Heat Pump Strategy Report

May 2022

WLPGA

LPG EXCEPTIONAL ENERGY

Navigation via links on letters

Report Overview

1. Heat pumps should not be used to decarbonise all homes		
Themes	**Description**	**Key pushback points**
(a) Heat pumps have a high upfront cost and limited cost down potential	Capex costs are much higher than traditional boilers (400-600%). Costs will fall, but we anticipate that reductions will be limited (25-45%).	Upfront will fall as mass-market is achieved. Policy instruments can reduce costs or smooth over time.
(b) Disruption because of installation, fabric/radiator upgrades etc	Installation times exceed those of a boiler, particularly when ancillary upgrades are included.	HPs can operate in almost all buildings, including many that would be considered to unsuited to their use. Not all buildings need upgrades, especially given high-temperature heat pump developments.
(c) Technical difficulties in certain homes (space constraints etc)	Some homes will not have the space for a hot water cylinder or external heat pump unit.	The industry is innovating to solve these challenges (see units placed on roofs in NL). All heating solutions suffer from constraints.
(d) Low installer base and high barriers to entry	Consumers interact directly with installers – they play an important role in the transition. Only 10% of installers in Germany and Poland are able to install a heat pump.	As heat pump market matures, more installers will retrain to install heat pumps due to reliable demand
(e) Adverse electricity grid impact & connection challenges	Some electricity grids will need to be invested in to accommodate EV and heat pump deployment. Fuse limits are also a constraint in certain properties.	Hybrid systems, smart metering and improved insulation may reduce need for grid reinforcements
(f) Consumer choice, and disruption in the way buildings are heated	Consumers often prefer the status quo. Disruption comes at a (non-market) cost – hassle factor.	

Navigation via links on letters

Report Overview

2. Where heat pumps are deployed, LPG can enable heat electrification		
Themes	**Description**	**Key pushback points**
(a) LPG is used as a refrigerant in heat pumps	R290 (propane) good especially for use in air-to-air HPs (big markets for these in USA and Asia), growing use too in air-to-water. Used in HTHPs too.	Requires very high purity for use as a refrigerant so bulk bought LPG may not be suitable
(b) Hybrid heat pumps (HHP) have good potential in many homes	Good potential where household does not want to upgrade heat emitters, and/or the property is relatively inefficient or large.	Default option for homeowners switching to hybrid systems will be a heat pump with a natural gas boiler, potentially changing to a hydrogen boiler in the future
(c) LPG can be used in gas-absorption heat pumps	LPG could be used as a fuel to drive a gas-absorption heat pump.	Very nascent market and little evidence of effectiveness domestically
(d) HHP: ability to support price arbitrage models – value of system flexibility	Flexibility and DSR is likely to become more valuable for the energy system as variable renewables replace very dispatchable fossil fuel generation. Fuel switching gives consumers potential price arbitrage benefit	Renewables may drive down cost of electricity in future leading to limited arbitrage potential
(d) LPG/rLPG boilers in HHPs provide consumers with a backup and energy security	Consumer’s value energy security – backup boilers can help provide this.	Lack of need for retrofit may lend itself better to a gas boiler in combination with a heat pump as opposed to a LPG/rLPG boiler hybrid

Executive Summary

The purpose of this report is to demonstrate that effective heating decarbonisation does not have a “one size fits all” solution and as such there are areas where LPG and rLPG can be used in combination with heat pumps or indeed instead of them. Policy around heating should avoid focusing solely on heat pumps and neglecting other technology by acknowledging that the end goal is to cut emissions and not choices.

For new build homes, it must be acknowledged that heat pumps are a very effective solution, however the housing stock across the world varies drastically by age, size, environment and many other characteristics. There are 40.7 million rural household in Europe alone where electrification is not always a viable option. Hence, a diverse set of technologies is the premier method of decarbonising heat accounting for the different needs of homeowners.

There is precedent for technologies across the spectrum to work in harmony, to deliver the most cost effective strategy towards home heating with each technology having its own equally important role. Whether this is through hybrid solutions, gas absorption heat pumps or standalone boilers, LPG and rLPG has the potential to play an important part here.

Key Data Points

- A 6-10kW heat pump has an average upfront cost of £9,000 and £14,300 for air source and ground source respectively. This makes air source heat pumps four times more expensive to install than an LPG boiler and ground source heat pumps 6 times more expensive (BEIS)
- Only 10% UK homes could meet peak winter demand at a flow temperature of 55ºC meaning 90% require fabric efficiency upgrades to efficiently use a HP(BEIS)
- Only 10% of installers in Germany and Poland are trained to install heat pumps (EHI)
- 14% survey respondents in Europe, noted that being familiar with their heating system was important for their choice of heating. This would deter them from installing a heat pump which they are unfamiliar with (Eurogas)
- To reach CCC projections of 5.7 million heat pumps by 2035, £40.7 billion would have to be spent on grid reinforcement resulting in £1,500 electricity bill per customer (CCC)
- HHPs can use backup LPG/rLPG boiler in times of peak heating demand. By reducing peak electrical demands, the need for grid reinforcement is limited, saving an estimated €6-7 billion per year in Germany alone (HHE)

1.(a) Heat pumps have a high upfront cost and limited cost down potential

Key message

- An electric heat pump typically costs 4-6 times the price of an LPG boiler to install (BEIS)
- Heat pumps are a mature technology (EC). Air-to-air systems are used commonly to provide heating and cooling / air conditioning
- For residential installations, cost savings can be delivered – particularly by streamlining the installation process. This is the approach taken by innovative energy companies in the UK. But industry does not expect to see very significant cost-down from the manufacturing of the systems

Comment and pushback points

- Important to highlight that heat pump installation costs will fall as volumes increase, owing to margins being squeezed across the value chain, optimisation of design / production process, and installation efficiencies. These reductions are unlikely to reduce costs towards current boiler prices
- Policymakers in many markets have established subsidy and grant schemes to tackle this challenge, however these are unlikely to be made available to all households, and often do not cover the total investment cost. Low-cost loans may enable greater uptake
- As upfront cost is such a barrier for heat pump uptake, a hybrid system – whereby a smaller heat pump is supported by an existing backup (bio)LPG boiler – could be an effective route to offer a consumer who prefers a heat pump solution, a heating system
- Arguably a quite high cost down potential if installation times decrease and equipment costs are decreased by improved supply chain efficiency

Research and sources

- Due to the specialist nature of installing heat pumps, the additional work required and the expensive equipment, the total installation costs for heat pumps are larger than that of an LPG boiler (Delta)
- A 6-10kW heat pump has an average upfront cost of £9,000 and £14,300 for air source and ground source respectively. This makes air source heat pumps 4 times more expensive to install than an LPG boiler and ground source heat pumps 6 times more expensive (BEIS). Additionally, the upfront cost is actually growing, increasing by over 15% since 2018 (Nesta)
- In Massachusetts, ASHP's have an upfront cost of $4,042 per tonne with a median capacity of 2.38 heating tonnes, meaning a median cost of $9,620 (MA DOER). In Europe, the annualised CAPEX of heat pumps is 4 times greater than that of a stand-alone gas boiler at 77,100 €/MWth /y (EC) . Furthermore, only 8 EU countries have an acceptable payback time of 8 years or less with the estimated cost of spreading this to all countries at €70 billion (EEB)
- 3 quarters of survey respondents indicated they would not pay the current price for a heat pumps and 56% said they would not install a heat pump even if they were priced the same as a gas boiler. Furthermore, these are low estimates as there were no real stakes in the experiment design (BI team)
- Many of the equipment components for heat pumps are already mass market and the heat pump market is relatively mature with 700,000 sold a year in Europe. Therefore, the equipment cost down potential is limited and so the most potential is from increasing competition in the installer market and improving supply chains (Delta)
- Even with the potential cost down of 28%, heat pumps remain 2.5 and 4.1 times more expensive than LPG boilers for air source and ground source respectively (Delta)

1.(a) Heat pumps have a high upfront cost and limited cost down potential

Key charts

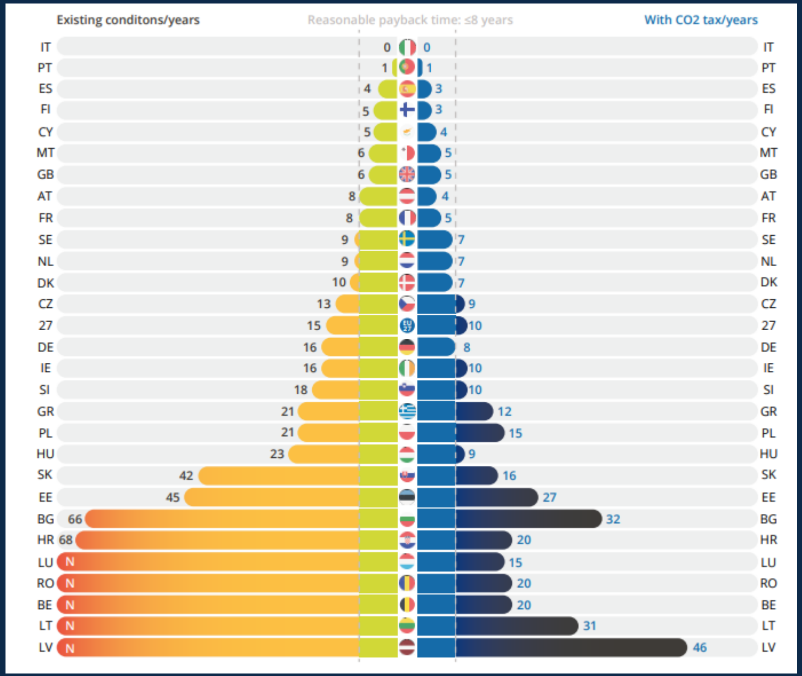


Figure 1. (a) (i) Reasonable payback time of heat pumps across the EU + UK with and without a CO2 tax (EEB)

Heat Pumps in most European countries exceed the reasonable payback time of 8 years

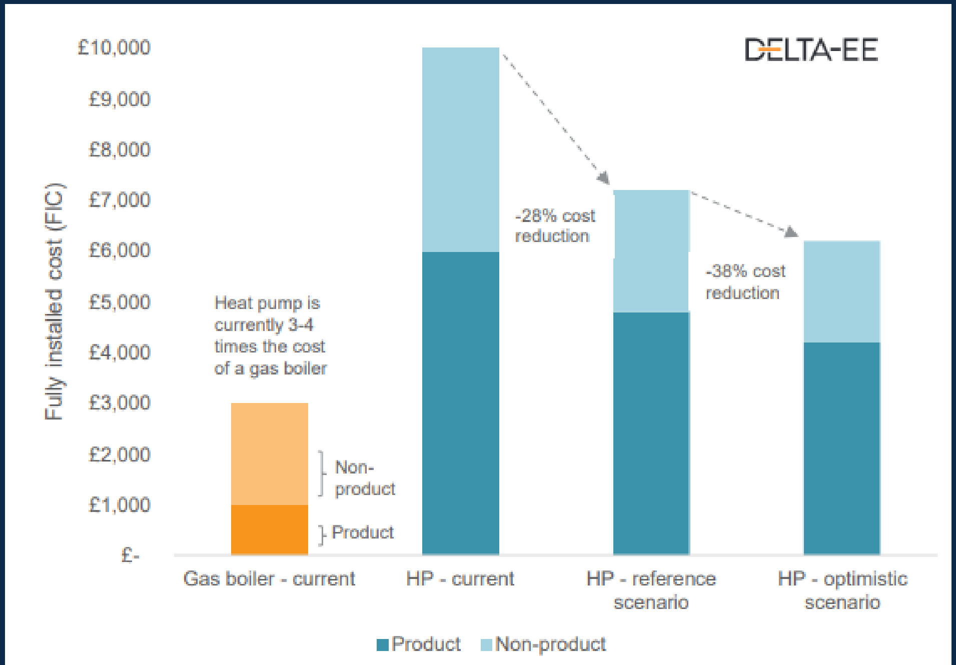


Figure 1. (a) (ii) Cost Down Potential for heat pumps (Delta)

Cost down potential of heat pump is insignificant when considering the current difference in price between them and conventional boilers

1.(a) Heat pumps have a high upfront cost and limited cost down potential

Key charts

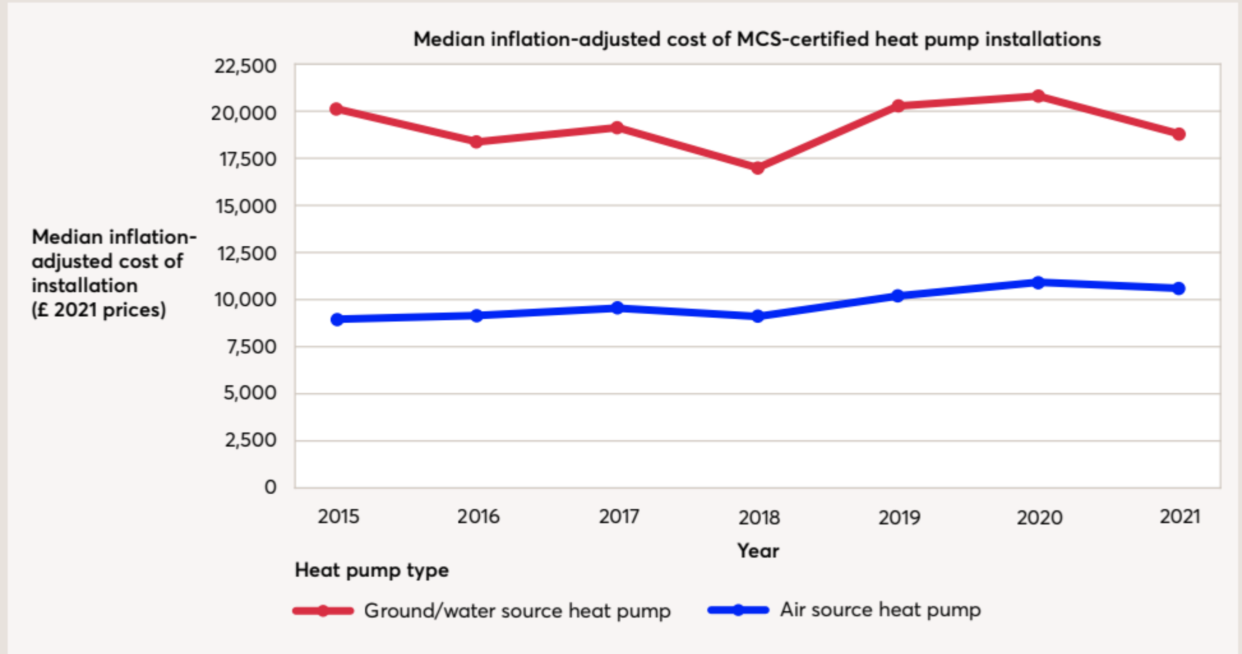


Figure 1. (a) (iii) Median Heat Pump Upfront Cost (Nesta)

Installation Costs for ASHPs are increasing rather than decreasing

1.(b) Disruption because of installation, fabric upgrades etc

Key message

- In most EU countries, half of the residential housing stock was built before 1970, i.e. before the first thermal regulations (EC). This is consistent across many advanced economies
- Particularly, for properties with poor thermal efficiency characteristics, upgrades will likely be needed in order to install a heat pump
- In the off grid-market, more homes are poorly insulated and large so greater disruption required for fabric upgrades

Comment and pushback points

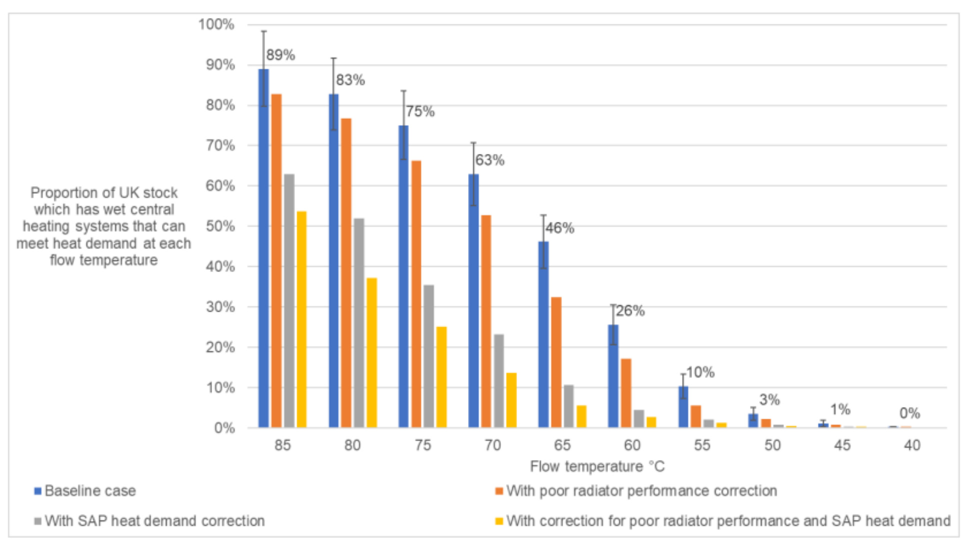
- High-temperature heat pumps can operate at higher flow temperatures, which reduces the need for ancillary upgrades. Currently this comes at the expense of higher running costs compared to conventional heat pumps although this is expected to change as HTHP efficiency improves
- Insulation improvements are a no-regrets GHG reducing solution
- Hybrid heating system could be used with the heat pump having an increasing share of the heating as the insulation improves over time

Research and sources

- Heating system changes are often “distress purchases” meaning the greater disruption associated with heat pumps can be a major influence on consumers choice of system (BEIS). Eight in ten people are unwilling to install a heat pump due to the high levels of disruption (BI team)
- Heat pumps not only have a longer installation time, taking four to ten times as long as a LPG or rLPG boiler, but there is additional time associated with the extra research required and sourcing an installer. Other potential home improvements such as fabric efficiency upgrades or the installation of a water cylinder may be required for heat pumps (LGUK)
- Heat pumps work by using electrical energy to move heat across a thermal gradient rather than generating heat itself. They work most efficiently at a low thermal gradient and as the outside temperature is determined by the weather, the important factor is the flow temperature of the HP. Hence fabric efficiency not only reduces the total heat demand but increases the efficiency of the heat pump (element)
- Only 10% UK homes could meet peak winter demand at a flow temperature of 55ºC meaning 90% require fabric efficiency upgrades to efficiently use a HP. These upgrades require additional time and retrofit costs of around £2,200 (BEIS). Additionally, homeowners can expect to pay £200-300 for each radiator that needs to be replaced (Western Power)
- The difference in requirements for home upgrades means there is large variation in the cost of installation, with 16% being more than £15,000 and 18% below £8,000 (Nesta)
- Having to undertake initial renovation work was the most common factor deterring consumers from installing an environmentally friendly heating system in a European survey (eurogas)
- Three quarters of the EU building stock is energy inefficient with 90% of this expected to be still in use by 2050, so homes will still require EE upgrades in the future (Hybrid Heating Europe)

1.(b) Disruption because of installation, fabric upgrades etc

Key charts



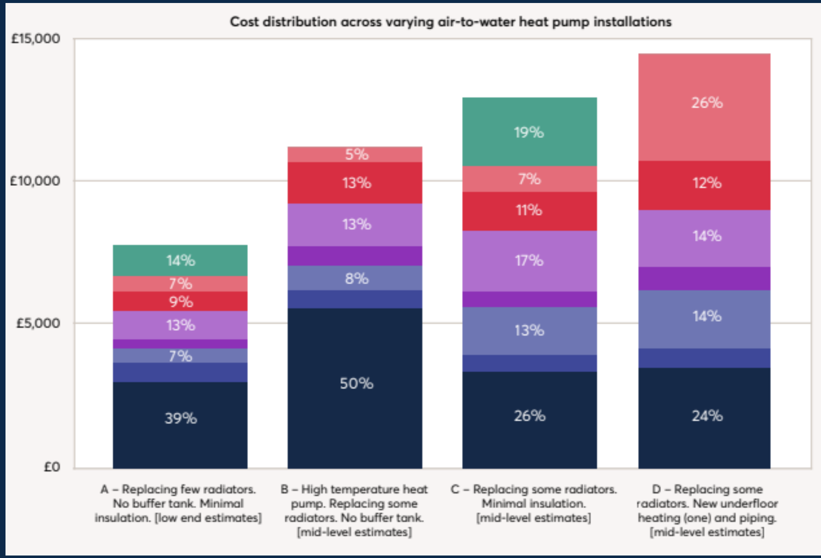


Figure 1. (b) (i) In order to operate at low flow temperatures, (55^0C and lower), 90% of wet central heating systems in UK homes will need to be upgraded (BEIS).

Almost all UK homes would require disruptive home improvement measures

Figure 1. (b) (ii) Cost distribution of heat pump installation across different housing archetypes (Nesta)

Difference in technical specifications of homes means disruption and cost has very large variability

1. (c) Technical difficulties installing heat pumps in certain homes (space constraints etc)

Key message

- Even if a home is financially suitable for a heat pump, there are additional technical constraints which can make them unsuitable
- In some cases additional installation measures are needed to accommodate for the size and noise associated with a heat pump
- A water cylinder and effective insulation are required to install a heat pump

Comment and pushback points

- Most homes already have a water cylinder especially those with wet heating systems (SEAI)
- Improvements in heat pump designs are helping to solve these issues – especially around noise and size (EHI)

Research and sources

- Heat pumps require large external and internal components. This is more so the case for ground source heat pumps which require some garden area for digging of the ground works (EHI). The pipework requires trenches 2-3m deep and spread over a large area. ASHP's also require a lot of space and must be mounted on a wall with good air flow and no foreign objects in the near vicinity (Western Power)
- Although most homes already have a water storage cylinder with their current heating system, those that do not will need to incur an additional €1,225 cost and may not have the space for the cylinder (SEAI)
- The reason good insulation is required is covered in 1b. Based on guidance from the UK MCS, homes with a peak heat loss greater than 100 W/m^2 floor area are technically unsuitable for a HP (SEAI)
- The noise can also be an issue especially in dense residential neighbourhoods, with the compressor generating noise within electrical heat pumps and the fan generating some sound in air-to-water heat pumps. This is usually solved via acoustic measures however this requires extra cost and space (EHI). An ASHP has noise of approximately 40-60 decibels from one metre away, similar to a vacuum cleaner (Western Power)
- For some homes that have been plumbed with microbore tubing, all the microbore piping must be removed at a cost of approximately £10k for a four bedroomed home (Western Power)
- Even some homes with heat pumps are not technically suitable, resulting in 28% heat pumps in UK homes having efficiencies lower than 2.5 SPF (RECC)

1. (c) Technical difficulties installing heat pumps in certain homes (space constraints etc)

Key charts

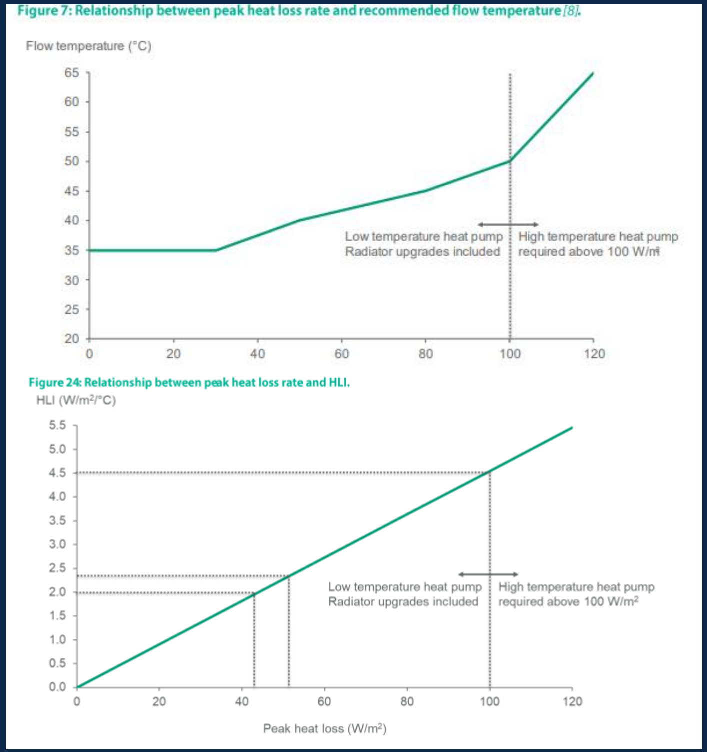


Figure 1. (c) (i) Relationship between peak heat loss and recommended flow temperature (SEAI).

Homes with high peak heat loss are unsuitable for low temperature heat pumps and may be better suited to LPG/rLPG boilers

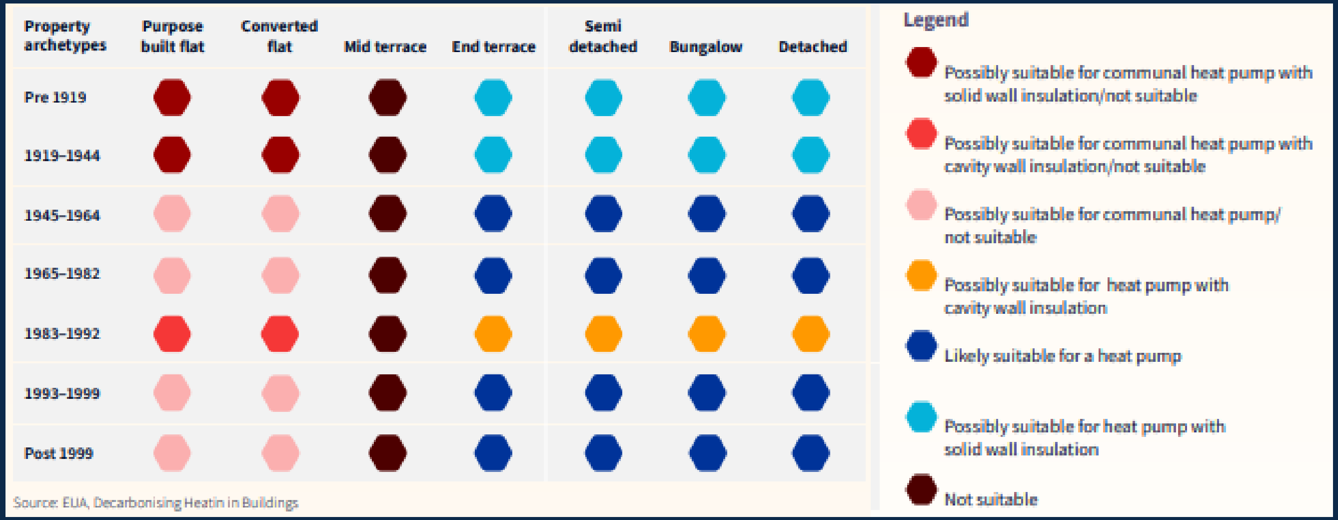


Figure 1. (c) (ii) Suitability of homes for heat pumps across archetypes (Guidehouse).

Many homes are unsuitable for heat pumps without major renovations

1.(d) Low installer base and high barriers to entry

Key message

- Not only will this make the deployment of heat pumps slow, the low competition in the installer market means installation costs are high and there is little incentive for efficiency and quality improvements.
- Sourcing a quality installer is difficult and often comes at great expense
- LPG/rLPG boilers work on more conventional heating technology so there is a far bigger pool of engineers to install them

Comment and pushback points

- As the demand for heat pumps grows and the market matures, more installers will be willing to retrain (SMF)
- France already has 25% of its installer base trained for heat pumps showing that when the demand is there, installers are willing to retrain (EHI).
- Some measures have already been taken to address this in many nations although they have been limited (RHITSS)

Research and sources

- The renewable energy directive in Europe, requires installers to have certain qualifications to install heat pumps. This training involves understanding the refrigerants and dimensions of a heat pump. Only 10% of installers in Germany and Poland are trained to install heat pumps (EHI)
- Of the 130,000 gas safe registered engineers in the UK, only 1,800 are trained to install heat pumps. With the UK government hoping to install 600,000 heat pumps every year by 2028, there is a clear divide between demand and supply of installers (SMF)
- The barriers to entry of the installer market are high. The cost of the course is ~£1,000 and takes 5 days (HPA) meaning self employed engineers miss out on regular income of ~£1,160. Additionally, certification and accreditation can mean additional costs of around £798 per year to install heat pumps (MCS)
- The main barrier to entry is a lack of sustained demand for heat pumps and uncertainty around the future of heating in government policy. Engineers are unwilling to take the financial hit of the course without confidence in the heat pump market and government net zero policy (SMF)
- The low competition and stagnant productivity growth in the installation market means the labour costs associated with installing a heat pump have increased by over 15% since 2015 (Nesta)
- There is also need for quality as well as quantity in the installer base. Currently this is not the case, reflected by many installations failing to meet benchmark efficiencies. Analysis of detailed Ofgem data on 2,000 installations showed an average ASHP SPF of 2.69 (RECC)
- With LPG/rLPG boilers being more simple and familiar pieces of equipment to install, there is already a large pool of well-skilled installers available

1. (d) Low installer base and high barriers to entry

Key charts

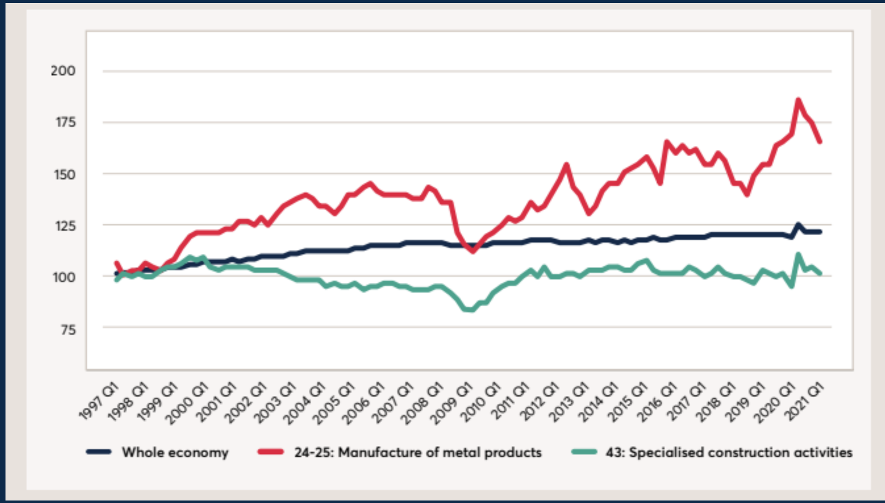


Figure 1. (d) (i) Demand for installers in Germany (EHI)
Installer base may need to double over next ten years to keep up with demand – this will be difficult to achieve

Figure 1. (d) (ii) Productivity growth in installation market (UK) (Nesta)
Stagnant productivity growth amongst installers is making disruption and cost around heat pump installations grow

1.(e) Adverse electricity grid impact & connection challenges

Key message

- The additional electricity demand from heat pumps and electric cars will mean electricity grids will need to be reinforced with this expense being passed onto the consumer. Additionally, local distribution network or connection upgrades can take several weeks and months to complete which is frustrating for consumers which may require heating in this period
- LPG/rLPG rely on existing infrastructure to distribute and so will not require grid reinforcement

Comment and pushback points

- Some of these grid challenges will be addressed via smart metering (Western Power)
- Need to reinforce grid will also decrease as homes become more insulated (Western Power)
- Use of hybrid heating systems could reduce peak heating demand significantly and reduce the need for grid reinforcement (2b and 2d)
- Distribution network investment will represent less than 4% of the cost per kWh of electricity in the UK (CCC)

Research and sources

- The conversion of heating systems from gas to electricity will cause an increase in the demand for electricity. Therefore, additional peak capacities will be required and infrastructure investments will be required so that the grid can distribute and handle this higher load (EC)
- Grid operators have already recognised that the electricity grid will need to be reinforced and this will come at a significant cost (EHI)
- These additional connection costs are estimated at £1,000 to £3,000 for an existing home (Western Power).
- To reach CCC projections of 5.7 million heat pumps by 2035, £40.7 billion would have to be spent on grid reinforcement resulting in £1,500 electricity bill per customer. Two thirds of this would be spent on underground network lines (CCC)
- Majority of network reinforcements will occur in semi-rural areas where LPG/rLPG boilers could have a comparative advantage (CCC)
- Homes with a single-phase supply usually have fuse limits varying between 30A and 100A. Many distribution networks will need to upgrade fuse limits to 100A which can take a couple of weeks causing disruption to the consumer (Scottish Government).

1.(e) Adverse electricity grid impact & connection challenges

Key charts

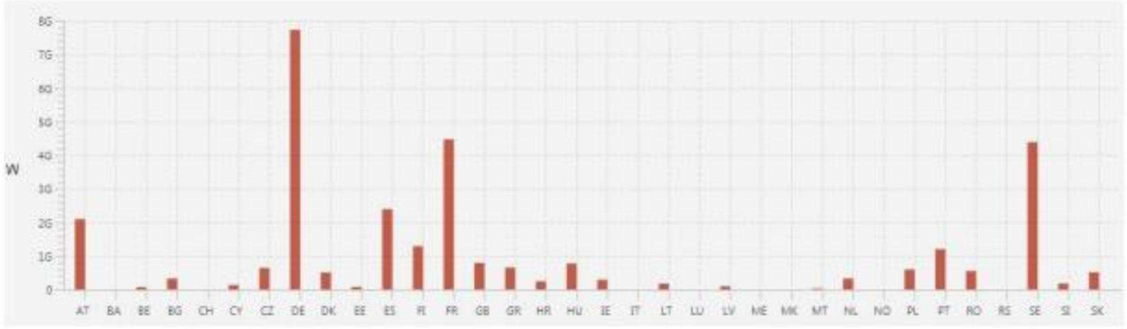


Figure 16 - Increase in power consumption peaks related to additional heat pumps in scenario REF16-2030 (by country, Option A vs 0)

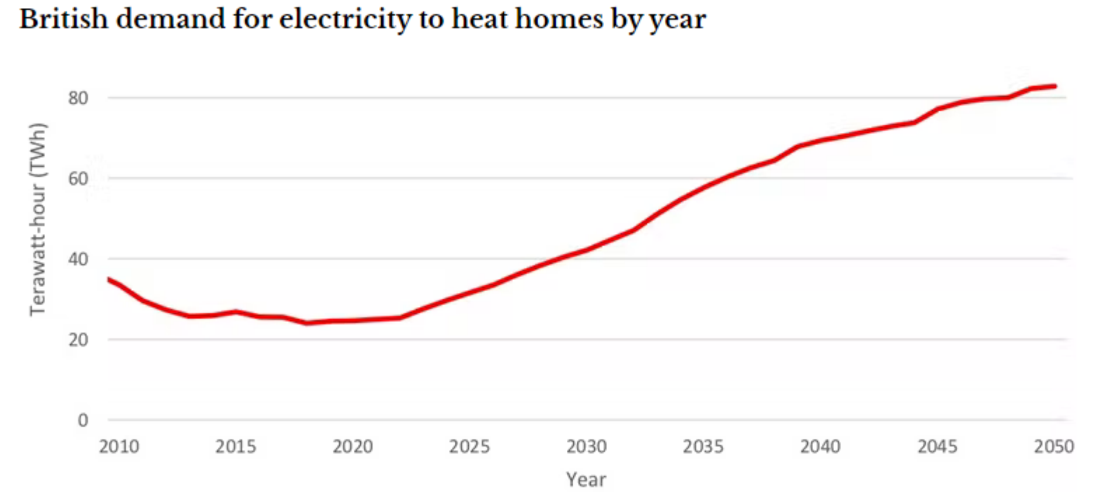


Figure 1. (e) (i) Additional demand across EU associated with heat pumps in reference scenario (EC)

Current grid will not be able to support additional demand generated due to electrification of heat especially during times of peak demands

Figure 1. (e) (ii) Projected increase in electrical demand for heating (The Conversation)

Electricity demand for heating will increase rapidly in the coming years as a result of heat pump deployment

1.(e) Adverse electricity grid impact & connection challenges

Key charts

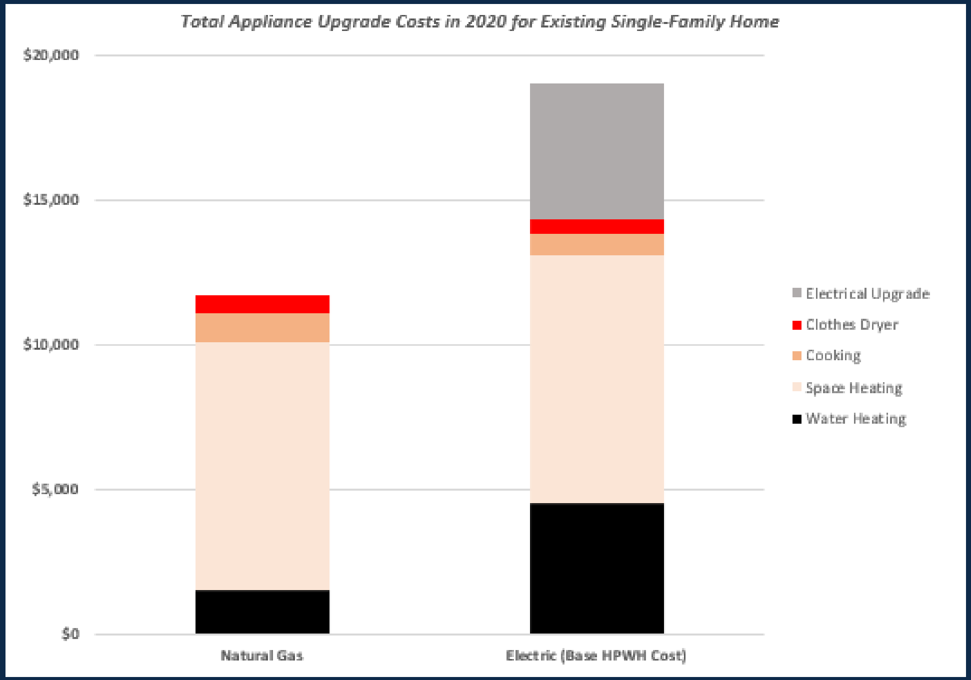


Figure 1. (e) (iii) Total Appliance Upgrade Costs for Existing Single Family Home (E3)

Electrical Upgrades means additional upfront cost to consumers installing heat pumps

1.(f) Consumer choice, and disruption in the way buildings are heated

Key message

- Consumers recognise a role for heat pumps but also have concerns regarding their installation and use – including noise, visual unsightliness and space requirements. When surveyed (see National Grid), consumers are keen hat the technology is installed in the right locations and the appropriate properties
- Research has demonstrated that many consumers take account of intangible disruption costs and *hassle factors* which consumers price into their decision regarding whether to switch heating system-type or not (Strachan & Li, 2019) (Scarpa & Willis, 2010)
- A LPG/rLPG boiler is a low-hassle option, which consumers should be free to choose

Comment and pushback points

- Some proponents and owners of heat pumps – particularly if they live in a well-insulated property – comment on the comfortable environment which can be achieved by a technology which operates consistently at a lower flow temperature (rather than a boiler which might operate at a high flow temperature for a limited period)
- Policymakers target key intervention points – for example when heating systems break-down, or when consumer's move home – to reduce the hassle and disruption associated with changing heating systems and changing the operation of the system
- Familiarity with heat pumps will likely grow as they are installed in more homes and get more media attention

Research and sources

- 14% survey respondents in Europe, noted that being familiar with their heating system was important for their choice of heating. This would deter them from installing a heat pump which they are unfamiliar with. Therefore only 21% felt changing their heating system was in their top 3 potential actions to tackle climate change (Eurogas)
- Nearly half (43%) of a cohort of consumers polled in the UK would not accept a heat pump in their home, citing practical considerations in terms of space requirements and suitability for older properties (National Grid). Consumers recognised that there is a role for heat pumps, but that the technology should be installed in the right location and property
- Consumers may also be adverse to the uncertainty around the cost of heat pumps and what price for their home should be. This uncertainty may also mean consumers are overcharged or suppliers price incorrectly (Nesta)
- If consumers opt for a smaller external unit they could be charged a 10-15% premium (Nesta)
- Researchers recognise that some consumers will be motivated by and accepting of novel technologies like heat pumps ("innovators"), whilst other consumers will have a preference for the status quo ("laggards") ((Strachan & Li, 2019). Consumers should be free to make their own decision based on their preferences and the degree of disruption caused by the property retrofit
- The switch to a LPG/rLPG boiler is far less disruptive so more likely to be accepted by consumers

1.(f) Consumer choice, and disruption in the way buildings are heated

Key charts

Importance of factors, by market
Showing of % top 3 most important factors when choosing a new system

In Luxembourg, 64% rank environmental friendliness as one of the top three important factors in choosing a new heating system.

	Average	France	Finland	Germany	Greece	Ireland	Italy	Latvia	Netherlands	Poland	Romania	Spain	United Kingdom
Cost of monthly bills	55%	50%	52%	52%	61%	59%	45%	63%	52%	55%	57%	51%	60%
Cost of installation	50%	51%	48%	40%	65%	57%	46%	54%	39%	56%	40%	49%	53%
Environmental friendliness	38%	42%	39%	49%	41%	37%	43%	29%	34%	40%	37%	39%	34%
Ease of use	30%	33%	41%	18%	24%	27%	31%	41%	29%	30%	32%	26%	32%
Ease of maintenance	30%	31%	27%	33%	25%	29%	32%	43%	21%	19%	36%	30%	28%
If subsidies are available	24%	15%	20%	26%	29%	28%	31%	13%	31%	28%	21%	28%	17%
Avoiding home renovations / building work	22%	18%	20%	20%	25%	20%	29%	19%	16%	25%	19%	33%	20%
Familiarity with the system	14%	14%	10%	13%	14%	13%	14%	14%	12%	16%	23%	10%	14%
What neighbours or family / friends have	5%	6%	4%	5%	8%	5%	3%	4%	6%	7%	6%	5%	5%

Q4. Imagine you were choosing a new heating system. Please rank the following options in terms of how important they would be to you in choosing a new system, the top being the most important to you. Base: France; Finland; Greece; Italy; Latvia; Netherlands; Poland; Romania; United Kingdom (n=1000 per country), Germany (n=1006), Spain (n=1002), Ireland (n=750), Luxembourg (n=101)

Figure 1. (f) (i) Survey responses for importance of factors influencing choice of heating system (Eurogas)

Many consumers find system familiarity as an important factor when choosing a new heating system

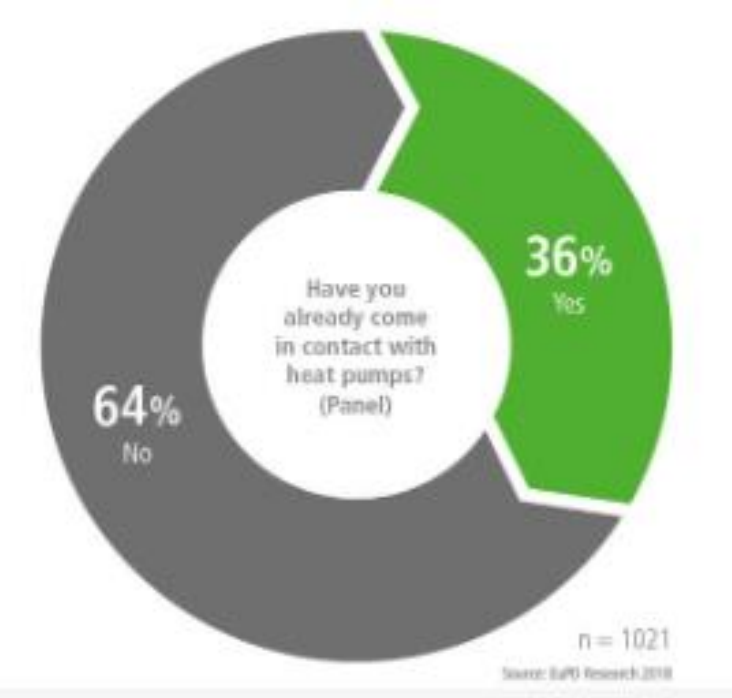


Figure 1. (f) (i) Heat pump contact rate across German Survey Respondents (E3DC)

Low consumer familiarity with heat pumps

Where heat pumps are deployed, LPG can enable heat electrification

2. (a) LPG is used as a refrigerant in heat pumps

Key message

- LPG has increasingly been used as a refrigerant within heat pumps
- Far lower global warming potential and greater performance compared to hydrofluorocarbon alternatives
- Where heat pumps are used, LPG and rLPG can help their deployment

Comment and pushback points

- Requires purity greater than 98.5% for use in refrigerant so bulk purchased LPG may not always be suitable (CIBSE)

Research and sources

- LPG is already used in fridges and freezers as a refrigerant, proving its benefits compared to alternative refrigerants (CIBSE)
- Using R290 (propane) as a refrigerant can result in 696 times lower global warming potential than the use of corresponding hydrofluorocarbon alternatives such as R410A and 225 times lower than using R32. Additionally using LPG as a refrigerant can allow for flow temperatures of 75 degrees Celsius meaning higher efficiency over the course of the year (Vaillant)
- Heat pumps using R290 as a refrigerant can achieve efficiencies as high as 5.03 SCOP. At the same time they are able to operate at a lower noise (46dB(A) from a metre away) compared to heat pumps with more conventional refrigerants, allowing them to be used in densely populated areas. Whereas conventional heat pumps have a noise similar to a vacuum cleaner, a heat pump using an LPG refrigerant has a noise similar to rainfall when stood a metre away from the unit (Vaillant)
- LPG refrigerants have a lower system pressure drop and higher heat transfer performance compared to HFCs and HCFCs meaning a 40-60% lower refrigeration charge. Additionally LPG is non toxic and has no ozone depletion potential (CIBSE)

2. (a) LPG is used as a refrigerant in heat pumps

Key charts

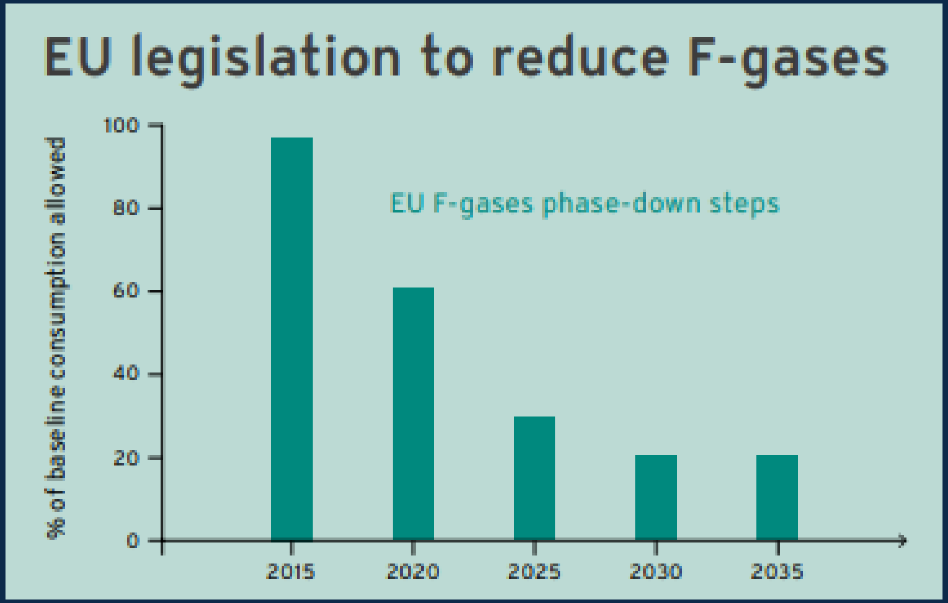


Figure 2. (a) (i) EU phase out of fluorinated gases (Vaillant)

Using LPG as opposed to a fluorinated refrigerant can help heat pump manufacturers meet EU legislation

Refrigerant	Propane (R290)	HCFC (R22)	HFC (R134a)
New equipment	Yes	Banned	Yes
Retrofit possibility	No	Banned	Yes
Ozone depletion potential (ODP)	0	0.055	0
Global warming potential (GWP)	3	1,810	1,370
Boiling point @ 1 bar	-42°C	-41°C	-26.6°C
Critical temperature	97°C	96°C	100.3°C
Critical pressure	43 bar	50 bar	40.6 bar
Molecular weight	0.0411kg/mol	0.08647kg/mol	0.1023kg/mol
ASHRAE safety group	A3	A1	A1
Flammability lower limit	2.1% by volume	Not applicable	Not applicable
Flammability upper limit	9.5% by volume	Not applicable	Not applicable
Compatible oils	Mineral oil, alkybenzene, polyolester	Mineral oil, alkybenzene,	Polyolester
Appearance	Colourless	Colourless	Colourless
Odour	Sweet	Slight ethery	Slight ethery

Figure 2. (a) (ii) Principal properties of propane, compared with a pair of alternative refrigerants historically used in chillers (CIBSE)

LPG is a viable and low carbon solution for equipment requiring refrigerants

2. (b) Hybrid heat pumps (HHP) have good potential in many homes

Key message

- Hybrid heat pumps can operate effectively in buildings which are inefficient and have a high heat loss rate
- Hybrids using LPG/rLPG are a flexible long-term solution especially for off grid homes as they are suitable in many homes and can increase the share of the heat provided by the heat pump component in the future

Comment and pushback points

- Default option for homeowners deciding to install hybrid systems will be gas boilers combined with a heat pump
- With an increasingly renewable grid, variation in electricity prices is expected to increase meaning savings from smart metering will only increase (HHE)

Research and sources

- In a HHP, the LPG/rLPG boiler can help meet peak heating demands such that a smaller heat pump component is required than for a standalone HP. Therefore, the upfront equipment cost can be up to £2,800 lower. Also the size and noise of the unit is limited compared to a standalone HP, meaning space and noise constraints are less of an issue (Guidehouse)
- Rolling out HHPs using LPG/rLPG will offer an accelerated route to net zero compared to standalone HPs as local networks will not need to be upgraded and homes won't require such strict insulation measures. Taking into account the lower fabric efficiency improvement requirements means the total upfront cost can be £30,000 lower than a standalone. The radiators and piping also do not need replacing and no hot water tank is needed as water is heated via the boiler. Therefore, disruption to the consumer is minimised (Guidehouse)
- Using LPG/rLPG in combination with a heat pump is preferable to a hydrogen boiler with a heat pump as it will not require replacements to the current gas pipe structure (Guidehouse)
- Almost ½ of homes are not suitable for standalone heat pumps, with this number being higher off grid, so HHP's offer a flexible alternative for these homes. They provide a viable solution for off grid homes of which for 44%, retrofit to install a heat pump would not be cost effective. A HHP offers lower running costs and upfront costs compared to other low carbon alternatives in the off grid market (Guidehouse)

2. (b) Hybrid heat pumps (HHP) have good potential in many homes, and can provide important system flexibility

Key charts

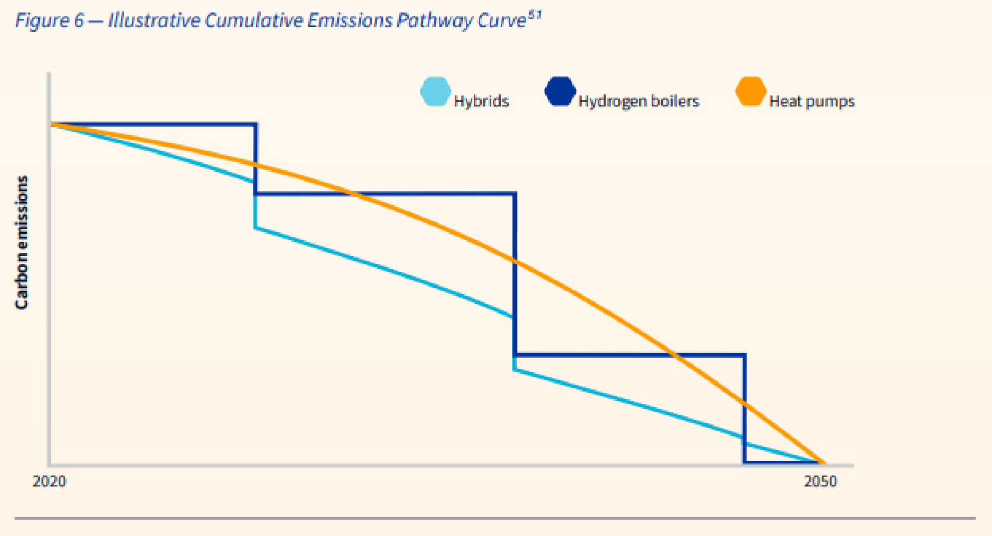


Figure 2. (b) (i) Cumulative emissions pathway of standalone HPs, hybrids and Hydrogen Boilers (HHE)

Hybrids can reduce emissions through smart metering compared to standalone HP/ boilers – although the graph shows Hydrogen boilers the same logic applies for LPG/rLPG boilers

2. (c) LPG can be used in gas-absorption heat pumps

Key message

- Using LPG/rLPG in a GAHP offers a low carbon heating system with greater consumer familiarity than an electric heat pump
- Despite the lower efficiency of GAHPs, the cost of fuel is lower compared to ASHPs and so running costs have the potential to be lower

Comment and pushback points

- This is a nascent market (especially domestically) and the upfront costs are currently higher than ASHPs (BEIS)
- Little published evidence as to the effectiveness of GAHPs domestically (BEIS)
- Although they require no internal unit, GAHPs require a very large external component (BEIS)
- As grid becomes increasingly renewable, ASHPs may have an advantage on GAHPs

Research and sources

- Despite having a lower efficiency (130% GUE) compared to a conventional heat pump, the lower price of LPG/rLPG compared to electricity makes the running costs of GAHPs lower. The high efficiency relative to conventional boilers combined with the low emissions factor associated with LPG/rLPG therefore makes GAHPs a viable and cost effective low carbon heating option (EM)
- GAHPs use a condensing heat generator combined with a premixed modulating gas burner allowing for minimal levels of nitrogen oxides (EM)
- GAHPs require only 1.09kW electrical supply for a 35kW unit so there is no requirement for increased electrical supply or grid reinforcements (EM). GAHPs are compatible with current infrastructure and consumers may be accepting due to familiarity with gas heating systems (BEIS)
- LPG/rLPG heat pumps do not require an internal component unlike a conventional heat pump so space constraints are less of an issue (EM)
- GAHPs can reach temperatures of 65 ˚C and so can be used with existing radiators . BEIS estimates the annual market at 100,000 to 210,000 units (BEIS)

2. (d) HHP: ability to support price arbitrage models – value of system flexibility

Key message

- Hybrids can minimise emissions and running costs by fuel switching to LPG/rLPG when grid carbon intensity and prices are high
- With an increasingly renewable grid, variation in electricity prices is expected to increase meaning savings from smart metering will only increase (HHE)
- Alternative heating method offers system flexibility as backup system can be used during times of peak electricity demand

Comment and pushback points

- Increasing use of renewables may drive down electricity costs meaning decreased potential for arbitrage

Research and sources

- A LPG/rLPG hybrid system offers long term flexibility and is a low regret option. As homes modernise and improve insulation, a HHP can remain viable to the future by switching more of the heating requirement to the HP component (Guidehouse)
- HHPs combined with smart metering, can also optimise the use of electricity and LPG/rLPG in tandem with grid carbon intensity and electricity prices to deliver the lowest possible running cost and carbon emissions (Guidehouse)
- In trials, LPG boilers working in combination with an ASHP, operated at around 20% of the time, with high overall system efficiencies delivering large cost savings despite temperatures as low as 6ºC (Freedom Project)
- HHPs can operate under extreme weather conditions and during intermittent electricity generation by fuel switching in times of system stress. This also offers a benefit to the system as a whole by reducing peak demand from the heating sector. This means overbuilding renewable supply can be avoided (Guidehouse)

2. (d) HHP: ability to support price arbitrage models – value of system flexibility

Key charts

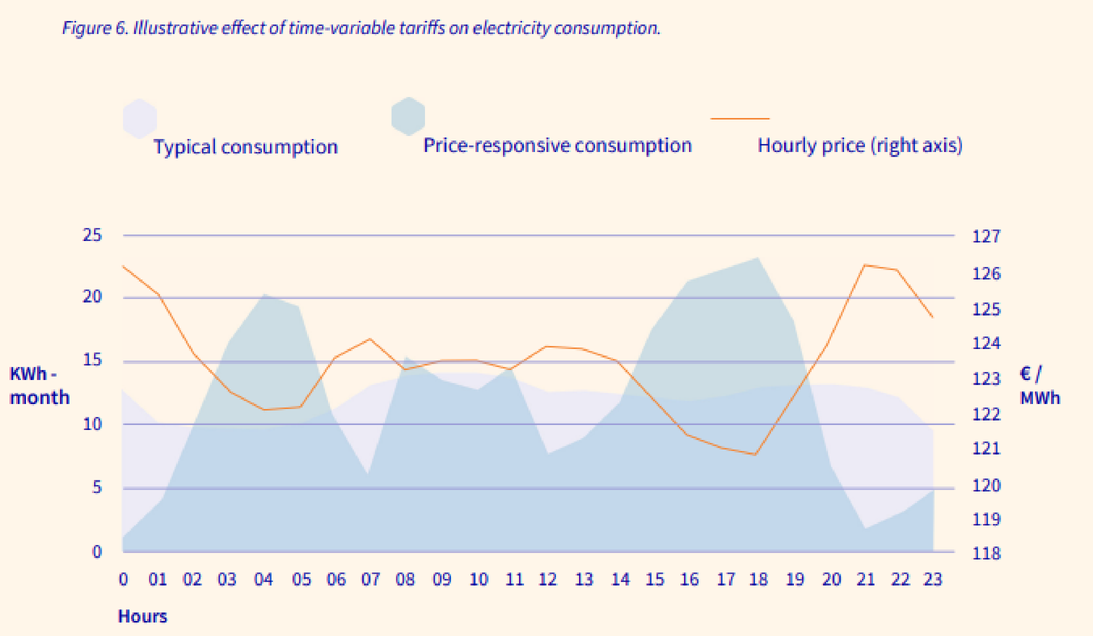


Figure 2. (b) (i) Effect of variable tariffs on electricity consumption (HHE)

HHPs can respond to price signals optimally to minimise running costs compared to sub optimal manner electricity is currently consumed

2. (e) rLPG boilers in HHPs provide consumers with a backup and energy security

Key message

- Having LPG/rLPG as a backup energy supply can deliver a reliant heating system despite intermittent production in an increasingly renewable grid
- For off grid homes, a LPG/rLPG hybrid heating system is the most efficient low carbon method of home heating whilst avoiding high cost energy efficiency measures
- Having a backup heating system run on domestically produced LPG/rLPG can deliver energy security, a factor which is increasingly important to consumers

Comment and pushback points

- The lack of need for retrofit lends itself better to a gas boiler hybrid heating option for on grid homes
- Electrical lines will be needed despite how people heat there homes so likely there will still be wildfires without any heat pumps at all. Additionally, wildfires more likely to happen when weather is warm and so backup LPG/rLPG boiler would not provide any heating support

Research and sources

- With an increasingly renewable grid, the need for backup heating is more pressing as renewable production is often intermittent and weather dependant. Therefore reducing peak electrical demands and having backup heating methods is a key move in avoiding blackouts and/or loss of heating (HHE)
- HHPs are a proven technology with a mature market shown by 32,000 installations delivered in 2019 across Italy, Germany, France, the Netherlands and the UK. They offer a quicker route to energy security than other options such as improved insulation measures with a low rate of energy renovation across Europe of 1% (HHE)
- Use of HHPs can help reduce peak winter electricity demand by up to 17GW according to National Grids Leading the Way Scenario (FES). By reducing peak demands, the need for grid reinforcement is limited, saving an estimated €6-7 billion per year in Germany alone (HHE)
- Smart metering in combination with hybrid heating systems can ensure energy security whilst reducing system energy costs by as much as £15 billion per year compared to full electrification. This makes hybrids the lowest cost route to home heating decarbonisation (Freedom Project)
- Increased electrification means greater reliance on power lines, which can cause wildfires in some climates. Wildfires have a history of massive cost to human life and the environment. PG&E power lines alone have caused 1,500 California wildfires in the past six years (Business Insider)
- Utilities providers are sometimes forced to shut off electrical supply in times of extreme weather conditions in case power lines are knocked over. Due to this, Californians have been told to expect blackouts for at least the next 10 years (NPR)

2. (e) LPG/rLPG boilers in HHPs provide consumers with a backup and energy security

Key charts

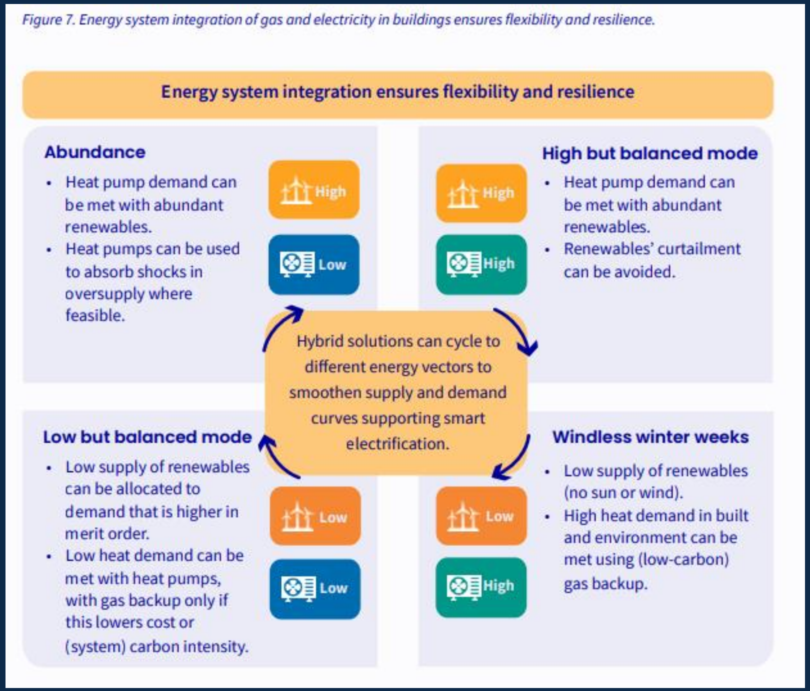


Figure 2. (e) (i) Demonstration of hybrid heating system in delivery energy resilience (HHE)

Switching fuel can absorb peak power supply in times of high renewable production to prevent curtailment and provide system security and resiliencee

Conclusions

- This report shows that there are many areas where LPG or rLPG can, and should, be used instead of heat pumps or to support their deployment
- Above all, this report argues for flexibility in heating solutions and an acknowledgment that the most effective decarbonisation route requires creating options not removing them

Annex

Glossary

- Flow Temperature – temperature of the water in the supply pipe of a heating system
- Gas Absorption Heat Pump – a heat pump driven not by electricity, but by a heat source such as natural gas, LPG or solar-heated water. Also commonly called gas-fired heat pumps
- Oversizing Factor – equal to the rated output divided by room heat loss. Greater oversizing factor tends to result In higher efficiency (see figure 3i)
- HLI – heat loss indicator – measure for determining suitability of homes for heat pumps. HLI shows the rate of heat loss per unit temperature difference between inside and outside the home
- Hybrid Heat Pump – a system which uses a heat pump alongside another heat source, usually a fossil fuel based system

Additional Graphs

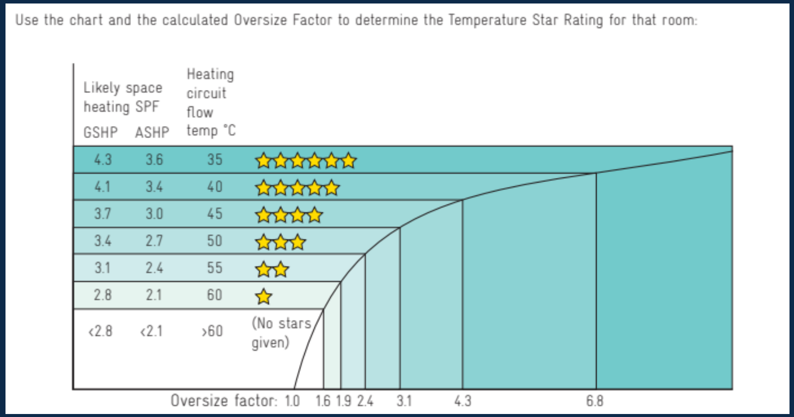


Figure 3. (i) Heat pumps operating at different oversizing factors([ZLC])

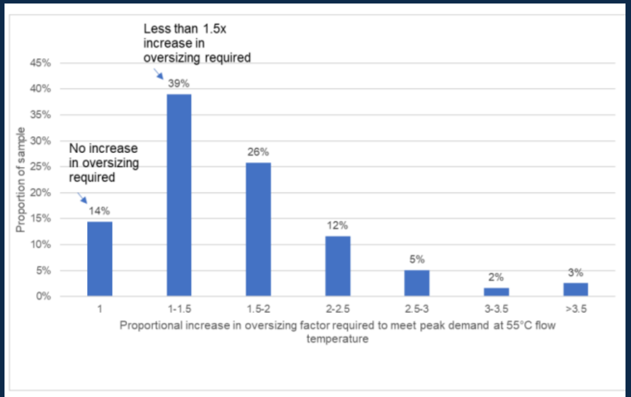


Figure 16 - The proportional increase in oversizing factor required to meet heat demand (kW) across the sample at 55°C.

Figure 3. (ii) Proportion increase in oversizing factor to meet peak heat demand at flow temperature of 55ºC ([BEIS]).

Most homes require an increase in oversizing to meet peak heating demand

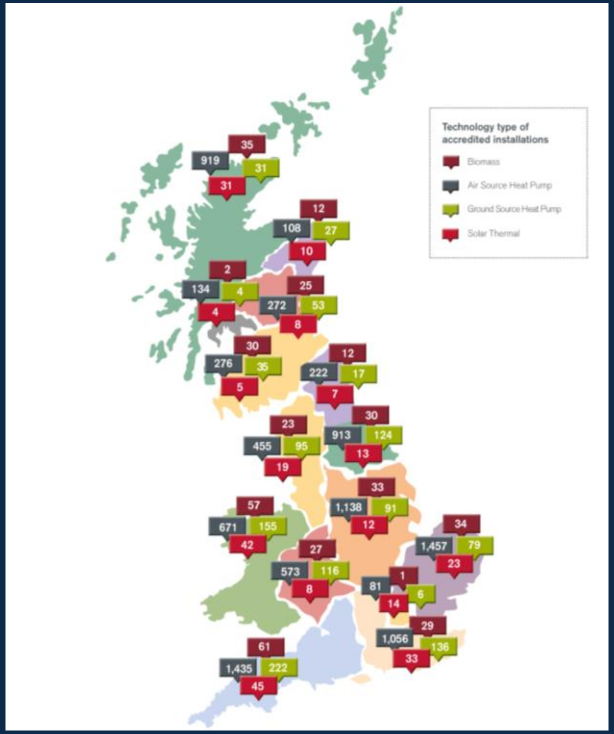


Figure 3. (iii) RHI deployment across regions UK – 2020-2021 ([OFGEM])

Technical difficulties such as large size and noise means deployment is lower in densely populated areas such as London