Smart meters, smart controls and time-variable tariffs are emerging in the various member states and will gain key momentum in the next decade. As of 2019, consumers in six member states had access to retail electricity products which include remote control of consumption [25].

The systems' ability to respond to such signals is key to support the energy system in windless winter weeks, or peak heat demand in cold winter spells when there is little wind or sun.

3.3 Continued use of existing infrastructure

Hybrid systems allow continued use of existing gas infrastructure. This saves costs, and installation complexities and disturbances, compared to laying out new district heating infrastructure. This is especially the case in areas with lower building density.

Continued use of existing infrastructure and avoiding investments in extra capacity of the electricity transmission and distribution grid can save up to €10-€17 billion per year, see figures above. This includes the requirement to maintain the gas grid and is supported by research on national energy systems. Analysis on the UK energy system indicates that only 16%-50% of transmission and distribution costs are required for a hybrid heating scenario compared to all-electric [19].

In general, hybrid heating systems should not compete in districts where alternative low carbon systems are more cost-effective.

There are areas where it is likely that new district heating will be the most cost-effective solution. For example, large apartment buildings with an existing boiler room and associated heat distribution systems are well-positioned for connection to a district heating system, with little refurbishment required inside the building.

Where homes are already well insulated and have low-temperature (underfloor) heating systems, e.g. in new housing districts, all-electric heat pumps are an attractive solution.

4. Climate benefits

The efficiency and maturity of hybrid solutions bring climate benefits today and fit a net-zero future system. Hybrid heating solutions reduce carbon emissions because of the efficiency and smart use of heat pumps. They can accelerate carbon emission reductions in the building stock because of their wide and immediate applicability compared to low carbon alternatives in a significant share of the existing EU building stock. Finally, hybrid heating solutions fit a net-zero energy system using green electricity when available and biomethane or hydrogen when it is not.

Hybrid heating solutions add flexibility in the decarbonisation journey of the EU building stock. They enable the decoupling of four independent system developments:

- Installation of more efficient heat sources like heat pumps
- Insulation of buildings
- Greening of gas
- Greening of electricity

With this flexibility a smoother transition will follow, giving the opportunity to decarbonise faster, with less hiccups in the system.

4.1 Real emissions reduction from day one

Currently, almost half of energy used for heating and hot water in the building sector comes from natural gas. Once installed, hybrid systems can provide a baseload of heat to a building using a highly efficient heat pump. Extensive field testing shows that hybrid systems can meet 70%-95% [4] of heat demand using electricity, immediately and significantly reducing natural gas consumption. With the high efficiency of the integrated heat pump, this directly translates into as much as 55% CO_2 emission reduction [26], [4] compared to natural gas boilers alone. It can even have lower CO_2 emissions compared to all-electric heat pumps, depending on the electricity grid emission factor [12], [27].

Even in largely decarbonised electricity markets, hybrid systems provide similar emission reductions as all-electric solutions [28]. In addition, as biomethane and green and blue hydrogen are scaled-up, hybrid heat pumps achieve immediate emission reductions.

During periods of high carbon intensity electricity production, when there is not enough wind or sun to meet demand, hybrid systems can respond to grid signals and switch from electricity to gas. Field tests [12], [8] have shown how such smart grid orchestration enables the least carbon intensive way of heating the building stock.

This response to carbon intensity is especially useful when considering that the carbon intensity of peaker plants is higher than the grid average in most EU countries. The peak hourly emissions intensity of European electricity supply is almost 42% higher than the lowest observed hourly carbon intensity [29]. When operating such peaker plants can be avoided, carbon emissions are avoided, as long as the peaker plants themselves are not zero emissions.

4.2 Accelerated carbon reductions in the next decade

Compared to alternative low-carbon systems such as all-electric or district heating, hybrid systems can be more widely adopted and scaled sooner. This acceleration supports meeting the recently increased ambition of the EU to reduce greenhouse gas emissions by at least 55% compared to 1990 levels [30].

District heating developments typically require years of planning and several weeks of construction work. Hybrid systems can be installed in as little as a single day and can be deployed in low-density areas where district heating is not a viable option.

All-electric, like hybrid systems, can be installed much more quickly compared to district heating systems. But if too many are installed in a single street, the electricity grid will not be able to accommodate the increased demand and additional time will be required to upgrade the grid. If many are installed in a city, a region, or a country, the same applies to higher-voltage levels in the electricity grid.

Hybrid systems also have a wider immediate applicability compared to all-electric due to less stringent requirements on the building's insulation level. Increased efficiency measures like insulation or switching to low temperature radiators can be taken later if necessary, in line with the investment life cycle of the homeowner. Where a building must be renovated to make all-electric solutions feasible more time and up-front investment will be required compared to hybrid solutions. This will lead to delayed investments and thus delayed emission reductions. In other words, hybrid systems help deploy heat pumps faster.

To help achieve the EU's climate objectives, hybrid heating solutions can complement all-electric solutions by offering a solution for buildings not immediately relevant to the application of all-electric systems due to lower current levels of energy efficiency.

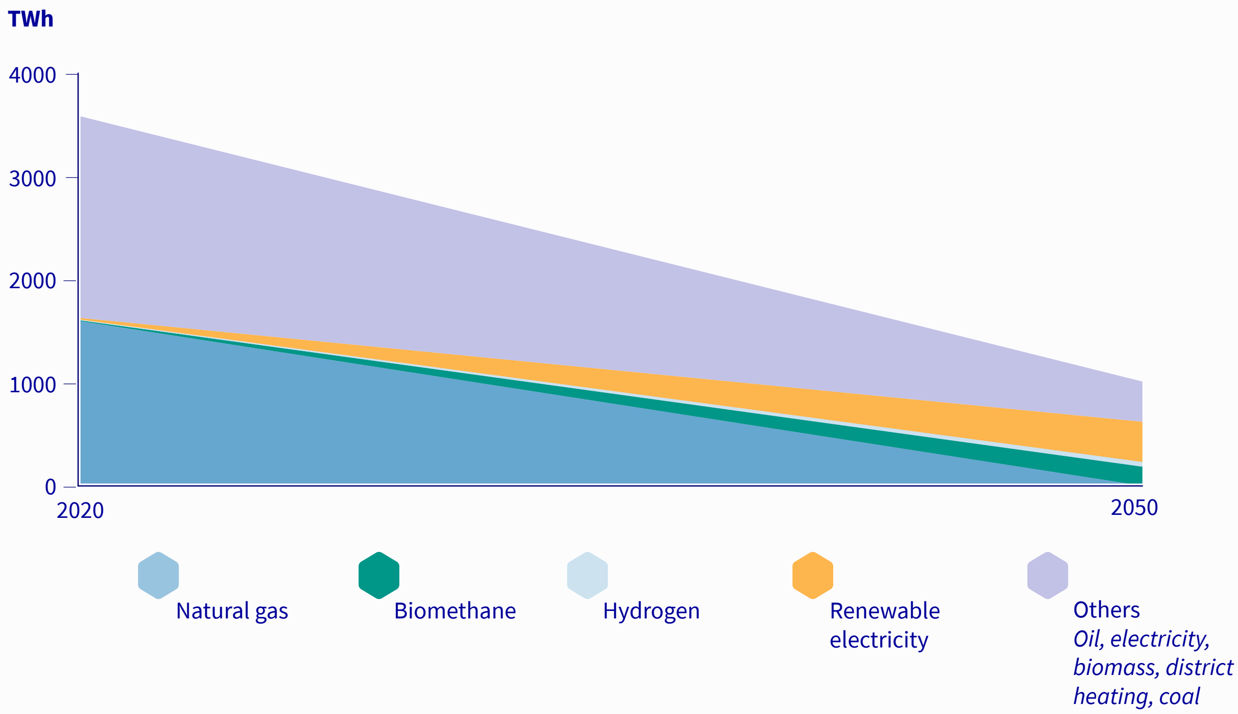
4.3 Fit the net-zero emission future

Hybrid systems fit a net-zero energy system, using a smart combination of renewable electricity with renewable and low carbon gas.

With increased penetration of renewable electricity in the grid, hybrid solutions reduce greenhouse gas emissions of the built environment. Even if hybrid heating solutions save carbon from day one, the decreasing emissions intensity of power generation will only help this effect increase. And as the insulation level of buildings improves over time, less and less energy will be needed to live and work in comfortably warm buildings.

As figure 8 illustrates, hybrid systems significantly reduce gas consumption in buildings. This absolute decrease in gas demand allows low-carbon gas to increase its relative share in gas supply. Over time, the availability of low-carbon gases such as biomethane or hydrogen is projected to increase sufficiently to meet the full demand in the built environment of 185 TWh and 45 TWh, respectively, with the remainder met by renewable electricity and district heating, as illustrated in figure 8. [31]

Figure 8. Illustrative decarbonisation pathway of energy use in buildings. Adapted from Gas for Climate. [31]



5. Recommendations

Ensuring that hybrid heating systems make the energy transition fast, resilient, affordable and easy

Hybrid heating solutions can help the EU meet its decarbonisation targets while simultaneously increasing affordability and energy system resilience. Hybrid systems complement alternative low carbon heating solutions and are relevant for a large share of the EU building stock where the alternatives are not straightforward in the short term. But more needs to happen for hybrid systems to play this role. We distinguish between recommended actions for hybrid system manufacturers, energy providers and policy makers below.

1.Hybrid system manufacturers

- Further optimise hybrids and increase attractiveness for an even larger group of homeowners.
- Facilitate integration, interoperability, and smart grid readiness of hybrids.
- Support installers and users for optimised installation, commissioning and operation of hybrids.

2. Energy providers

- Accelerate roll out of smart meter technology and introduce dynamic tariffs to help hybrid systems respond to carbon and price signals to ensure hybrid systems' contribution fully supports renewable heating, the integration of renewable electricity generation, enables energy system integration and helps consumers monetize flexibility.
- Work with hybrid system manufacturers to develop bundled consumer offerings, lowering the hurdle to invest and install hybrid solutions.

3. Policy makers

- Recognise the societal, energy system and climate benefits of hybrid systems in the built environment and the role they can play in delivering the renovation wave goals and include them in calculation methods in policies targeting renewables in heating, energy efficiency and the energy performance of buildings.
- Promote hybrid systems in recovery packages and recognise that hybrids create a societal value by reducing the investments required for energy system upgrade and increasing system resilience.
- Promote the local and regional coordination of gas and electricity, to optimise system integration of distributed resources when adapting electricity and gas distribution grids, according to the evolution of local demand and renewable production.
- Establish hybrid systems as a dedicated product category in Ecodesign and energy labelling policies, still allowing the manufacturer a flexible combination of their components, to meet a broad range of customer requirements.
- Consider incentives for hybrid heating systems to overcome end customer hesitations and foster the market introduction process.
- Introduce EU-wide targets for the production and distribution of low-carbon gases
- Recognise renewable gas-ready hybrids as green technologies in the different national incentive schemes.

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Annex

Societal cost savings estimate

The estimation of cost savings from applying hybrid heat pumps is based on literature data and expert assumptions. No explicit modelling took place. Where figures on the EU level are not available, country specific values were extrapolated.

All underlying studies compare scenarios with a focus on renewable gas (respectively. balanced scenario) and hybrid heat pumps to scenarios with an all-electric focus. However, these scenarios do not focus on gas only or electricity only but assumed further heating systems (e.g. district heat) to a reasonable share. Except for the METIS study [17], all other studies foresee a role for district heating in their scenarios. The share ranges from 10%-20% (e.g. [15], [16]). The main difference in the scenarios is the future share of hybrid heating systems, heat pumps and gas boilers and the differences in cost assumptions (technology, energy, infrastructure).

Table 1 shows the ranges of societal cost savings in 2050 of renewable gas scenarios with hybrid heat pumps compared to scenarios with all-electric focus.

Table 1. Annual cost savings in 2050 per cost block for renewable gas scenarios with hybrid heat pumps compared to scenarios with all-electric focus (€ billion).

Societal cost savings	Min.	Max.
Heating technology costs	4.7	47.0
Insulation costs	0	21.0
Energy costs for heating	-7	
Infrastructure costs	9.5	17.0
Electricity production	-3.8	17.8
TOTAL	**3.4**	**102.8**

Note: Insulation costs as part of the societal costs:

- In general, the efficiency first principle should also be applied for a hybrid heating pathway compared to an all-electric pathway.
- We mainly see a pull forward effect where the fast installation of hybrid heat pumps can save CO_2 sooner compared with the situation of energetic retrofits (when they make sense in the lifecycle of buildings) and applying electric heat pumps only after these retrofits
- Partial renovations are often applied, which makes sense in the life cycle of buildings. Components should be replaced when their lifetime has come to an end (e.g. façade plaster or roof tiles). At this moment, energy renovations should occur to moderate additional costs. Uneconomical energy renovations outside this cycle should be avoided.
- However, there are situations where full energy renovations are economically not feasible (e.g. for heritage buildings or buildings with high efforts in constructive details etc.). Here a threshold could be determined (e.g. in €/m^2) – if the additional costs of energy renovation (in case of a renovation activity or a major renovation) would be above this threshold, then hybrid heating systems would be good option. In this case, energy renovation costs (insulation costs) could be saved in a hybrid heating pathway compared against the all-electric pathway.

Sources used

The societal cost savings for the different cost blocks were derived from studies and expert assumptions. Existing studies partly show substantial differences:

- Different scopes: Focus on a specific sector or on all sectors, country specific or EU level or on specific technologies
- Methodology for calculating costs (annual savings in 2050, accumulated costs over the time, additional costs or total costs)
- Broad range of different assumptions and parameters in the scenarios, e.g.
    - Target of scenario (e.g. full decarbonisation in 2050, etc.).
    - Development of different technologies in the future.
    - Future mix of renewables.
    - Cost assumptions.

Based on a larger literature scan three key studies and several additional studies for data points were filtered.

Key studies

- Gas for Climate(GfC) [16]: Compares optimised gas with minimal gas scenario, EU scope
- FNB [15]: Compares electricity and gas storage with electricity and green gas scenario, scope: Germany.
- METIS [17]: Compares all electric (heat pumps) with heat pumps and hybrid heat pumps (25%) scenario. This scenario does not reach climate targets and has thus less meaningfulness, however it focuses on hybrid heat pumps. Scope: EU level
- Other studies used are e.g. [12], [18], [8]

Methodology

In a first step, ranges for the cost savings per cost block were derived based on literature. Where data at the EU level was not available, country data was extrapolated (e.g. FNB [15]) based on distribution of floor area and final energy consumption in the building sector. Where cost savings were only available for all sectors, in a second step, the amount of savings that corresponded to the building sector were derived (in case of infrastructure cost savings and electricity production cost savings) based on expert guess. In a third step costs savings were validated based on expert guess and other available data points.

Savings

- **Infrastructure**

Infrastructure costs: savings from €9.5 – €17.1 billion.

According to literature the costs impacts for all sectors are €19 – €22.8 billion.

Minimum value [16]: The study has a strong focus on biomethane, including detailed costs for renewable methane infrastructure maintenance, gas infrastructure decommissioning, biomethane connection to gas grid, transport hydrogen in retrofitted gas infrastructure, electricity distribution and transmission infrastructure.

Maximum value [15]: The study has a strong focus on electrolysers, and thus a high saving potential for electricity peak demand in the heat sector. The high share of savings is due to the high investment in the reference case (high cost adaptation of distribution grid).

Only a share of the infrastructure cost savings that have been derived from literature has been allocated to the building sector. More than half of the savings have been allocated to the building sector (50-75%).

- **Heating technology**

Heating technology cost savings: €4.7 – €47 billion.

According to literature the costs impacts range from €0.9 [17] to €47 billion [16].

Minimum value [17]: The scenarios of the study are not in line with climate targets. The study compares a heat pump scenario (100%) with a mixed (heat pump and hybrid heat pump) scenario (70% / 30%). The study underestimates in our opinion the savings since the scenario is not sufficiently ambitious and does not reach climate targets. Additionally, the hybrid heat pump scenario has a future scenario with 25% hybrid heat pumps. In a hybrid heat pump scenario this could be more than double. Considering these two effects we estimate the data point the cost savings are 3-5 times higher than the study indicates.

Medium value [15]: The study indicates cost savings of about €30 billion. Driver is the heat pump: HP is implemented almost only in new construction in the electricity and green gas scenario (and gas boilers with renewable gas in the existing buildings) whereas in the electric scenario a high share of heat pumps is implemented. The high savings stem mainly from the difference between investment costs for heat pumps and gas boilers.

Maximum value [16]: the study indicates relatively high technology cost savings that are mainly driven by two aspects: First, hybrid heat pumps can deliver heat using the existing heat delivery systems, avoiding replacement of existing heat delivery systems. Second, the equipment is relatively low cost, because the expensive part of the heat pump capacity (at low temperatures) is replaced with low-cost gas boiler capacity. The optimal gas scenario applies hybrid heat pumps in 2050 in all buildings that currently have a gas connection (around 37%).

- **Insulation**

Insulation cost savings: €0 – €21 billion.

Minimum value: €0

Medium value: €12 billion. [18]

Maximum value [16]: €21 billion. The driver in the Gas for Climate study is the use of hybrid heat pumps (about 37%, i.e. all households that have a gas grind connection currently). These buildings require less insulation which to cost savings compared to the other scenario.

- **Energy costs for heating**

Additional energy costs for heating: €7 billion.

Energy costs for heating saving: Gas for Climate indicates not savings but additional costs of about €7 billion due to higher costs for heating energy in the building sector. The values are driven by biomethane and hydrogen demand.

- **Electricity production**

Electricity costs savings: - €3.8 billion – + € 17.8 billion in the building sector

According to literature the cost savings for all sectors range from -€15.2 billion (additional cost) to €54 billion (cost savings).

Highest additional electricity cost [15]: the study indicates additional costs for all sectors. This is driven by almost 100% synthetic hydrogen and therefore higher electricity costs [18].

Highest electricity cost savings [16]: this study indicates a high share of biogas and therefore has significantly lower electricity costs in all sectors.

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