Hybrid Heating Great Britain

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Hybrid heating systems can help the UK achieve its net zero target

The challenge

The building sector is responsible for **17%** of the UK's GHG emissions.

The energy efficiency of the UK's building stock is poor and requires large-scale upgrades.

Almost **½** of UK properties are not suitable for standalone heat pumps due to their thermal properties and other limitations.

Climate benefits

Hybrid systems can effectively decarbonise UK buildings well ahead of 2050:

- **Rapid Decarbonisation**
- **Long Term Solution**
- **Decarbonising Off-Gas-Grid Heating**

Consumer benefits

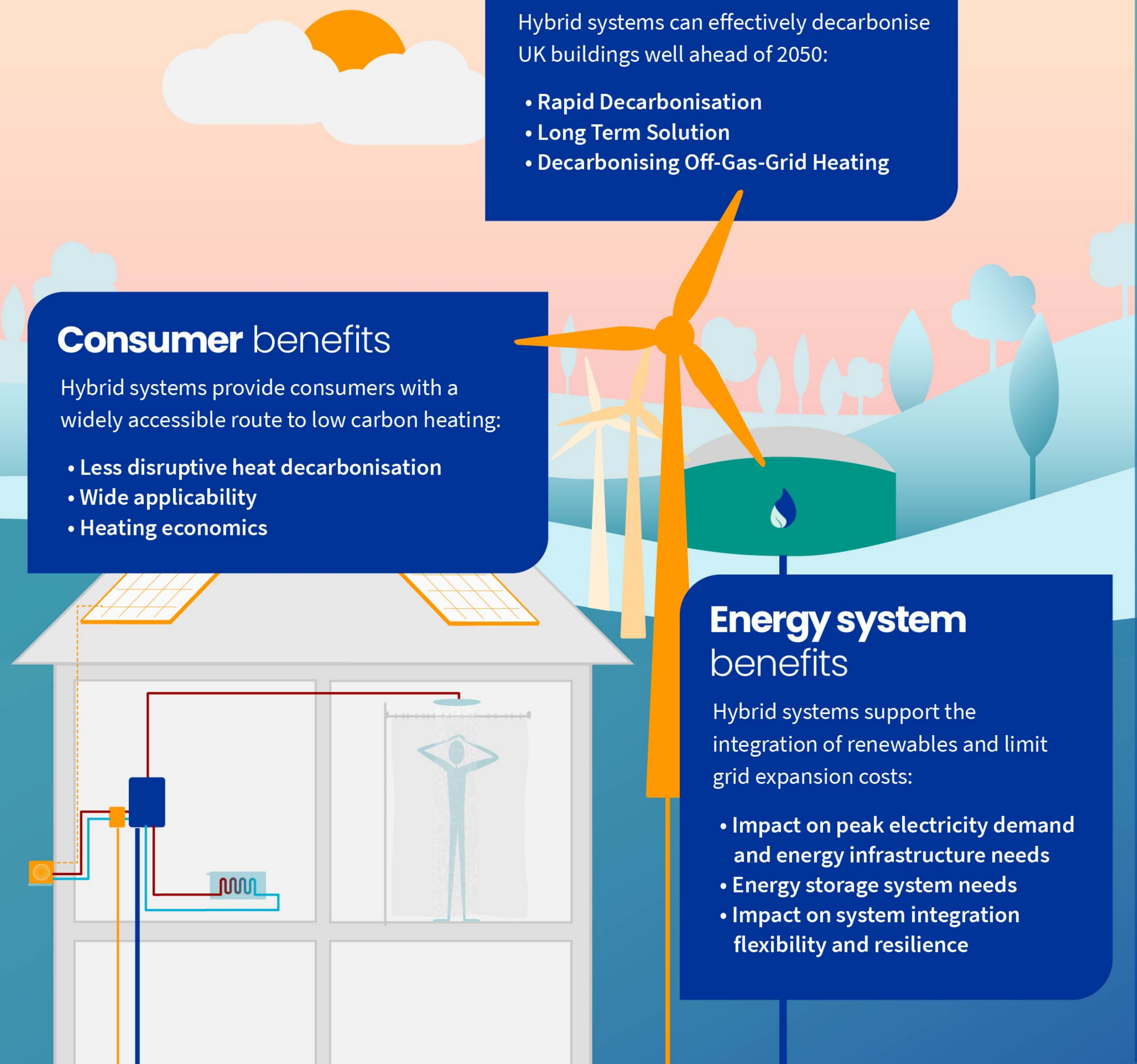
Hybrid systems provide consumers with a widely accessible route to low carbon heating:

- **Less disruptive heat decarbonisation**
- **Wide applicability**
- **Heating economics**

Energy system benefits

Hybrid systems support the integration of renewables and limit grid expansion costs:

- **Impact on peak electricity demand and energy infrastructure needs**
- **Energy storage system needs**
- **Impact on system integration flexibility and resilience**



Action needed

Policymakers

- **Recognise** immediate and long-term benefits of hybrid systems.
- **Set up** large-scale national trialing of hybrid systems.
- **Include** hybrid systems in low-carbon heating incentives and grants.
- **Introduce** targets and incentives for low-carbon gas.

Energy suppliers and network operators

- **Accelerate** the roll-out of smart meters.
- **Develop** flexibility markets that engage domestic users.

Equipment manufacturers

- **Further** improve applicability of hybrid systems across the housing stock.
- **Develop** an industry standard for hybrid system servicing and repair.

Objective

The Hybrid Heating Great Britain coalition is a diverse group of energy networks, energy suppliers, and equipment manufacturers committed to the rapid decarbonisation of the building sector in Great Britain. The objective of this vision and action paper is to outline the group's thinking on the role that hybrid heating systems (HHSs) should play in the decarbonisation of heating in buildings and to bring insight and evidence on their importance in meeting the Government's interim and longterm net zero targets.

The UK Government's Heat and Buildings' strategy acknowledges the role that HHSs will play in the short term for decarbonising heat, and the clear synergy between hybrid heat pumps and the use of sustainable biofuels which are 100% bio-derived or which can demonstrate a clear trajectory to removing all fossil fuel content, with potential application to many off grid homes. This paper provides further data and insights into the benefits of HHSs for the consumer, the energy system and the climate. These benefits demonstrate the important role that HHS can play as an attractive solution throughout the pathway to Net Zero.

Our Vision for Hybrid Heating Systems in Great Britain

HHSs provide a robust pathway from fossil fuels to zero carbon heating in the UK. These systems:

- Enable accelerated carbon emission reduction from home heating without having to wait for the building stock and local electricity network to be upgraded or hydrogen or biomethane supply to increase;
- Involve very low levels of disruption to homes and minimal behaviour change for householders on and off the gas grid;
- Are an effective low carbon solution for many homes that do not have a hot water cylinder;
- Provide future-proofing as they can continue in service without fossil fuel by using hydrogen, biomethane, or bio-LPG;
- Guarantee the lowest heating bills through optimisation of electricity and gas/oil costs, including dynamic pricing;
- Deliver a whole system carbon backstop by utilising background controls to minimise carbon emissions between the use of gas /oil and flexible generation;
- Offer a low regret option for consumers, allowing future flexibility of policy and technology while making the best use of existing infrastructure;
- Benefit the wider UK energy system by enabling a secure and diverse mix of energy sources, cost-effective peak energy supply, and valuable energy storage on a daily, weekly, and seasonal basis;
- Complement heat pumps and other renewable options for domestic heating and provide an additional tool for decarbonising heat across the building stock.

1. Introduction

Policy context

The UK Government has set the goal for the UK to become carbon neutral by 2050. In 2019, direct greenhouse gas (GHG) emissions from buildings amounted to 87 Mt CO_2e - 17% of total UK GHG emissions.[1] Of these emissions, 77% is attributable to homes, 14% to commercial buildings, and 9% to the public sector.

In the heating sector, the trend over the past 30 years has been for declining emissions, with CO_2 emissions decreasing by 17%. This percentage is relatively low compared with the electricity sector where emissions have dropped by 41%[2] in the same period. A reduction in building emissions five times greater than what has been achieved is required to meet the 2050 goal.

The Climate Change Committee (CCC) recognises building heating presents one of the greatest challenges to achieving deep emissions reductions by 2050.[3] The CCC highlights three key activities for reducing emissions:

- Changing behaviour, which reduces energy consumption
- Increasing energy efficiency of buildings
- Fuel switching away from fossil fuels to low carbon alternatives

Heating equipment lifetimes of 15 years mean that significant changes are needed by the early 2030s to achieve the 2050 net zero target. This need leads to the CCC's recommendation for a hybrid first approach, pursuing low regret actions now alongside deployment of hybrid heat pumps in on-gas grid properties.

The CCC recommendations form a key independent input to the policy action undertaken by the Government. To date, UK Government policy has been outlined in two key documents from the Department for Business, Energy & Industrial Strategy (BEIS):

Energy white paper: Powering our net zero future states that "delivering our net zero target means largely eliminating emissions from domestic and commercial buildings by 2050" and commits to supporting the transformation of heating for homes and workplaces away from fossil fuels to clean energy sources. Ninety percent of homes in England currently use fossil fuels for heating, cooking, and hot water.[4]

In **The ten point plan for a green industrial revolution**, point 7 delineates Government aspirations to put homes, workplaces, schools, and hospitals at the heart of the green economic recovery.[5] The Future Homes Standard will be implemented quickly so that new buildings are highly energy efficient and use low carbon heating. The UK Government aims to achieve 600,000 HP installations by 2028 and will bring forward regulations to support this goal, especially in off-gas-grid properties. The plan also sets out ambitions for trialling full hydrogen heating in multiple scenarios.

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[1] Climate Change Committee, *The Sixth Carbon Budget*, December 2020.

[2] Energy and Climate Intelligence Unit, UK Energy and Emissions, https://eciu.net/analysis/briefings/uk-energy-policies-and-prices/uk-energy-and-emissions

[3] Climate Change Committee, *Hydrogen in a low-carbon economy*, November 2018.

[4] Department for Business, *Energy & Industrial Strategy, Energy white paper: Powering our net zero future*, Chapter 4: Buildings, December 2020.

[5] Department for Business, Energy & Industrial Strategy, *The ten point plan for a green industrial revolution*, November 2020.

The UK Government has committed to tackling emissions of buildings and acknowledges that doing so will take many years. Therefore, building decarbonisation must start now.

"The 2020s must be a decade of action to put the country on the path to net zero emissions by 2050."[6]

Importantly for HHSs, the choice as to whether the UK will ultimately pursue hydrogen heating, an electrified heating system, or a mixture of both remains open and the UK Government will continue to pilot the options.

Additional relevant UK Government policy initiatives include:

- **Heat and Buildings Strategy**
- **Hydrogen Strategy**
- BEIS consultation on regulation to phase out fossil fuels in homes off the gas grid
- **Sustainable Warmth Strategy** (for fuel-poor households) including the Warm Home Discount extension
- **Review of the Gas Act** (especially the consultation on whether it is appropriate to end gas grid connections to new homes).

A range of Government schemes are focused on heat decarbonisation, including:

- **Green Homes Grant:** A grant for homeowners or residential landlords towards the cost of installing energy efficient improvements to homes. The grant stopped receiving applications in March 2021. The grant covers up to twothirds of the cost of chosen improvements, with a maximum Government contribution of £5,000. The grant covers low carbon heating measures, including HPs and HHSs.
- **Renewable Heat Incentive (RHI):** People who join the scheme and adhere to its rules receive quarterly payments for 7 years for the estimated amount of clean, green renewable heat produced by their heating system. The scheme was due to end in March 2021 but has been extended by the Government for a year. The RHI also includes biomethane installations.
- **Clean Heat Grant:** The successor to the domestic RHI, the Clean Heat Grant gives £4000 towards the costs of installing an HP. The grant is still being designed and the Government did a consultation ending in March 2021. Disappointingly, HHSs are not expected be included.
- **Public Sector Decarbonisation Scheme:** Provides grants for public sector bodies to fund heat decarbonisation and energy efficiency measures. Phase 2 of the scheme provides £75 million of grant funding for the financial year 2021 to 2022. It supports the public sector in taking a whole building approach when decarbonising their estates.
- **Homes Upgrade Grant (off gas grid):** Supports deep renovation measures for low income households living in highly inefficient homes.
- **Social Housing Decarbonisation Fund:** This fund is not yet in use. A demonstrator launched in July 2020 will support social landlords to demonstrate innovative approaches to retrofitting social housing at scale.
- **Green gas support scheme:** A proposed scheme to increase the proportion of green gas in the grid through support for biomethane injection. A consultation ran earlier in 2021 and has now closed.

The UK's first Hydrogen Strategy was recently published and outlines how hydrogen could be used as part of a decarbonised renewable energy system. The strategy sets out the requirements for production, distribution, storage and use of hydrogen and emphasises the role of hydrogen in the UK. The importance of decarbonising heat in buildings is discussed, in-

[6] Department for Business, Energy & Industrial Strategy, *Energy white paper: Powering our net zero future*, Chapter 4: Buildings, December 2020.

cluding the need to transition urgently and cost-effectively.

The Heat and Buildings Strategy, which was recently published, sets out the UK Government's plan for transitioning to low-carbon buildings and acknowledges that hybrids could play a transitional role in the 2020s and 2030s. However, the strategy contains no targets for HHS installations or manufacture. It stated there was a clear synergy between hybrid heat pumps and the use of sustainable biofuels which are 100% bio-derived or which can demonstrate a clear trajectory to removing all fossil fuel content, with potential application to many off grid homes.

The UK building sector

There are an estimated 28 million domestic buildings in the UK.[7] The condition of the building stock is poor; two-thirds of buildings have energy efficiency ratings (via energy performance certificates) of D or lower.

Of the domestic properties, several archetypes can be identified: terraced, semi-detached, detached, bungalow, converted flat, purposebuilt low rise flat, and purpose-built high rise flat. In 2018, most homes in England (63%) were owner occupied, 20% were privately rented, and 7% and 10% were owned by local authorities and housing associations, respectively.[8] In Wales and Northern Ireland, the picture is similar, whereas Scotland has a significantly higher proportion in social housing (38%).[9]

The energy efficiency of the building stock is linked to the age of buildings. Given the relatively old age of the UK building stock, energy efficiency levels are low compared with similar countries in Europe.

Building decarbonization

The challenge of decarbonising heat and buildings in the UK requires two major actions:

- Improving the energy efficiency of the building stock;
- Installing new, low carbon heating technologies.

Improving building stock efficiency will not only reduce energy requirements but also open the door for alternative, low temperature heating technologies. Both require clear customer action and a level of personal engagement and investment in their properties. Creating an integrated policy and plan of action to enable this engagement in the required timeframe will require bold decisions that are oriented towards customer benefits.

Given the scale and cost of required interventions in the building stock, there is a real threat that the Government targets will be missed. Furthermore, there is a need for solutions that reduce emissions as soon as possible in order to fit within carbon budgets.

Key future low carbon heating solutions considered in the UK are currently all-electric HPs (air-sourced and ground-sourced) and boilers using green gases: hydrogen, biomethane, or a blend of both. These solutions would replace the traditional gas boiler and plug into existing heating systems. A third option is an HHS, which combines both an HP and a gas- or oil-fuelled boiler.

Hybrid Heat Systems

A Hybrid Heat System (HHS) is a unit that uses a small HP combined with a boiler to provide hot water and central heating to a building. The HP element can generate heat with a very low (or

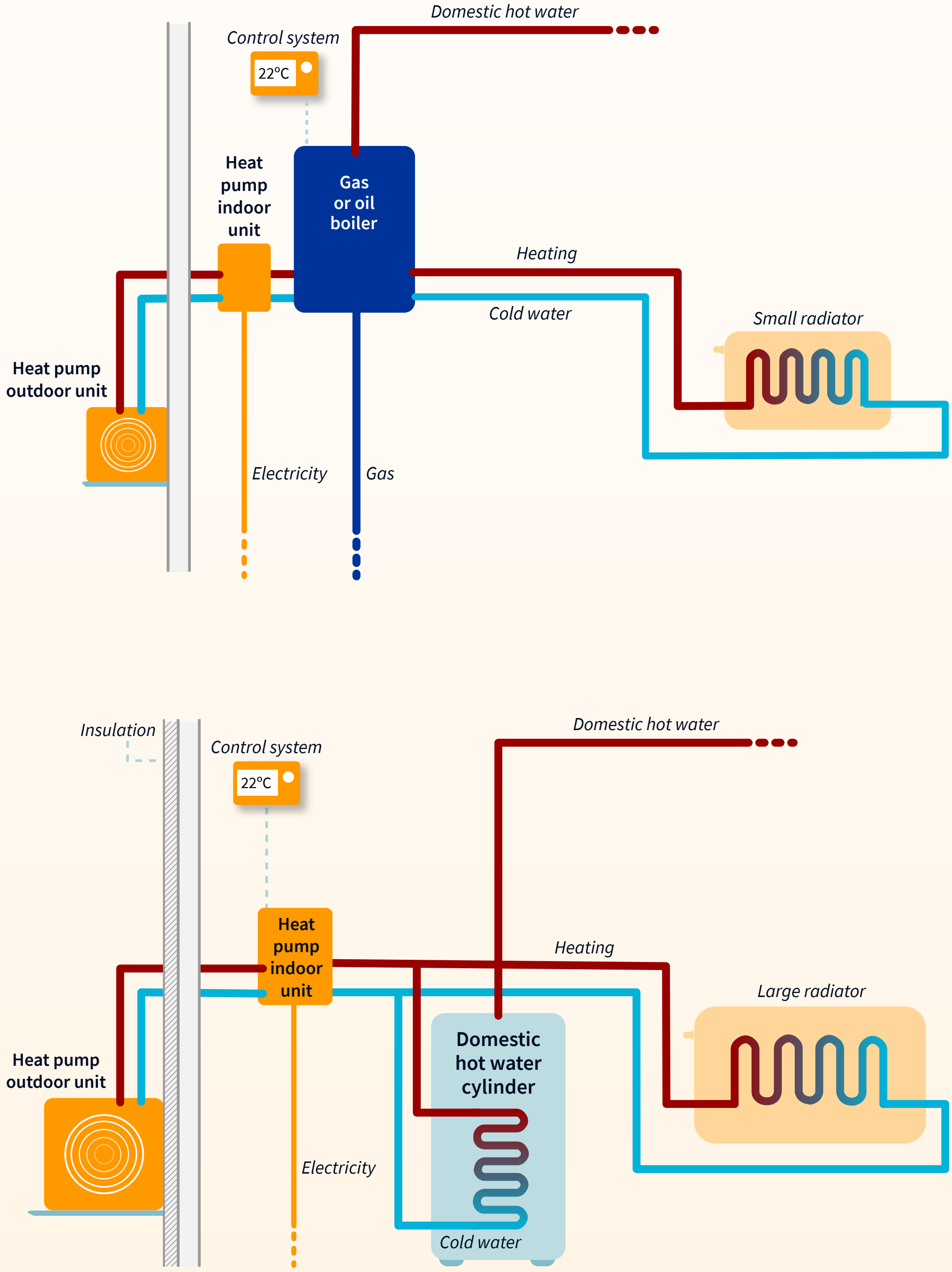
[7] BRE Trust, *The Housing Stock of the United Kingdom*, February 2020.

[8] Ministry of Housing, Communities, & Local Government, *English Housing Survey*, July 2021.

[9] Scottish Household Survey Team, *Scottish House Condition Survey: 2019 Key Findings*, December 2020.

zero) carbon intensity when the electricity that it uses is low carbon. At times of high demand from very cold weather or when renewable electricity isn't available, where the HP cannot meet demand or to supply heat with lower total system carbon/higher total system efficiency, an HHS uses the boiler element to supply heat. The effect is low carbon heat while not compromising comfort. Currently, the boiler element of an HHS runs on natural gas, LPG, or oil, but in the future, it is envisaged that the boiler will run on low carbon gas supplies such as biomethane or hydrogen, or the oil can be fully replaced by low carbon Hydrotreated Vegetable Oil (HVO).

Figure 1 — Comparison of a Hybrid Heating System (above) and an All-electric Heat Pump (below)



2. The Benefits of Hybrid Heat Systems in Great Britain

HHSs provide a robust pathway from fossil fuels to low carbon heating in the UK, with benefits for consumers, energy systems, and the climate.

Consumer benefits

Low disruption heat decarbonisation

HHS installation is much less disruptive and costly than that of all-electric HPs. HPs provide water at a lower temperature than boilers, typically 45°C-55°C compared with 75°C. To provide the same amount of heat, HPs require larger radiators and larger piping throughout the property. For most buildings in the UK that do not meet very high energy efficiency standards, accommodating an all-electric HP would require significant intervention. This process would normally include removing the old radiators, replacing the pipes within walls and under floors, and installing larger radiators. Installing underfloor heating is also an option for increasing the emitter area, which is equally disruptive. In addition, the building may need to undergo a deep retrofit consisting of solid or cavity wall insulation and floor insulation to achieve a reduction in the heat energy demand.[10] In trials, some consumers have found installing HP systems in their homes to be disruptive[11] due to particular technical barriers, such as not having enough space for the outdoor HP unit, high fabric upgrade costs, and noise pollution from the HP.

Hybrid systems alleviate disruption by removing the need for increased emitter area and working with the pipework insitu (including microbore). Although the HP element can supply most of the heating demand throughout the year, the boiler can be used to meet peak demand on the coldest winter days. This setup enables an HHS to meet the useful energy demand of the building while using conventional radiators and piping and thereby minimising the amount of retrofit required. At the same time, HHSs offer the same levels of comfort and ease that consumers expect from their heating supply. Consumers who have switched away from gas boilers have generally been satisfied with the ease of use, reliability, and thermal comfort provided by HPs,[12] and hybrid solutions will only improve comfort for the consumer. Consumer comfort can be maintained regardless of electricity system constraints and capacity limits.[13]

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[10] Guidehouse, *Gas Decarbonisation Pathways 2020–2050,* Gas For Climate 2020.

[11] Department for Business, Energy & Industrial Strategy, *Electrification of Heat Demonstration Project,* June 2020.

[12] Department for Business, Energy & Industrial Strategy, *Electrification of Heat Demonstration Project*, June 2020.

[13] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

Experience suggests that HHSs can be installed far quicker than all-electric Hps, especially where deep retrofit of the property is not required. Evidence from trials indicates that customers have been pleased with the installation process of their HHSs.

Applicability

HHSs can be rolled out across a much larger portion of the UK's building stock compared with all-electric HP systems. Almost half of the buildings in the UK are currently unsuitable for all-electric HPs without significant building upgrades, primarily because of their thermal properties, space requirements and other limitations. For instance, only 10% of UK dwellings could meet heat demand with a low flow temperature (55°C) as would be supplied by a standalone HP.[15]

To accommodate an all-electric HP, many buildings across the housing stock would need to undergo a deep retrofit (e.g., solid or cavity wall insulation and floor insulation) as opposed to a moderate retrofit (e.g., high performance glazing and loft insulation), which would be required in the case of low efficiency buildings installing HHSs.[16] The recently published Heat and Buildings Strategy outlines plans for installation of heat pumps but no concrete support for building retrofit. This lack of energy efficiency incentives will hinder the rollout of all electric HPs and slow down the decarbonisation of the building stock. HHSs therefore complement all-electric HPs as a solution and increase the proportion of the housing stock which can be decarbonised easily and cost effectively. They have already been successfully deployed across a broad range of building types without making changes to the building insulation or the existing wet heating system.[17] They are genuinely applicable across the different types of housing stock, offering a practical solution for homes that are not highly energy efficient. Air source HPs will play an important role in heat decarbonisation in many properties and HHS will enable broader applicability across building archetypes.

Practical and space considerations place limits on the application of all-electric HPs in some situations, including a lack of external space or other spatial constraints. As the capacity of the HP in an HHS is lower compared with an all-electric HP, the outdoor unit of the HP is smaller, making it viable for a greater number of households.

The first commercially available compact HHS does not require any outdoor space, making it particularly attractive for listed properties or those with no outdoor space.[18] Another consideration is that standalone HPs require the addition of a hot water tank to provide hot water on demand. With combination boilers accounting for more than 80% of boiler sales in the UK, many properties no longer have space for hot water tanks, and the need to add one makes the proposed installation of an all-electric system more challenging. HHSs alleviate this constraint due to their ability to provide instant hot water from the boiler. [19]

[14] Energy & Utilities Alliance, *Decarbonising heat in buildings: Putting consumers first*, April 2021.

[15] Department for Business, Energy & Industrial Strategy: Heat Distribution Systems Evidence Gathering

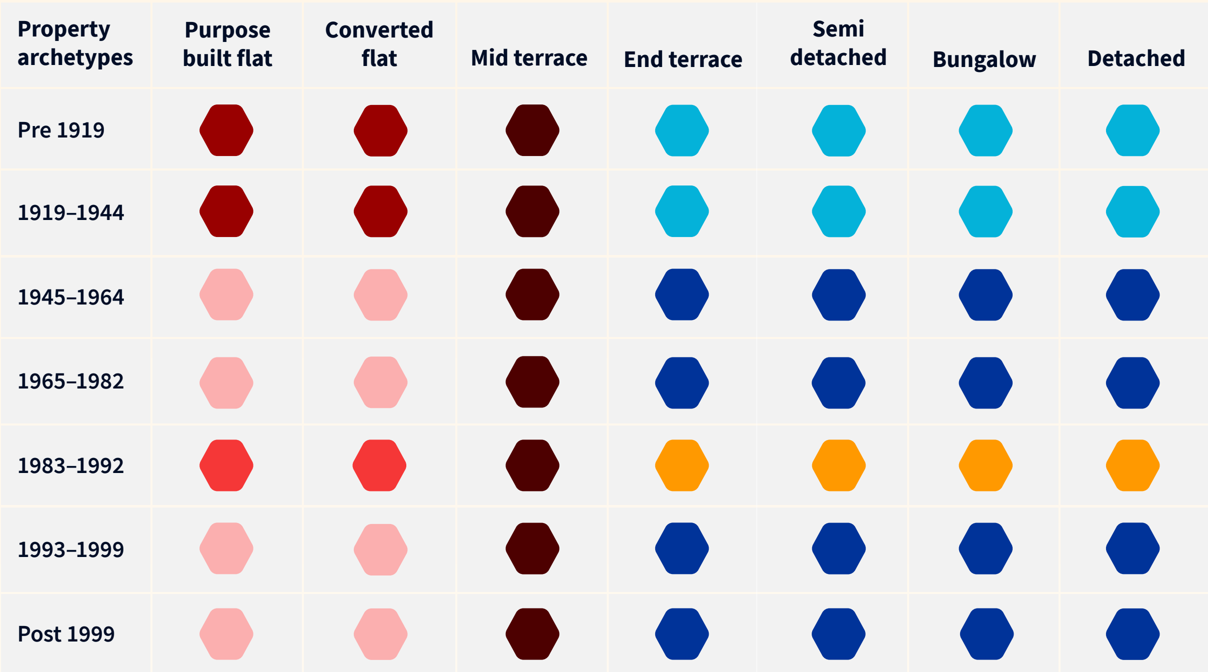
[16] Guidehouse, *Gas Decarbonisation Pathways 2020–2050*, Gas for Climate, 2020.

[17] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[18] Energy & Utilities Alliance, *Decarbonising heat in buildings: Putting consumers first*, April 2021.

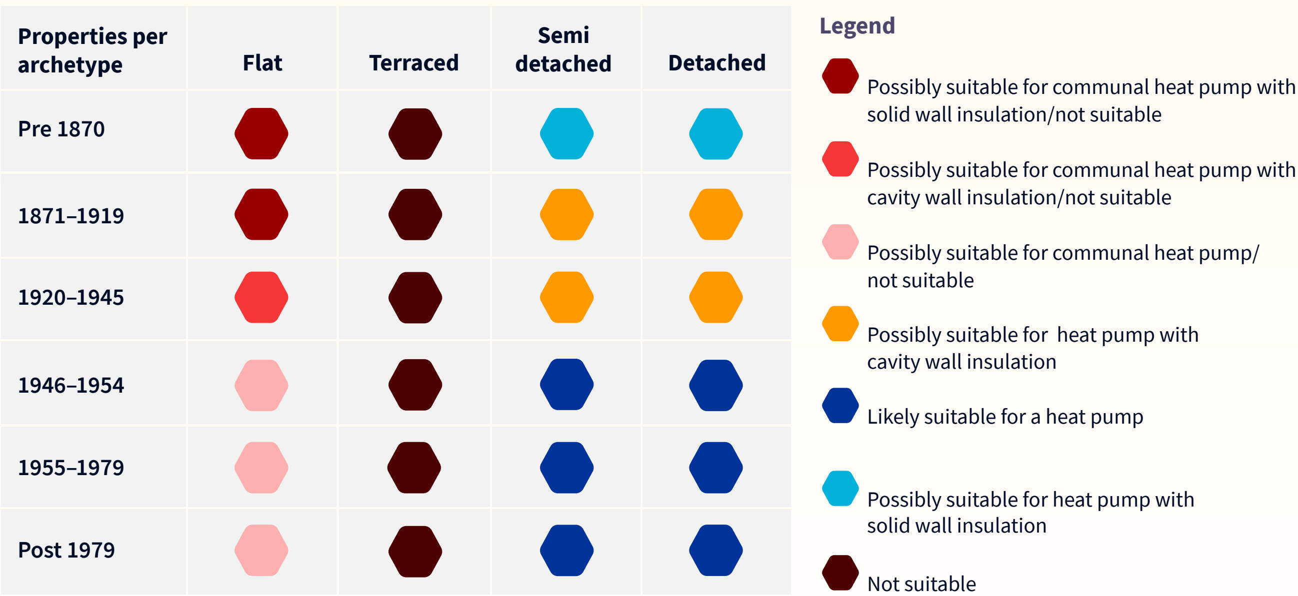
[19] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

Figure 2 — Overall suitability of properties in England and Wales to a heat pump



Source: EUA, Decarbonising Heatin in Buildings

Figure 3 — Overall suitability of properties in Scotland to a heat pump



Source: EUA, Decarbonising Heating in Buildings

Reliability of heating supply is important for consumers, particularly in more extreme weather conditions or when fuel supply is less reliable. HHSs can operate at extreme temperatures and provide the consumer comfort required. HPs in hybrids operate more efficiently than HP-only systems as they aren't being forced to work as hard and have demonstrated operation with a good coefficient of performance even when operating at -6°C when paired with a boiler.[20] This capability demonstrates that HHSs can switch a large portion of operation to the HP and deliver high efficiency despite the smaller HP size. HHSs also provide the capability to switch between fuels, which can provide higher resilience for meeting heating needs during times of system stress and create opportunities to optimise operating costs.

Heating economics

The cost of decarbonisation is a significant concern for consumers looking to decarbonise their homes.[21,22]

Upfront Costs

Hybrid systems have a lower appliance capital cost than all-electric HPs. The upfront equipment costs are lower for HHS compared with HP by as much as £2,800. Even more significant are the cost savings that result from eliminating the requirement to perform a deep retrofit of the house. The combined cost savings from equipment and renovation can be as high as £30,000.

HHSs and standalone HPs both have £5,000-£7,500 higher upfront costs than a gas boiler. However, for a typical semi-detached house, HHSs offer upfront equipment cost savings of £450-£2,800 compared with a standalone HP.[23] This amount represents savings of 25% on the initial costs. The upfront investment for HHSs can be smaller than that of a standalone HP because the HP in a hybrid solution is typically smaller, as it is not sized to meet total peak demand. Additionally, there is no need to replace existing radiators and no need for a hot water tank because water can be heated using the boiler.

As previously mentioned, HHS installations remove a major financial barrier for HP adoption in many situations as no immediate building upgrades are needed. Most UK properties already have gas boilers, so the only incremental cost is associated with the addition of a small HP and a control system. Standalone HP solutions require replacement of the pipework and emitters (radiators), as well as typically needing significant building renovation to improve thermal properties of the building. These costs can be extremely high and are a significant barrier for many households. For example, external or internal wall insulation can cost £8,600 or £7,300, respectively, for a semi-detached home.[24] The cost of a deep retrofit in a typical UK home including wall and underfloor insulation[25] is estimated to be 85% more than the costs for moderate insulation, and the overall cost of converting a house from gas boiler to HP heating could be in the range £23,000-30,000.[26] These costs make HHS a pragmatic solution for households for which building renovation could be a barrier to changing the heating system.

[20] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[21] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[22] Calor, *Off-Gas-Grid Decarbonisation Survey*, November 2020.

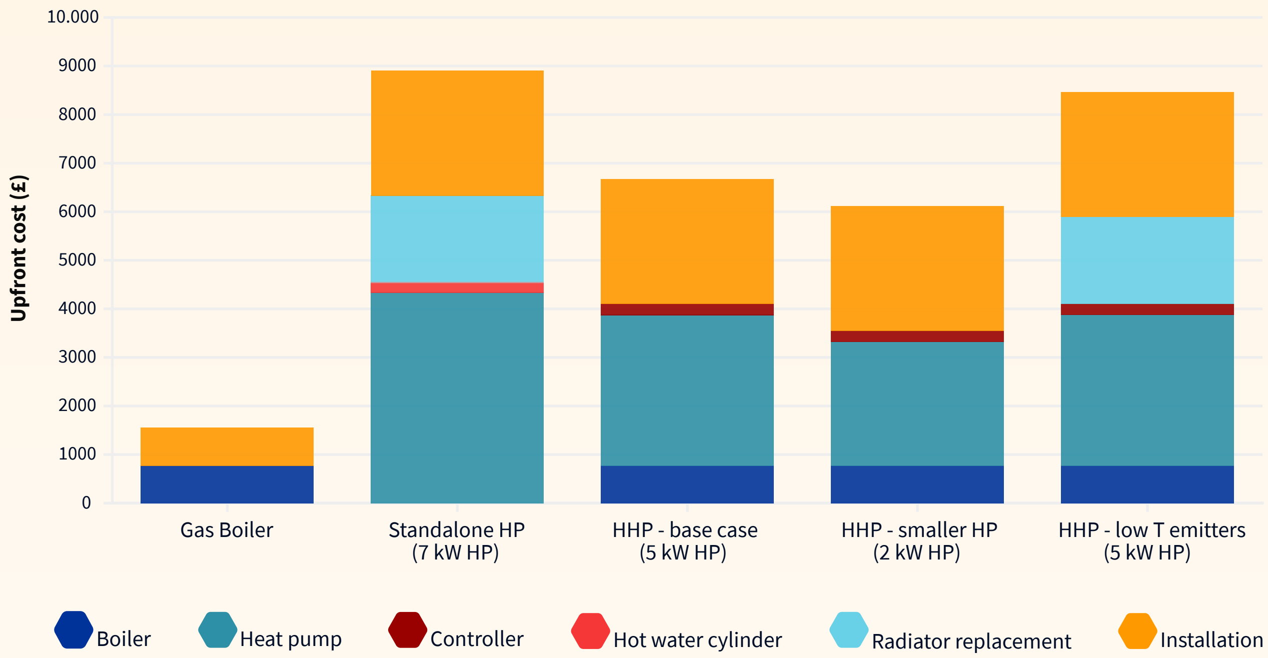
[23] Department for Business, *Energy & Industrial Strategy, Hybrid Heat Pumps*, December 2017.

[24] Climate Change Committee, *The Sixth Carbon Budget: Methodology Report*, December 2020.

[25] Ipsos and Navigant, *Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU*, November 2019.

[26] Matt Lipson, *3 Steps to Low Carbon Heating*, Energy Systems Catapult, October 2019

Figure 4 — Comparison of heating equipment costs[27]



Source: Department for Business, Energy and Industrial Strategy. Hybrids Heat Pumps Final Report. December 2017

Operating Costs

Once installed, HHS operating costs are lower compared with current gas boiler use because the system reduces the amount of gas consumed as the control system optimises for when it is best to use gas vs electricity. Trials have shown that the amount of natural gas declined by greater than 50% in most properties.[28] Cost optimisation makes sure that the use of an HP doesn't exceed the cost of providing heat with the boiler. Typical use of HPs to keep temperatures comfortable at times other than cold winter days means that HPs may operate for 70%-80% of the time within a hybrid system. Smartly coordinated low carbon technologies, including HHSs[29] deliver potential annual savings greater than £200 per household. This value includes electricity cost savings and revenues from TSO and DSO services. The energy bill is also reduced by the HP's high operating time and the possibility to make smart use of price signals. Data from trials[30] indicates that 94% of HHS installations would pay themselves back within the required payback period by the savings that they provide.[31] Future operating costs will depend on the relative retail price level of gas and electricity. A group of energy suppliers have called for an energy bill reform to improve the relative economics of HPs.

[27] Department for Business, Energy & Industrial Strategy, *Hybrid Heat Pumps*, December 2017.
[28] WOON BEDRIJF - INNOVATIEF 390. Dutch Trial
[29] PassivSystems with Western Power Distribution, MADE project.
[30] WOON BEDRIJF - INNOVATIEF 390. Dutch Trial
[31] WOON BEDRIJF - INNOVATIEF 390. Dutch Trial

Off-Gas-Grid Properties

HHSs are a particularly attractive solution for off-gas-grid properties, which tend to be older and less energy efficient than the national average. Of homes that currently use heating oil, 44% would not be cost-effective to carry out a retrofit (to allow the use of an HP) or for direct electrification. Of the 56% that would be cost-effective to electrify, the high upfront costs could be unaffordable for many. Furthermore, many off-gas-grid homes have space and technical constraints that may prevent these installations.[32] The need to provide the required comfort and necessary electrical power are barriers facing all-electric heating in off-gas-grid homes.[33] HHSs are an effective and achievable way for off-gas-grid homes to reach low carbon heating and reduce spending on energy; when HHSs have been installed by off-gas-grid consumers, those consumers have achieved significant savings on their heating bills.[34]

HHSs are also cheaper to operate than other all-electric alternative methods for heating off-grid homes. Heating units such as storage heaters or panel heaters appear to be attractive low carbon heating options if green electricity can be supplied. However, the running costs of these solutions are very high[35] and the electricity supply may be intermittent. Whereas HPs can enable significant energy savings compared with current systems, direct electric heating systems save very little and require more significant grid capacity reinforcements.[36]

Optionality regarding future heating technology

HHSs provide greater flexibility regarding the timing and extent of building upgrades. As buildings are upgraded in time and become better insulated, the share of heat provided by an HP will increase. This development will lead to increasing carbon reductions as the share of heat provided by gas decreases, subject to progress with carbon intensity of both vectors, particularly for flexible marginal generation.

HHSs are also a low regret option that allow longer-term flexibility regarding the choice of heating technology. As extensive changes to building fabric are not required, HHSs offer flexibility to explore alternative low carbon heating technologies in the future. Customers could decide to keep their gas boiler if the gas supply is switched to a low carbon fuel such as bio-LPG or biomethane. If an HHS is made hydrogen-ready, the boiler would be able to run on a natural gas, biomethane, or hydrogen supply (see Energy System Benefits below). Consumers could also decide to keep or upgrade their HP as the sole solution in the long term, allowing them more time to upgrade their building to the required energy efficiency level.

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[32] Ecuity Consulting and Liquid Gas UK, *A Practical Approach: Analysis of Off-Grid Heat Decarbonisation Pathways*, February 2021.

[33] Delta Energy & Environment, *Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings*, December 2018.

[34] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[35] Element Energy, *Electric and bioenergy heating in off-gas grid homes: evidence gathering*, September 2019.

[36] Delta Energy & Environment, *Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings*, December 2018.

Consumer choice, diversity of fuel supply and future benefits from flexibility

HHSs give consumers the flexibility to enjoy the benefits of renewable electricity and low carbon gas for heating their homes. Moreover, unlike gas-only or HP-only heating systems, most hybrid systems can provide cooling, for which the UK is seeing increasing demand.

HHSs provide the capability to switch between fuels, which can provide higher resilience for meeting heating needs during times of system stress and create opportunities to optimise operating costs and carbon. Fuel switching will grow in importance as time-of-use electricity tariffs are increasingly used and as power prices become more volatile due to growing capacities of intermittent renewables and flexible backup and storage options in the GB electricity system. As flexibility frameworks develop, customers will be able to generate revenue by providing flexibility services to the electricity network, offering further savings to their energy bill, as discussed previously.

Energy system benefits

HHSs have an important advantage over any single-fuel heating technology in that they can switch between fuels depending on customer settings or system requirements. This capability is an important advantage for the energy system because it reduces the peak demand from the building sector, thereby reducing the need for costly network infrastructure expansion. They also help to avoid overbuilding other underutilised capacity, such as low carbon and backup generation, hydrogen production, and storage assets. Furthermore, the flexibility of HHSs improves electricity system resilience as they can absorb abundant renewable electricity on sunny and windy days and reduce the risk of outages when the power system is tight. Whilst the benefits of HHSs to the energy system are clear, it is important that they are well recognised by network operators and policymakers so that potential HHS users can be appropriately rewarded for the value they bring to the energy system.

Impact on peak power demand and energy infrastructure needs

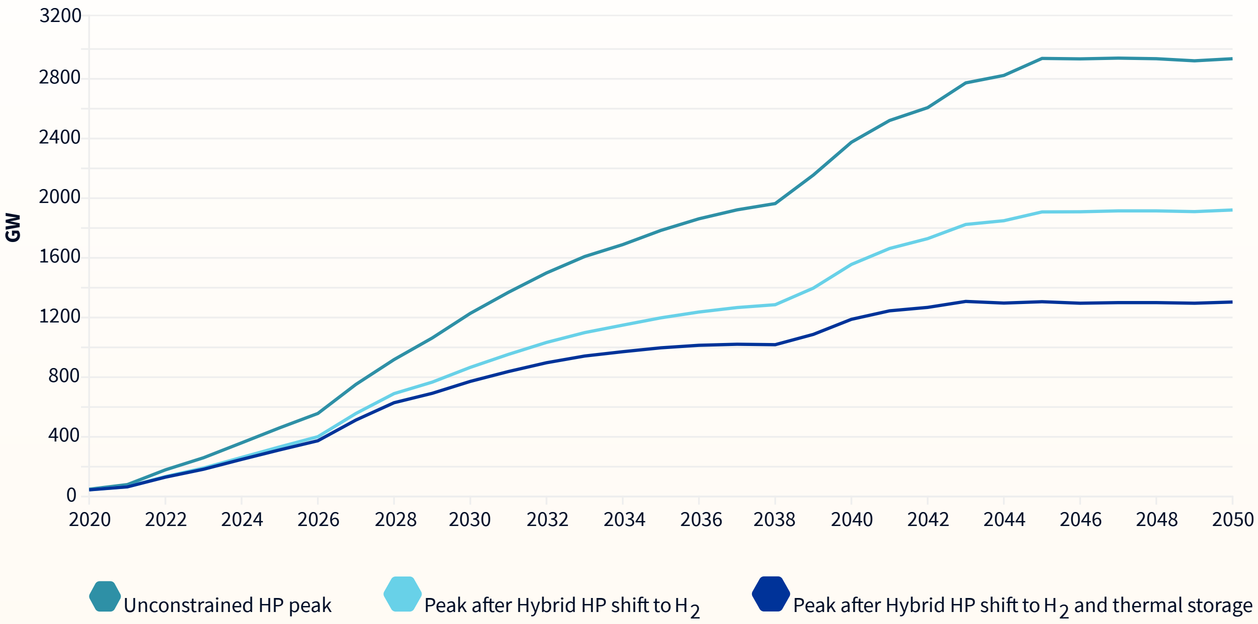
The electrification of heat is expected to have a significant impact on future electricity peak demand, which spikes on cold days when heating requirements are the highest and HP efficiencies are at their lowest. The future electricity network will need to be dimensioned to provide heat for buildings on the coldest days of the year in addition to significant demand arising from the electrification of transport. The large uptake of HPs will therefore necessitate the expansion of the power distribution network. Infrastructure expansion is disruptive and costly, with costs paid for by energy consumers in their energy bills through higher network charges.

HHSs are an effective solution to reduce the impact of heat decarbonisation on peak power demand because the gas boiler can be switched on at times of the highest heat demand. One UK pilot[37] indicated home energy consumers could reduce 35%-40% in peak loads thanks to HHSs. National Grid's Future Energy Scenario[38] indicates that by 2050 winter peak demand may be lower by 8 GW (System Transformation scenario) to 17 GW (Leading the Way scenario shown in Figure 5) if HPs are deployed as part of hybrid heat systems.

[37] PassivSystems with Western Power Distribution, MADE project.

[38] The latest 2021 release of the Future Energy Scenarios projects that up to 5.8m HHSs may be installed by 2050 (System Transformation scenario), of which 5.5m are ASHPs with hydrogen boilers and 0.3m are ASHPs with BioLPG/BioLiquid.

Figure 5 — Residential winter peak electricity demand for heating and flexibility from heat pumps and hybrid heat pumps



Source: FES 2020 Leading the Way

The cost savings from avoided energy infrastructure development can be significant. One study for the Energy Networks Association shows that overall infrastructure costs in GB can be £8 billion/year lower in a scenario with 75% of buildings equipped with HHSs compared with an all-electric scenario (which assumed no HHSs).[39] Similarly, analysis from the CCC[40] indicates that network costs in a pathway with HHSs were significantly lower than in an all-electric pathway. In the 30 Mt case, the hybrid pathway is £8 billion/year less costly, whereas the savings for the 0 Mt case is £34 billion/year,[41] providing evidence that the hybrid approach becomes more valuable with more stringent carbon targets. Similarly, other reports[42,43] conclude that estimated energy system cost savings for an HHS case could amount to £15.4 billion/year. The difference in costs is driven by less need to invest in transmission and distribution lines, transformers, and power generators whilst utilising existing gas infrastructure for situations of peak demand and at times of low renewables on the system.

The impact on grid upgrades may be particularly strong in off-gas-grid areas where the existing electricity grid has lower capacity to absorb increases in peak demand. One study indicated that in a 1-in-20 winter, 30% of feeders would be overloaded if off-gas-grid areas used only HPs. The costs saved from costly reinforcement of rural grids will be reflected in lower network charges levied on all energy customers.[44]

[39] Guidehouse, *Pathways to Net-Zero: Decarbonising the Gas Networks in Great Britain*, Energy Networks Association, October 2019.

[40] Imperial College of London, *Analysis of Alternative UK Heat Decarbonisation Pathways, Committee on Climate Change*, August 2018.

[41] Imperial College of London, *Analysis of Alternative UK Heat Decarbonisation Pathways, Committee on Climate Change*, August 2018.

[42] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[43] Carbon Trust, Flexibility in Great Britain, May 2021.

[44] Delta Energy & Environment, *Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings*, December 2018.

The deployment of hybrid systems will also limit future investment required in the emerging hydrogen system, including hydrogen production and storage capacities.[45] Studies show that hybrid deployment reduces overall hydrogen production capacity needs by 29%[46] by optimising its use for when it is most necessary in domestic heating (in addition to use in industry and transport).

The use of gas boilers as part of HHSs is facilitated by existing gas infrastructure. Continued use of the gas network wherever feasible reduces the need to build new infrastructure and saves the cost of decommissioning existing gas infrastructure. This approach reduces the risk of stranded assets with gas infrastructure continuing to play a role as a provider of large-scale storage and flexibility for heating, power generation, transport, and industry.

Energy System Storage needs

Existing fossil fuels provide significant amounts of energy storage, which in turn support security of supply both in the short and long term. A large amount of energy is stored in the form of oil, coal, and gas to manage seasonal swings in energy demand in today's energy system. Despite extensive research and commercial development of batteries and other forms of electricity storage, it will be difficult to replicate today's scale of seasonal storage using electricity alone. Even if intra-day storage is manageable, weekly fluctuations and the need for seasonal storage will remain an issue for electricity.

The CCC[47] indicates that the storage required to meet seasonal swings in energy demand cannot be met by batteries alone. By making use of various forms of low carbon gas as part of the fuel mix, HHSs allow higher levels of energy system storage that in turn support overall security of supply.

Impact on system integration, flexibility and resilience

As the electricity system decarbonises through the addition of intermittent renewable capacity in the system, grid stability will become more challenging. Demand side flexibility will be an important tool for grid operators to ensure the distribution grid remains resilient and stable, and systems integration of new low carbon generation sources can occur in a timely and effective manner.

Unlike all-electric HPs, HHSs can provide flexibility as heating demand can be met by a gas boiler, which eliminates demand for electricity when prices are high and supply scarce. Conversely, at times of high renewable production, an HP can be used to absorb excess electricity, which can be used for water heating as well as pre-heating homes very cost-effectively as part of demand response schemes. Trials in the UK[48] show that HHSs provide fully flexible loads that can respond dynamically to network, price, and carbon signals and constraints.

Provision of large-scale rapid flexibility from heating is particularly important for ensuring system resilience. HHSs can provide high value fast-frequency response required to manage grid stability on a second-by-second basis. Given, the ability to shift electricity demand indefinitely within seconds, HHSs can contribute to managing larger swings in the energy system, e.g., in an event of unforeseen outages or extreme weather, the integrated system can be better managed, provided there is the ability to switch between electricity and gas. Ensuring energy system resilience will become increasingly important as a form of adaptation to the long-term impacts of climate change on weather volatility and frequency of extreme weather events.

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[45] Energy Networks Association, Gas Goes Green – Britain's Hydrogen Network Plan, https://www.energynetworks.org/creating-tomorrows-networks/gas-goes-green

[46] Wales & West Utilities, HyHy Project.

[47] Imperial College of London, *Analysis of Alternative UK Heat Decarbonisation Pathways,* Committee on Climate Change, August 2018.

[48] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

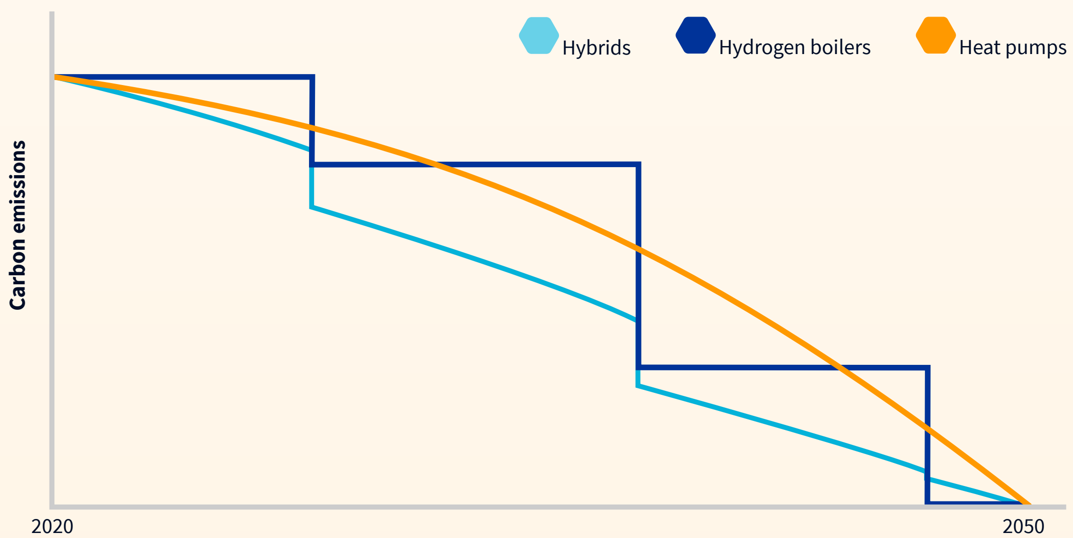
Climate benefits

HHSs can play an important role in reducing carbon emissions in the building sector, especially in the next ten years. Emissions reductions in the short term are made possible by the HP element of HHSs, which can be very energy efficient in well-insulated buildings or on most days when heating requirements are moderate. Thanks to their broad applicability, HHSs can be deployed rapidly across a wide range of properties and accelerate emissions reduction. Given the constraints of the UK's net zero carbon budget, any acceleration of emissions reductions is welcome as it reduces the risk of missing targets, alleviates the impact of mitigation delays in other areas of the economy, and minimises cumulative emissions, which in turn reduces the climate change adaptation action required. At the same time, HHSs are a long-term solution to building heat decarbonisation as the electricity and gas networks decarbonise through renewable power, biomethane, and hydrogen uptake.

Rapid Decarbonisation

HHSs can be highly effective in accelerating carbon emissions reduction in the UK's building sector because they do not face the significant barriers faced by HPs in some settings, such as the need to improve the energy efficiency of buildings through costly and intrusive retrofits and the highly disruptive change of heating installations such as installation of larger radiators or underfloor heating. Other low carbon heating options such as district heating networks can take many years to be constructed and require complex urban planning and engineering as well as the same retrofit of buildings as required for low temperature systems. Given the versatility of HHSs, the CCC recognises that the solution can make a substantive difference and lead to rapid decarbonisation if deployed at scale.[49,50] Figure 6 illustrates the total cumulative emissions from hydrogen boilers, HPs, and HHSs. The total emissions to 2050 are calculated as the area underneath each curve. The hydrogen path is stepped as local areas are converted to 100% hydrogen supply, whereas the HP path experiences gradual decline in emissions as the proportion of low emissions electricity in the overall supply increases. The hybrid pathway benefits from the deployment of low carbon electricity capacity driving down HP emissions as well as the hydrogen steps, resulting in the lowest cumulative emissions of the three.

Figure 6 — Illustrative Cumulative Emissions Pathway Curve[51]



[49] Climate Change Committee, *Hydrogen in a low-carbon economy*, November 2018.

[50] Climate Change Committee and Vivid Economics, *Accelerated Electrification and the GB Electricity System*, April 2019.

[51] Wales & West Utilities, HyHy Project.

Most of the UK building stock is currently heated with natural gas in gas boilers. HHSs have the potential to reduce carbon emissions because most heat demand can be met by the HP element, reducing natural gas consumption from the outset. In a recent trial,[52] 69% of properties achieved greater than or equal to 50% reduction in gas usage compared with 2016 levels. Analysis for the UK[53] indicates that reduced reliance on fossil fuels for heating can lead to annual emissions savings of 55% when compared with gas boilers; those savings increase to 72% in 2030 and 83% in 2050 as the power grid decarbonises.

A significant number of homes off the gas grid use fossil fuels (ie oil) for domestic heating; applying HHS in these homes would yield a significant reduction in emissions.

The rapid decarbonisation benefit of HHS is important given the realities of carbon budgets, which put a higher value on action that is taken sooner rather than nearer to a long-term target date. Reducing carbon emissions in the building sector early on yields contingency for delays in carbon reduction in other sectors of the economy.

Thanks to the fuel flexibility intrinsic to HHSs, these installations can be controlled to choose the lowest carbon-intensity fuel depending on the locational and temporal carbon intensity of the power and gas grids. For example, at times when coal-fired or gas-fired generation is the marginal source of electricity, burning gas in boilers may be less carbon intensive. UK trials[54,55] show that HHSs can be optimised in a way to minimise carbon emissions, with one employing live carbon forecasts so that the HP could track marginal grid carbon intensity and use a minimum HP COP threshold to avoid operating in periods when highly emitting fossil fuel plants were generating electricity on the grid.

Long Term Solution

An additional benefit of HHSs is their potential to enable and accelerate hydrogen demand in the UK through blending. One of the key challenges facing hydrogen development is the lack of an existing demand base. HHSs can help overcome this problem by encouraging demand in the short term and enable the large-scale development of a hydrogen economy. In the long term, HHSs will benefit from hydrogen demand and supply for other sectors such as heavy goods transport and industry; 42% of domestic heat is in "superplaces" around industrial hubs. Hydrogen supply will be high in these regions, driven by industrial demand, and HHSs can take full advantage of this supply.

[52] Woon Bedrijf: Innovatief 390. Dutch Trial

[53] Element Energy, *Electric and bioenergy heating in off-gas grid homes: evidence gathering*, September 2019.

[54] Western Power Distribution, Wales & West Utilities, PassivSystems, Delta-EE, City University and Imperial College London, FREEDOM Project.

[55] UK Power Networks and Wales & West Utilities, HyCompact Project.

As hydrogen and other renewable gases such as biomethane are developed, HHSs can become a long-term solution for heat decarbonisation. At the same time, as the UK building stock energy efficiency levels improve, HHSs will become more efficient and require less energy. Hydrogen-ready boilers are expected to become commercially available from 2025,[56] which means that HHSs with new boilers installed after this date would be zero carbon ready and fit-for-purpose in the long run.[57] The CCC recognises that hydrogen will play a valuable role as part of a heating solution for UK buildings and highlights the potential for combining hydrogen with an HP as part of an HHS. The CCC assessment is that 'heat pumps, powered by increasingly low-carbon electricity, offer the potential to provide heat efficiently for most of the time, with hydrogen boilers contributing mainly as back-up to meet peak demands on the coldest winter days.'[58] This assessment affirms the place of HHSs, using hydrogen or other renewable-fuelled boilers, as a long-term, low carbon, domestic heating solution.

Decarbonising off-gas-grid heating

Decarbonising off-gas-grid properties is a particular challenge given the relatively low levels of building insulation and current reliance on fossil fuels, such as LPG or oil. For hard-to-decarbonise homes, the CCC recommends 'developing policy to deliver decarbonisation of off-gas-grid homes at scale during the 2020s, with a focus on achieving rollout of HPs and hybrid heat pumps.'[59,60]

HHSs can lead to sizeable carbon emissions reductions whilst ensuring adequate levels of comfort throughout the year. In off-gas-grid homes, switching from a standard oil boiler to an HHS can lead to an emissions reduction of 77% after one year of operation. By 2050, emissions fall by 94% compared with running an oil boiler.[61] Assuming that both the elec-tricity and bio-LPG emissions intensity reduce further, HHS emissions could fall by 98% by 2050 compared with heating oil emissions.

[56] Jack Woodfield, "Worcester Bosch's Hydrogen Boiler Prototype Enters First Field Trial," October 2020, https://www.homebuilding.co.uk/news/worcester-boschs-hydrogen-boiler-prototype-enters-first-field-trial

[57] Climate Change Committee, *Hydrogen in a low-carbon economy*, November 2018.

[58] Climate Change Committee, *Hydrogen in a low-carbon economy*, November 2018.

[59] Climate Change Committee, *Hydrogen in a low-carbon economy*, November 2018.

[60] Climate Change Committee, *Analysis on Abating Direct Emissions from 'Hard-to-Decarbonise*' Homes, July 2019.

[61] Calor, Hybrid Analysis, June 2020.

3. Recommendations

HHSs are a comprehensive solution with important benefits to consumers and the broader energy system. They are also an effective tool to tackle climate change. However, HHSs play a limited role in the UK and have not enjoyed as much attention from policymakers and the public as other low carbon heating technologies. More needs to be done to boost the uptake of HHSs and ensure this complementary solution plays a larger role in decarbonising heat in the UK. We put forward recommendations for key stakeholders including policymakers, energy suppliers, network operators, and equipment providers.

Policy maker recommendations

Policymakers are key to driving the energy transition and the decarbonisation of heat in buildings given the complexity and need for government incentives. We recommend that policymakers:

1. Recognise the immediate and long-term benefits of HHSs for the consumer, energy networks, and the climate and the role HHSs can play in delivering the decarbonisation targets set out in *Energy White Paper: Powering* our net zero future and The ten point plan for a green industrial revolution.
2. Improve cooperation between electricity and gas networks on regional heat transfor-mation planning to identify the optimal low carbon solution rollout from a total system cost perspective.
3. Minimise the overall cost of achieving net zero for heat through optimising across building insulation and heating system retrofits, energy network costs, and in-vestment in peak electricity generation capacity, energy storage, and green gas production.
4. Identify housing archetypes and socioeconomic contexts in which HHSs are particularly suitable. Design policy and support packages to enable practical and deliverable deployment of HHSs, e.g., in UK homes on and off the gas grid where it is uneconomic to retrofit the building fabric for low temperature heating systems. Set up a retrofit fund for at scale national trialling of HHSs across a range of property types and in tandem with ancillary technologies (fabric upgrades, radiator replacements, smart controls) to provide evidence of the role of hybrids in heat decarbonisation and aid optimal policy design.

5. Work with industry and research institutes (e.g., BRE) to ensure that the value of smart grid connected hybrid HPs is captured within Standard Assessment Procedure (SAP) in buil-dings and building regulations so that the technology can contribute to energy targets in the retrofit and new build property sector. The current approach should be improved to better reflect the value of flexibility and formalised in the next version of SAP.
6. Include and encourage HHSs as part of incentive programs and grants such as RHI, Homes Upgrade Grant, Clean Heat Grant, Social Housing Decarbonisation Fund, and ECO4.
7. Remove barriers to entry for micro-scale and residential assets to tender in flexibility markets. Incentivise grid operators to pursue flexibility first over costly grid reinforcements.
8. Encourage installations of HHSs to help towards achieving the 600,000 HPs per year target.
9. Introduce targets and incentives for production of low carbon gases, which will be vital to fully decarbonise the UK building stock. The Green Gas Support Scheme, which follows RHI for biomethane, helps in this regard.
10. Develop strategies and support for low income households to implement HHSs or other low carbon heating options. Encourage and enable future-proof heating that, like hybrid systems, offer immediate and no-regret decarbonisation and are suitable in the long term and compatible with net zero.
11. View HHSs as a way of minimising the cost of net zero home retrofit by optimising across building upgrades, and spend on new low carbon heating technologies.
12. Include hybrid systems in industry regulation and consumer protection bodies, i.e., Microgeneration Certification Scheme. Ensure an industry standard is in place that is accessible for all installers and provides consumers with peace of mind.

Energy supplier and network operator recommendations

1. Accelerate the rollout of smart meter technology and in-home control systems to enable hybrid systems to respond to variations in gas and electricity prices and potentially carbon signals.
2. Develop flexibility markets that adequately incentivise demand side engagement from domestic consumers, including the significant value offered by aggregated hybrid system flexibility.
3. Work with hybrid system manufacturers to develop bundled consumer offerings, lowering the hurdle to invest and install hybrid solutions.

Equipment provider recommendations

1. Further improve hybrid technology choices and increase applicability across the housing spectrum, including properties that are smaller or have limited or no outdoor space.
2. Facilitate the integration and smart grid readiness of hybrids, including the ability to intelligently manage the property heat load and respond to dynamic price or carbon-intensity signals.
3. Ensure hydrogen-ready boilers are commercially available as soon as possible and that they are, or can be easily be, integrated into HHSs.
4. Acknowledge the distress purchase situation and develop methods for encouraging consumers to install a hybrid system before a distress situation occurs when their current heating system fails.
5. Provide clear warranty provisions for repairing a hybrid system or retrofitting an HP to an incumbent heating system.
6. Develop an industry standard for hybrid system servicing and repair.

Appendix

References and sources

Publisher	Source
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Calor	*Off-Gas-Grid Decarbonisation Survey*
Calor	*Hybrid Analysis with Bio-LPG*
Carbon Trust	*Flexibility in Great Britain*
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Delta Energy & Environment	*Technical Feasibility of Electric Heating in Rural Off-Gas Grid Dwellings*
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Department for Business, Energy & Industrial Strategy	*Hybrid Heat Pumps*
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Guidehouse	European Hydrogen Backbone plan
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Heating and Hotwater Industry Council	*Hydrogen ready appliances – the pathway*
House of Commons	The role of hydrogen in achieving Net Zero
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Ipsos and Navigant	*Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU*
MHEK	MHEK Hydrogen Hybrid Demo
Navigant	*HHE Vision Paper*
PassivSystems and Western Power Distribution	Multi-Asset Demand Execution (MADE) project
Public First	Options for Energy Bill Reform
Western Power Distribution, Wales & West Utilities, PassivSystems, Delta Energy & Environment, City University and Imperial College London	FREEDOM project
Wales & West Utilities	HyHy project
Dutch Trial	WOON BEDRIJF - INNOVATIEF 390. Dutch Trial

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