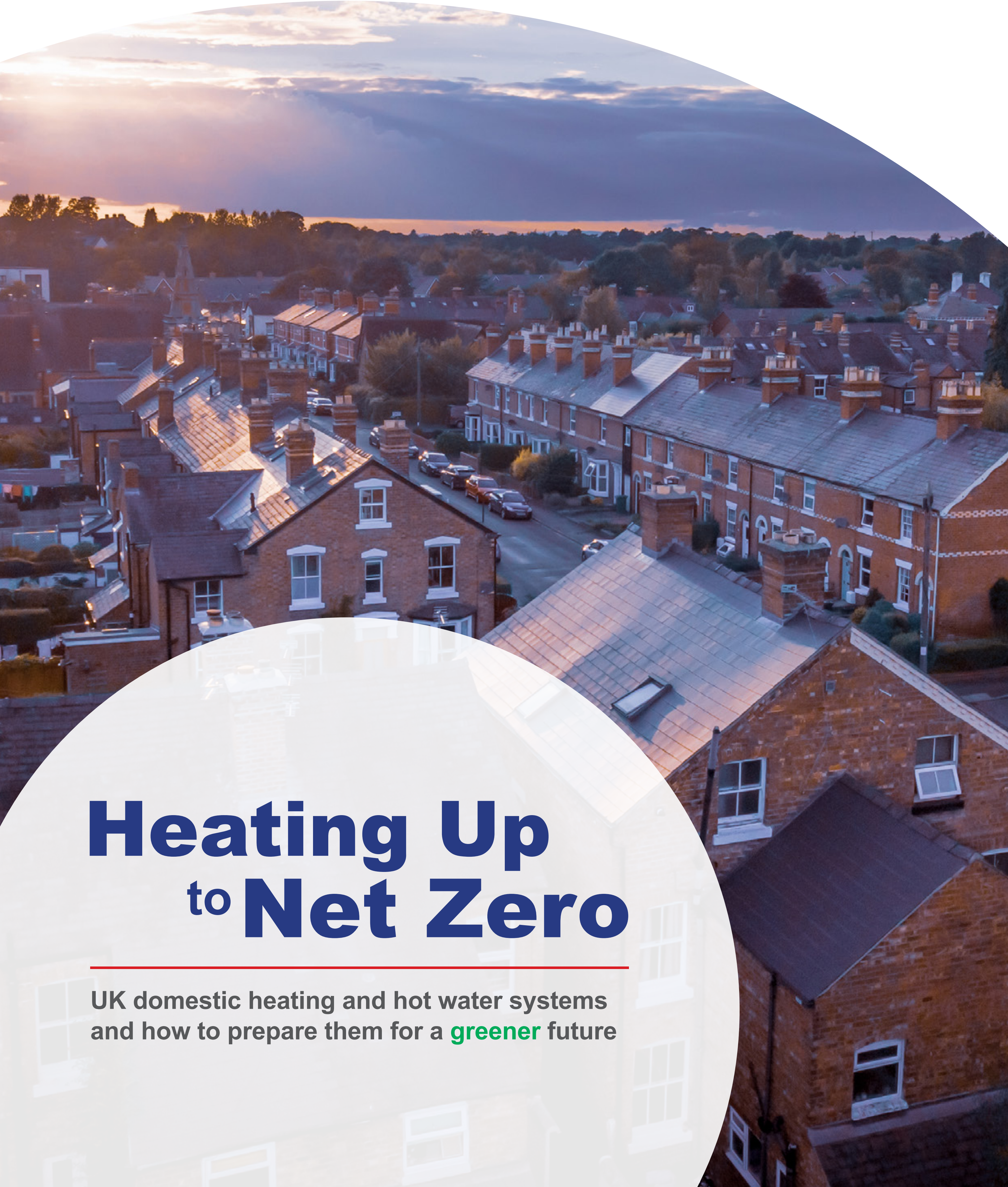
HEATING & HOTWATER INDUSTRY COUNCIL



Heating Up to Net Zero

UK domestic heating and hot water systems and how to prepare them for a greener future

HHIC is a member organisation committed to effectively driving, supporting and promoting the sustained growth of the UK domestic heating and hot water industry

The Manufacturers' Association of Radiators and Convectors is an organisation established to give a particular voice to the radiator and convector industry, focusing on the specific needs of, and issues faced by, manufacturers and distributors of radiators with factories in the UK and/or Europe.

The Hot Water Association (HWA) is a member organisation committed to effectively promoting the concept and use of stored hot water in domestic and commercial buildings in the United Kingdom and Republic of Ireland. HWA's membership accounts for nearly 100% of domestic hot water storage devices sold in the UK. The HWA exists to support, drive and promote the sustained growth and improvement of standards within the entire domestic hot water industry.

Contents

01. Executive Summary

Domestic heating and hot water are central to the UK's energy transition as it strives to achieve 'net zero' by 2050. Moving homes over to low-carbon technologies, like heat pumps and hydrogen boilers, will be key to meeting this target, as too will wider community schemes like district heating. 'Hybrid' approaches that use heat pumps alongside gas boilers will also play an important role, as they can help to drastically lower emissions in properties that are more difficult to treat.

However, the different heating systems that circulate heat and hot water in our homes are not adequately covered by strategy and policy work. This white paper aims to change that. It looks at what works well, where improvements need to be made and how different domestic systems can be aligned with the country's long-term climate targets. Research has been carried out by working groups comprised of industry experts. All contributors are members of the Heating and Hotwater Industry Council (HHIC), The Hot Water Association (HWA) and the Manufacturers Association of Radiators and Convectors (MARC).

The challenges the UK faces are clear. For example, it is known that fewer than nine million homes now have a hot water storage appliance and many radiators may need to be replaced for the transition to high-efficiency, low carbon heating systems. Yet it is also known between four- and five-million homes built in the last 30 years contain microbore pipework that may not be suitable for such upgrades.

This is just one example of where further works needs to be done and leaves aside other key concerns, including standards, education and guidance and development of future technologies.

This paper focuses on the core technical systems requirements and proposals to achieve decarbonisation first, followed by consequent discussion of installer training and customer information and awareness. However, Customer knowledge and understanding of the operation of decarbonised heating systems together with Installer heating system training is fundamental to the correct selection and delivery of the right solution for a customers property and therefore should take highest priority once the allowable technical solutions and selection processes are agreed and built into appropriate training and support programmes.

With that in mind, this paper has identified four key areas for discussion on the following pages.

1. Systemic Improvements and Practical Targeting

Appropriate targeting of low-carbon hydronic heating and hot water solutions into existing systems. This includes:

a. Reducing the heating flow temperature, may involve replacing radiators through correct sizing and making improvements using room-by-room heat loss calculations based on BS EN 442 [Ref 1]. Success will depend on a suitable government scheme, supported by information that explains how these new methods will differ to existing consumer systems.

b. The inclusion of energy saving individual room controls such as Thermostatic Radiator Valves (TRVs) as per the requirements set out in the latest draft version of building regulations and the European Energy Performance of Buildings Directive (EPBD) [Ref 2].

c. Mandated system balancing [ref 3] to drive innovation. For example, using products such as flow-controlled TRVs for all current radiator systems along with setting correct pump speeds to heat output (kW) requirements.

d. Encouraging homes to retain hot water cylinders or thermal stores where installed. Better still, replacement with better insulated and controlled models with high recovery heat exchangers (suitable for low temperature / low carbon systems) should be incentivised by a simple government scheme.

e. Resolving microbore pipe issues. Any new heating piping, including new heating systems, should be a minimum size of 15mm, with these requirements added to legislation. Main flow and return pipes in the primary heating circuit should be a minimum of 22mm. Any new system should have the necessary calculations completed and the system designed appropriately. Guidance will also need developing for situations where microbore pipes exist and a low-carbon heating appliance is to be installed.

f. Ensuring hydronic heating systems, regardless of the heat generation source, continue to operate at design efficiency throughout their lifecycle by the application of correct water treatment as defined in BS 7593:2019 and manufacturers installation instructions. This includes adding an inline filter within the circuit; cleaning the system after installation or maintenance; treating with an inhibitor and maintaining the level of corrosion inhibition by annual concentration checks and redosing every five years.

g. Waste water heat recovery is currently being considered for inclusion in eco-design and therefore this and other innovative water and energy system improvements should be considered for inclusion within domestic systems. Further work is needed to understand how these can be built into the consumer proposition.

2. Building Fabric Improvements

a. Building fabric performance needs to be developed alongside any improvements to the heating system. Reducing heat loss will lower carbon emissions, make low-carbon retrofitting easier and save on running costs. This paper shows that older properties upgraded with double glazing and loft and cavity wall insulation have significantly lowered their heat demand. This makes them better suited to low-temperature heating systems with potentially fewer system components changes required.

3. Upskilling and Training

a. Upskilling of current Gas Safe installer base, by completion of low-temperature heating system and heat pump courses.

b. Any government scheme should require record of a room-by-room heat loss assessment to establish low temperature emitter readiness.

c. Training for new starters should include recognised, staged development courses. This could include an accredited certification scheme, low-temperature heating system design and heat pump introduction, and expert-level courses supported by a skills card.

d. Produce a British Standard Code of Practice for the design of heating systems, including low-temperature designs, to help support training and guidance for building regulations.

e. Review of British standards to ensure sufficient information and guidance is available for the transition to low-carbon heating.

4. Consumer Information

a. Creation of a ‘low-carbon ready’ scheme and logo across all product and system types. This would need to be accompanied by impartial consumer guidance.

b. The Benchmark document records completed work but should also include assessment of future energy-saving heating system upgrades that can support the EPC. Heat loss calculations recorded can form part of a ‘low-carbon readiness’ indicator.

02. Introduction

Hydronic heating systems are dependent on hot water generated by a boiler or heat pump. This water is then circulated with a separate pump through pipework to a home's radiators or underfloor heating. These systems can include storage tanks though many use combination boilers to provide instant hot water. There are over 26 million homes that have a hydronic central heating system in the UK.

The demand for central heating in UK homes began in the 1970s. As a result, many domestic systems are now old and inefficient, in need of replacing or significant changes to meet carbon budget targets and the UK's net zero by 2050 deadline. Heating appliances are often replaced - mainly through age or a homeowner's decision to upgrade. However, the system component parts, such as radiators, cylinders and controls are typically left unchanged due to cost, inconvenience or complexity. This is a problem, not least because an efficient heating and hot water system makes a significant contribution towards tackling climate change. Greater awareness is now needed to help the public understand the energy savings these often-forgotten improvements can deliver.

Energy policy typically focuses on replacing appliances for more efficient models with lower emissions. But there are further system improvements that can be made to prepare home heating systems for a low-carbon future. This paper examines the UK's heating landscape, how industry can begin the process of improving domestic systems and the importance of increasing insulation in homes to reduce energy demand. Seeking to provide a more detailed view, the paper also looks at possible gaps in policy, regulation and guidance and questions whether financial incentives could reward installers for additional activities, like heat loss surveys. Perhaps most important of all, it questions what role government can play in facilitating positive change within domestic heating and hot water.

Thank you for reading.

03. Heating Systems by Number

Understanding what heating systems are currently installed in UK homes is critical for any large-scale change. This section examines the different types of housing stock together with current sales figures by system type. Looking at the market in this way can determine the current favoured system and the types of environment requiring change in order to accommodate upgrades.

The UK & I.E heating market sales by fuel type for 2020 is shown below.

Figure 1: Sales of different generic system types in U.K. Homes in 2020
(Source: HHIC Annual Heating Market Data)

UK Sales	2020	%
Wall-hung Gas Boilers	1,558,000*	92.6%
Floor Standing Gas Boilers	4,000	0.2%
Heat Pumps (Ground Source/ Air Source heat pumps)	27,000	1.6%
Direct Electric Heating	26,000	1.5%
Oil Boilers	55,000	3.2%
Solid Fuel Boilers	12,000	0.7%
Total	1,682,000	

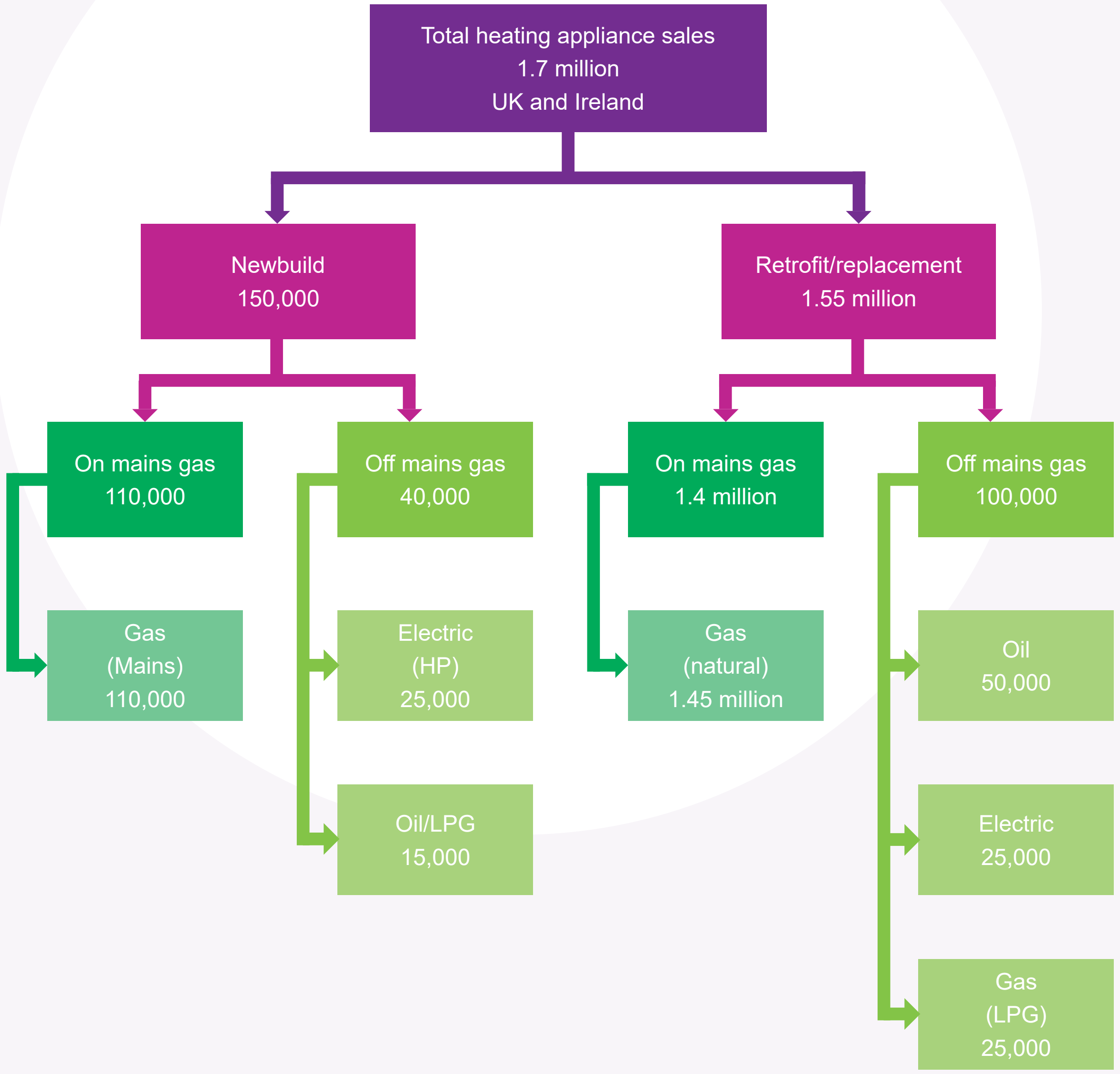
*1.22 million combination boilers, 150,000 system boilers and 190,000 open vented (regular) boilers

An indicative example that splits new build and retrofit sales is shown in figure 2:

Figure 2: Sales in New build and Retrofit U.K. & I.E. Homes in 2019

(Source: HHIC Annual Heating Market Data)

According to its 10-point plan and energy white paper, the government favours heat pumps for use in new build homes. In this section of the market systems can be designed accurately from the earliest stages to minimise performance issues.



However, the same cannot be said for existing building stock. Different building ages and designs make it difficult to retrofit heat pumps effectively. The relative cost of gas against electric is also currently a barrier. Clearly, different approaches will be necessary in this part of the market if carbon reduction targets are to be managed successfully against homeowner expectations. The sales volumes listed in Figure 2 show the biggest challenge centres around gas retrofit, with roughly 1.55 million wall-hung boilers installed in existing building stock each year [Ref 4]. The different housing types and ages are shown in Figure 3.

Figure 3: The age and type of UK housing

(Source BRE Trust: The Housing Stock of The United Kingdom)

	Pre-1919	1919-1944	1945 -1964	Post 1964	Number of dwellings / percentage
Terraced					7,829k 27.4%
Semi-detached					7,129k 25.0%
Detached					5,107k 17.9%
Bungalow					2,512k 8.8%
Converted flat					
Purpose built flat – low rise					5,958k 20.9%
Purpose built flat – high rise					
	Pre-1919 5,781k (20.6%)	**1919-1944** 4,284k (15.0%)	**1945-1964** 5,472k (19.2%)	**1965-1980** 5,698k (20.0%) **1981-1990** 2,287k (8.0%) **Post 1990** 4,923k (17.3%)	**TOTAL** 28,535k (100%)

Figure 4: Installed base of different generic system types in U.K. Homes in 2019

Figure 4 shows the installed base of heating systems in 2019. At 15 million the majority are gas combination boilers, with around nine million system/regular boilers (with DHW cylinder). Figure 5 forecasts changes to the installed base up to 2025. See Appendices for full figures.

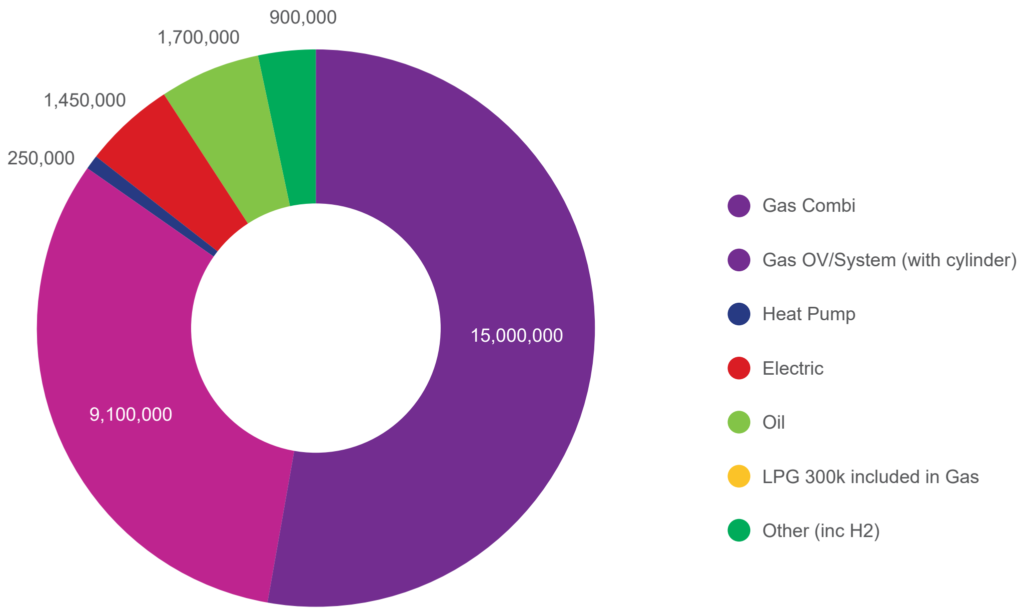
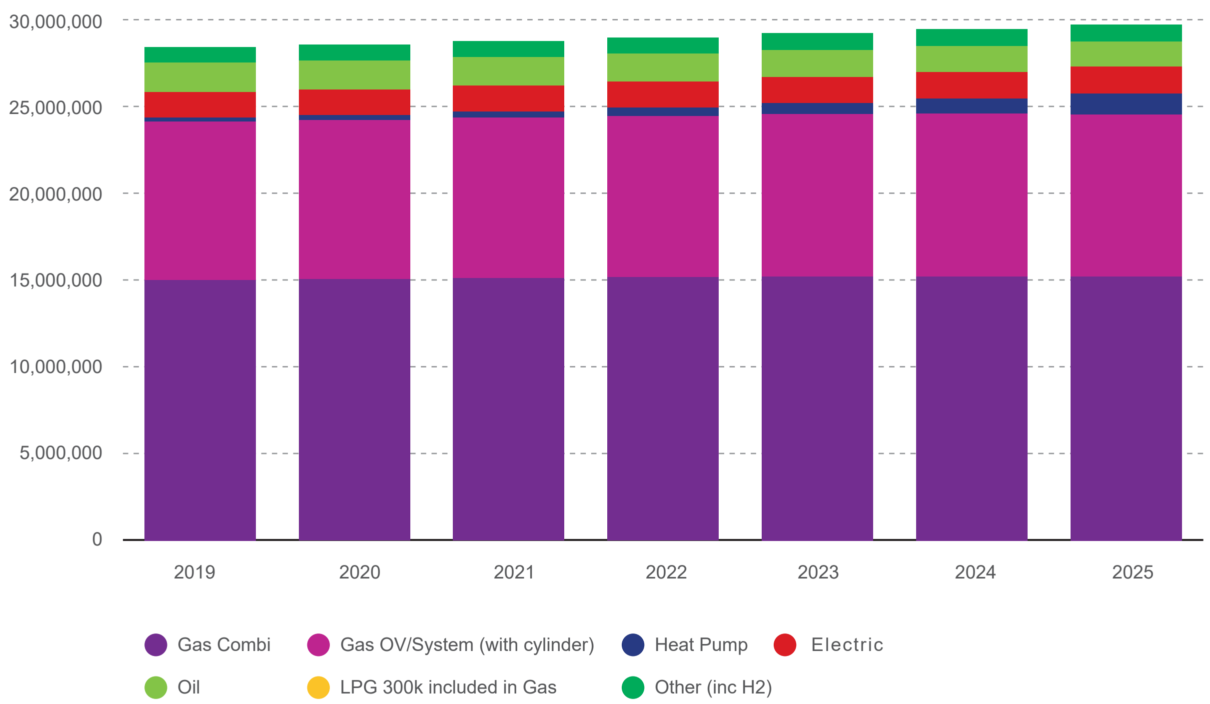


Figure 5: Installed base of different generic system types in U.K. Homes – forecast to 2025

(Source: HHIC annual market data)



04. The Retrofit Environment – Decarbonising Heating and Hot Water Systems

There are several factors to consider when decarbonising existing properties:

1. Building fabric upgrades to reduce heat loss
2. Upgrade of system controls
3. Systems upgrade for low-temperature heat delivery
4. Suitability of heat source for property and heat demand
5. Changes to the water quality regime necessary for low temperature heating
6. Domestic hot water provision

1. Building Fabric

Surveys of housing stock clearly show existing homes still have a long way to go in lowering heat loss. In 2018 the English Housing Survey, for example, found that only 38% of homes had loft insulation levels of 200mm or above and only 50% had cavity and/ or wall insulation [Ref 5]. Improving these figures will be vital for any system upgrade planning.

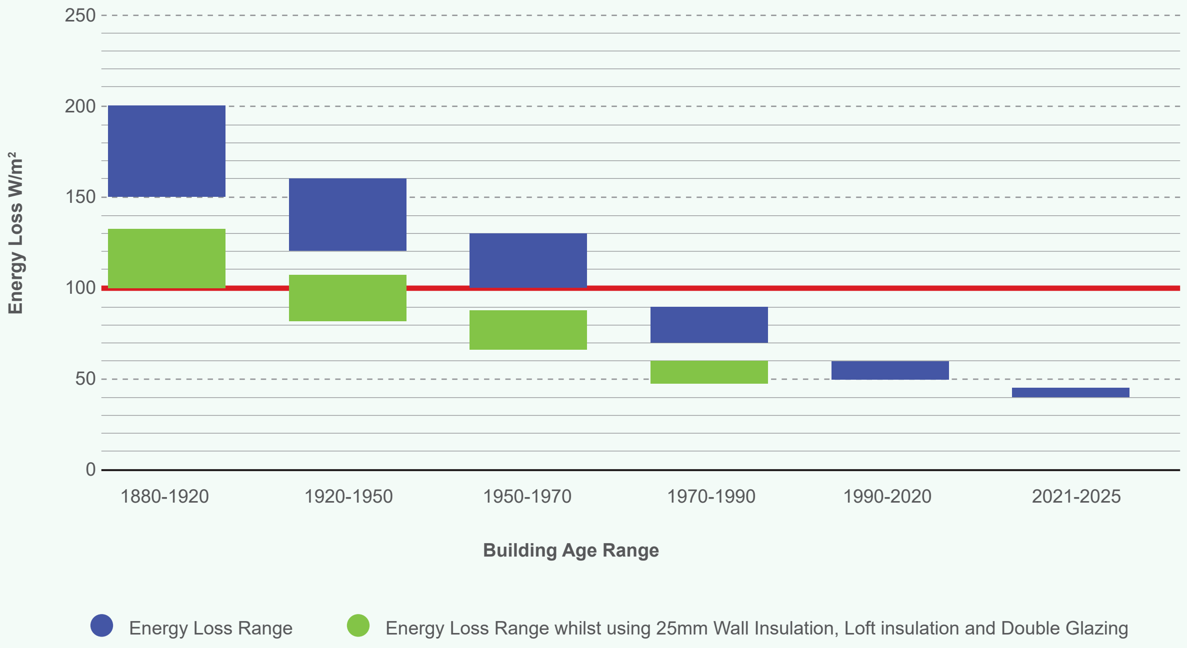
Figure 6 evaluates current UK housing stock and estimates energy requirements by age. For this purpose, the housing stock has been split into six groups ranging from late-Victorian to present day. A band of heat loss has been applied to reflect the likely range of energy requirements in each.

As new build techniques and materials evolve, the range of likely heat loss is reduced. This is especially clear since 1970s as the introduction of regulations began to limit the variance in build quality and therefore the energy performance characteristics of housing stock. In recent years, the variance in energy loss is minimal due to tighter regulations, better measurements and a desire to build more cost-effectively.

Figure 6 also shows the energy bands in W/m2 allocated to the different age groups. This ranges from 150W/m2 to 200 W/m2 for late Victorian/ early 20th century build, through to 40 to 45 W/m2 for present day. At these levels it can be assumed that no additional insulation work has taken place other than required by recent building regulation limits.

Figure 6: Energy loss for UK housing stock by age group and potential improvements through insulation measures

(Source: Vaillant, 2021)



If we take the same building model and factor in insulation updates, the improvement by each insulation measure can be applied as a percentage in terms of energy reduction over the same age ranges. Bigger values are seen in older properties as would be expected when making these kinds of changes.

The impact of applying the three most common thermal improvements to a property can be seen in Figure 6. The changes made are:

- 200mm of loft insulation
- Argon-filled double glazing
- 25mm of wall insulation

The chart shows no improvement for the later properties. This is likely due to newer properties already meeting these requirements through compliance. However, applying these three measures to an otherwise unaltered older building equates to a 33% reduction in energy loss.

Illustrative Example

The following example assesses the suitability of installing a single-phase air source heat pump into an older property.

Please note, a variety of heat pump systems are available. Fabric improvements for individual buildings should be fully assessed. The following is a typical, illustrative example.

Low-temperature heating systems, like heat pumps, have lower heating inertia when compared to similar sized higher-temperature systems. This becomes increasingly clear in older, higher heat loss housing due to its inability to quickly restore a desired temperature. Recognising this, the maximum output of the heat pump has been reduced by 10% in the example to give some system capacity to overcome reheating limitations in higher heat loss properties.

An output of just above 11kW can be expected when using a heat pump with a mean system temperature of 50 degrees and an outdoor temperature of -3ºC. Therefore, applying a 10% reduction as indicated above gives a heating load of 10kW. Output capacity can be maintained at lower external temperatures but this is dependent on specific heat pump performance, system design and design temperatures for that particular location.

At 100w/m2 a 100m2 property could be heated by a 10kW heating appliance. Figures 6 has a horizontal line added at the 100W/m2 mark represent this scenario.

Figures 6 shows properties built before 1970 would likely be unsuitable for heating with a 10kW single fan heat pump. However, by applying the three insulation measures discussed earlier, it can be seen that many properties built in the 1920-1950 range could be considered suitable for upgrades [Figure 6].

That said, there are other factors that should be considered:

a. For heat pumps to be effective, the recommended maximum flow temperature for hydronic heating systems would be 55°C or a mean primary flow temperature of 50°C. Sufficiently sized heat emitters would be necessary to support this as lower primary flow temperatures require a higher surface area. The amount of insulation added to a property would also determine whether radiators needed upgrading.

b. Houses built as new from the early 1970/80s are often fitted with microbore central heating pipework. Air source heat pumps require a relatively higher primary flow rate when compared to gas boilers so system suitability would need checking. It could prove expensive to replace a home's pipework and alternative solutions may have to be pursued.

c. New houses built after 1990 are fitted with combination gas boilers to provide central heating and instant hot water. The refurbishment of some older properties could have also have led to the replacement of the original heating boiler, the hot water storage cylinder and repurposing of the cylinder mounting space, i.e., the traditional airing cupboard. Replacing combination boilers with heat pumps would require a cylinder to be added back to the property to maintain provision of instant hot water. This could prove difficult or require expensive modifications.

Please note: In relation to increased insulation and consequent reduced air leakage, consideration should also be given to maintaining air quality.

2. System Controls Upgrade

Minimum efficiency and control levels are now specified for newly installed gas appliances. These include:

- 92% minimum appliance efficiency
- Time and temperature control
- Increased system controls (modulating/ smart)

Or

- Inclusion of a passive flue gas heat recovery device

However, at present these requirements are only applicable to combination boilers. By referring back to Figure 4, it can be seen that some nine million appliances are not currently required to comply with these standards. This presents a missed opportunity to improve system efficiency and lower carbon emissions, particularly as 350,000 of these appliances are installed in homes each year. Updating system components such as TRVs, system water filters and water treatment could bring further improvements. This will be discussed in more detail in the next section.

3. Systems Upgrade for Lower-Temperature Heat Delivery

Some opportunities do exist despite so many homes lacking the recommended levels of loft, cavity and wall insulation.

1. Homes that have added insulation measures after the original central heating install may now have effectively oversized radiators for the heat loss of the building.
2. Homes that have not added insulation could do so before a heating system upgrade to lower heat loss and allow for lower system design temperatures.

Achieving a lower mean water temperature would require a room-by-room heat loss calculation. This can help determine if there are rooms with radiators capable of running at lower temperatures while still meeting the design heat loss – some may not and would require upgrading. It is advisable to change very old, less-efficient radiators due to corrosion or incompatibility with TRVs.

Like gas boilers, heat pumps function best at lower system temperatures so changes would create efficiencies today and also prepare a system for a low-carbon future. Potential savings moving from a 70°C MWt to 50°C MWt have been calculated in the following section.

3a. Mean Water Temperature Reduction to 50°C

Calculations have been made for two property types of different ages to estimate the effect of running the central heating system water at a reduced mean temperature of 50°C. Use of compensating temperature control is included to demonstrate the effect of ensuring a system maintains its designed temperature.

The calculations are based on the mean efficiency differences of the appliance that could be derived from seasonal running at the mean water temperatures and control regimes and includes the delivery of domestic hot water loads. They are ‘like for like’ and include no other energy saving upgrades to the properties.

The results are shown in Appendix 4. They show by reducing the heating system to a mean flow temperature of 50°C, and controlling the system correctly, an energy saving between 6.4% and 8% can be achieved.

By reducing the mean temperature by design to 50°C, the system becomes more efficient for gas installations and suitable for change over to a heat pump system. Further reduction in mean temperature could result in increased efficiencies, however consideration should be given to maintaining consumer comfort in the home.

This change can achieve significant carbon reductions, lower running costs and prepare homes for future changes. HHIC believes a suitably funded government scheme would be ideal to promote this effective system upgrade.

4. Suitability of Heat Source for the Property and Heat Demand

Heat pumps are more efficient than gas boilers and will have a lower environmental impact as the electricity grid increases uptake of renewables. However, hydrogen boilers are also being explored by manufacturers and energy networks. Both technologies are able to contribute towards net zero and it is important industry identifies the correct strategy for each. Along with lower heating system design temperatures, UK housing stock poses two other key challenges when installing heat pumps.

1. The need to run at smaller temperature differentials in the system (higher flowrates)
2. The need for stored domestic hot water (see section 5)

When running at smaller differentials and higher flowrates, the primary flow velocities and pressure drops must be calculated for the system installed. This is a problem for microbore pipework that has been used regularly since the 1980s and believed present in an estimated four- to five-million UK homes.

Smaller heat pumps requiring lower volume flowrates could potentially be installed in these systems. However, a 5kW model may not be large enough for the heat losses of older housing stock shown in Figure 3. A system separation approach could be employed with separate pump and system decoupler but these options also increase cost and complexity. Further information on microbore is shown in the next section.

4a. Microbore Central Heating Systems (further detail)

In the early 1970s gas central heating became a standard installation within the domestic new build market. In the same period microbore pipe work with a diameter <15mm was introduced.

Microbore grew in popularity in the new build market for central heating installations as it was cost effective, easier to install with relatively fewer joints required. It can also be conveniently routed within the floors and walls of the property, making an installation tidier. However, because the pipework is predominantly hidden from view, replacement can be intrusive and expensive.

Microbore systems are hydraulically more resistive due to diameters. As such, problems could occur when upgrading to lower-temperature systems using a heat pump. This is not an impossible task but additional equipment may be required.

4b. Thermostatic Radiator Valves (TRVs)

Fitting TRVs is an efficient and effective way to control the temperature of the home. They work with the heat source’s timer control, wall mounted room thermostats and are a simple and affordable way of controlling the heat output of a radiator. TRVs are designed to control the air temperature of a room by automatically adjusting the amount of hot primary water entering a radiator. TRVs also allow the occupant to control the temperature in each room of their home, creating a warm comfortable space that’s more energy efficient and cost effective.

4c. System Balancing

System balancing is essential for efficient heating. Some radiators can take most the primary hot water from the boiler if flow is not balanced, leaving other radiators with little or none. This can also affect boiler efficiency and homeowner comfort as some rooms get too hot while others remain cold. Heating systems are typically balanced using a lock shield valve on the radiator. However, some models of TRV include an integrated balancing insert. This allows the system to remain balanced even if a radiator is removed for decorating or replacement

Lower mean water temperature heating systems may require higher flowrates and a narrower Delta T (ΔT). This means TRVs with standard inserts may not have sufficient flow capacity and valve authority (the ratio between pressure drop across the control valve compared to total pressure drop across the whole system). In these 'high duty' applications, a higher capacity TRV and lock shield valve would need to be specified. These are widely available from manufacturers.

4d. Radiator Specification

Delta T relates to the difference in temperature between the water circulating in the central heating system and ambient room temperature. If room temperature is 20ºC, and the mean water temperature inside the radiators is 70ºC, the ΔT value is calculated as 70 ºC - 20 ºC = 50º. Delta T 50° is the UK standard and is set to allow professionals and consumers to make comparisons of hydronic radiator and towel rail outputs from various suppliers and across a mix of product types. Information is available to allow specification of radiators to operate and deliver the heat requirement at ΔT 30 (50 MWt in radiators).

Following a room-by-room heat loss calculation, the Installer can establish if existing radiators are effectively oversized and able to run at lower temperatures, or if radiators need to be exchanged for larger/ multiple panel radiators. It is the responsibility of all manufacturers, distributors, wholesalers and resellers to ensure hydronic radiators and towel rails conform to the European testing Standard BS-EN442.

5. Water Treatment

Water treatment and other central heating system maintenance measures are specified in Building Regulations, British Standards (BS 7593 2019) and heating appliance manufacturers' installation instructions. These help heating systems perform reliably and efficiently throughout their expected lifetime.

Unlike traditional high-temperature condensing boiler systems, low-temperature hydronic heating systems with maximum flow temperature of 55°C operate below the pasteurisation temperature for bacteria. Consequently, bacterial growth can lead to slime formation and microbial induced corrosion within the heating system. Prevention of bacterial growth is achieved through the application of a long-term biocide.

Upgrading to larger radiators for low temperature operation increases both surface area of metals and the volume of water within the heating circuit. The volume of inhibitor added needs to be adequate to compensate for these increases. Water test kits supplied by water treatment manufacturers are a convenient way of checking the concentration of inhibitor within the system.

6. Domestic Hot Water Provision

In a standard heat pump system, domestic hot water is provided using a hot water storage cylinder as the lower heat output from these appliances means domestic hot water cannot be heated instantaneously. The hot water storage cylinder should ideally be designed to operate on low-temperature heat sources to ensure acceptable performance for the homeowner.

As seen in Figure 4, the most popular retrofit system today is the combination gas boiler. Around 1.2 million are installed each year, adding to the existing base of 15 million. Finding suitable space for a cylinder is difficult when combination boilers have been installed. New build developers likely never anticipated the need for this, while space in older properties will likely have been repurposed in the intervening years.

There are potential solutions, like adding horizontal cylinders in a loft space, siting the cylinder in a garage or opting for a hybrid heat pump solution but these can be expensive and complex jobs. Moreover, horizontally mounted cylinders are generally less efficient and have lower hot water output equivalent vertical models. That said, the UK still has an installed base of roughly nine million system and regular boilers with cylinders in place. Consideration should be given to incentivising the retention of the cylinder on boiler exchange and/ or promoting a cylinder upgrade to prepare for future low-carbon options, such as heat pumps or hydrogen boilers.

6a. Low-Temperature Ready Cylinders

The use of low-temperature system ready cylinders should be encouraged when replacing a hot water storage cylinder. These will have high levels of thermal insulation and either a high-efficiency coil heat exchanger fitted or the option to fit an external plate-to-plate heat exchanger at a later date. There are already models of this type on the market and choice will grow if the use is incentivised or mandated.

Hot water storage cylinders can also be adapted to accept excess electrical energy input from home PV arrays. There is also opportunity to connect the hot water store to flexible tariff electricity supplies, so that grid electricity can be used when there is excess generating capacity at low cost to the consumer. Treating hot water storage appliances as a thermal store is estimated to add 70GWh of energy storage to the current installed base.

6b. Shower Waste Water Heat Recovery

Many new build properties now include shower waste water heat recovery as an energy saving measure. Such complementary technologies could also be considered when installing a new cylinder. These devices exchange residual heat from used shower water with the cold water supply, pre-heating it to reduce the energy required to heat it to a usable temperature.

Actions

From this analysis it is clear that the following needs to be developed:

- Comprehensive industry guidance on how to retrofit low carbon heating appliances into older properties
- Comprehensive industry guidance on how to retrofit low-carbon heating appliances into properties that have micro bore heating systems
- Policy and regulatory steps to encourage the retention and installation of hot water cylinders
- Policy and regulatory steps to encourage the replacement of radiators with designs suitable for low-temperature heating systems
- Explore the potential for targeting specific types of heat appliances to certain housing types
- Policy and regulatory steps to include system balancing
- Consumer awareness of the benefits of heating controls including TRVs

05. Heating System Replacement Installations – Process

Lowering carbon emissions means reducing the amount of energy needed for heating and hot water. This change requires care, with consideration of the building type and existing system fitted. It also means applying best practice to deliver high-efficiency systems that offset the higher cost of electricity when compared to gas.

Installers will often replace like-for-like with an existing boiler, possibly adding a control upgrade on a combination system to comply with Boiler Plus regulation introduced in 2018. At present, control improvements are not mandatory on other systems but are desirable for energy efficiency.

To best prepare for the future, the following points should be considered and discussed with the homeowner.

- Can a heat pump be installed?
- Can a 'hybrid' heat pump be used?
  (e.g. installation of a heat pump together with the incumbent boiler if of newer specification)
- Can a low-carbon ready system with a new high-efficiency boiler be used?
  (This would prepare the system for hydrogen or heat pumps in the future)

The issue of additional cost over the traditional 'boiler swap' will be key for all of the above. Industry also needs to consider the inconvenience of having to find space for a DHW cylinder, the replacement of microbore pipework, the installation of larger surface area radiators and any increased fabric insulation.

The type of existing boiler fitted (combination/ system/ open vent) and level of home insulation has a significant impact on 'low-carbon ready' installations. The key here is to make sure an accurate evaluation of the home energy needs is carried out, with records kept for future examination at net zero plans progress. Even if a gas boiler is retrofitted, the system should be made low-carbon ready, operating at lower heating temperatures and delivering higher system efficiencies. This would then allow future installation of either a heat pump or hydrogen boiler as both operate effectively at a 50°C mean water temperature.

Older systems would likely have a been designed for a higher mean water temperature, largely an MWT of 70°C and more recently, in new build 60°C.

In principle, the following approach should be applied:

There should be detailed guidance to conduct this process, recording any interventions. It should also state

Assess – data opportunity (measure and record intervention?)

- Fabric
- System
- Heat Generator (incl. Fuel factor)

Design – Assessment NOW required every time, Low Carbon and Efficiency knowledge required

Fabric – suitable or requires upgrade

System – depending on fabric emitters stay as-is or upgraded to LC <55°C

Heat generator – repair, like for like replacement, change of tech

Hot water tank – first time install (i.e. change from Combi), replaced

Waste Water Heat Recovery – suitable for WWHR?

Install – skills and competence to fit in accordance with the Design and repair, service and maintain

Installed in accordance with the Design and Manufacturers instructions

Commission

Operates the installation for the first time and check its working as designed

Benchmark is the leading industry tool for commissioning – as a commissioning tool it could be extended for the installer to sign off and record any work done on the home. Final stage would be notified service step into a scheme to record the changes (link to ACS and Gas Safe equivalent to LowC scheme)

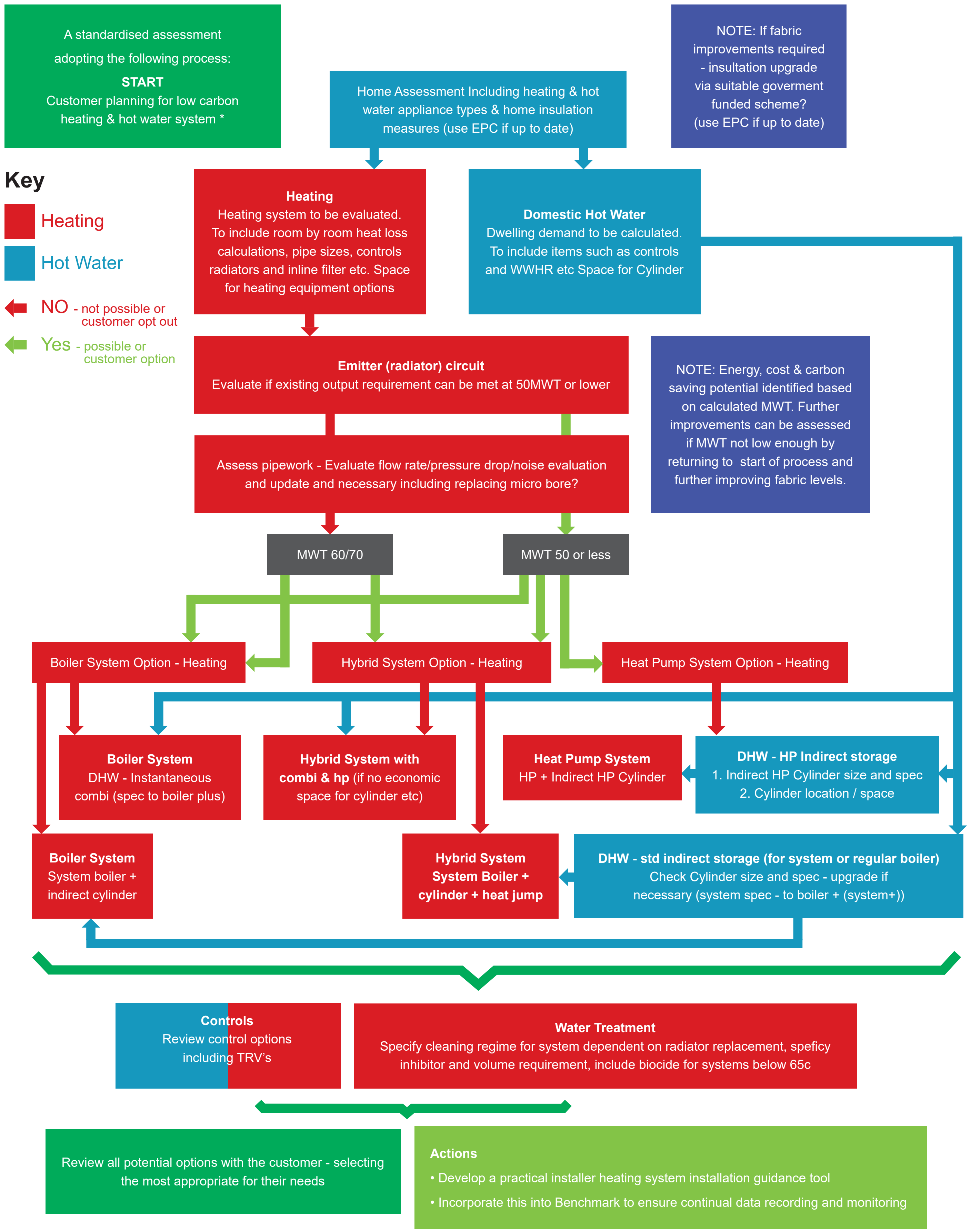
Record

Final stage would be a notified service step into a scheme to record the changes (links to ACS and Gas Safe equivalent low C scheme) – for all changes

Close look back into the assessment (BEFORE AND AFTER)

the resulting home condition, whether by EPC, or by a potentially more interactive and accessible method. The Benchmark scheme via its digital platform could be used for this purpose. This would give the installer, customer and government access to relevant information to allow monitoring and development of the housing stock and systems.

A standardised assessment adopting the follo



*The chart outlines the process planning for upgrading a system that can operate at 50c MWT or below which may be linked to a suitable government funding scheme. However, this process may not be suitable if the replacement heating system is required in a distress purchase situation

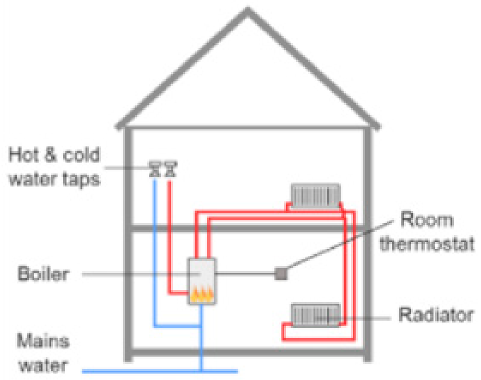
This diagram is general guidance and does not preclude future innovation

06. Typical Heating Systems in the UK

This section covers the different installed systems in the UK housing stock and identifies all potential areas where the system efficiency and carbon emissions could be improved.

Gas Combination Boiler System – c. 15 Million Installed

Combi Set Up Overview



Installed Base	2020 Volume
c. 15m (c. 60% on gas properties)	1.32m
Pros	**Cons**
• Compact size • Efficiency • Can be cheaper to purchase • Hot water on demand	• Not suitable for larger homes with multiple bathrooms requiring hot water at the same time • Needs good mains pressure

System Type	Boiler Type	System Components						
Combi	Combi	Control	Radiator	TRV	Pipework	Filter	Cleaner and inhibitor	
								• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100%	80%	25%	25%	Boiler swap 2% Boiler change and new location = 15%	90%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

There are several options when making an intervention due to product failure with a home's incumbent combination gas boiler system.

Product Repair

If the boiler can be repaired then possible systems upgrades listed earlier should be considered.

Product Replacement

There are number of options when replacing older appliances and readying them for a low-carbon future.

1. New Boiler

Boiler Plus legislation dictates that a new or replacement gas boiler installation must have a minimum ErP efficiency of 92%, as well as time and temperature controls installed if not already. For a combination boiler, either a controls upgrade (smart, weather compensation or load compensation controls) or flue gas heat recovery device must also be fitted. In line with the process detailed in section four, assessment of building fabric, heat losses and potential system improvements (radiators, TRVs, system filters etc.) should be supported.

2. Replacement with a Heat Pump System

In this scenario, a heat pump would require reinstallation of a domestic hot water cylinder. Combination boilers have been the product of choice for small- to medium-sized new build homes for over two decades, as have microbore pipework systems over the same time period. Radiator sizing is therefore likely to have been calculated on the heat loss of the property using a 70°C MWt heating system. Combining these facts, it is likely that many homes over the last 20 years will need upgrades or modifications for an effective heat pump install. The property would also need to have appropriate external space to site the heat pump outdoor unit and be positioned to minimise the noise. Consider for permitted development and planning if the size of the external unit exceeds 0.6 m3.

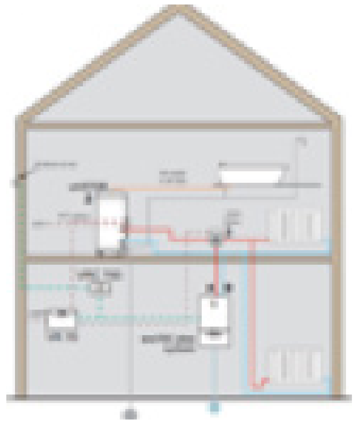
3. Upgrade to a Hybrid Heat Pump System

The changes required to fit a full heat pump system are significant. Installation of a hybrid heat pump system offers one solution if the homeowner does not want extensive changes made to their property. This approach can still yield up to 80% carbon savings with far less modification or disruption. Providing the existing boiler is relatively new, a heat pump could be sized at 50% of the property's maximum heat demand but still provide 80% of the central heating supply over a full year. This would satisfy demand for the majority of the winter, with the boiler providing heat for domestic hot water and only being used for heating during the coldest periods.

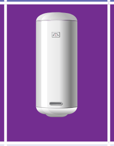
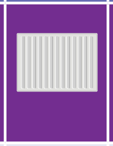
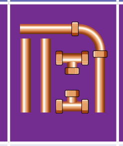
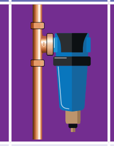
The property will still need to have appropriate external space to site the heat pump outdoor unit and consider planning permissions if the unit exceeds 0.6 m3. However, at 50% of the max heat demand of the property this is unlikely to be an issue. If the hybrid heat pump option is still not possible, it is worth concentrating on targeted upgrades of the system to improve efficiency and prepare it for hydrogen in the future.

Gas System Boiler – c. 5 million Installed

System Set Up Overview



Installed Base	2020 Volume
c. 5m (c. 25% on gas properties)	169k
Pros	**Cons**
• No tank in loft • Can serve multiple taps hot water – ideal for larger homes • Less susceptible to effects of frost build up since all components are built into the boiler itself	• Hot water isn't supplied instantly • Space for water tank

System Type	Boiler Type	System Components							
System	System	Cylinder	Control	Radiator	TRV	Pipework	Filter	Cleaner and inhibitor	
									• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100%	60%	80%	25%	25%	Boiler swap 2% Boiler change and new location = 15%	90%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

There are several options when making an intervention due to product failure with a home's incumbent gas system boiler.

Product Repair

If the boiler can be repaired then possible systems upgrades listed earlier should be considered.

Product Replacement

1. New Boiler

Boiler Plus does not currently apply to system boilers, though this may be reviewed in the future. It is highly likely system boilers will be need to meet similar requirements in the future. Again, assessment of building fabric, heat losses and potential system improvements should also be supported.

In this scenario the home will already have a cylinder in place. Incentives should be considered to retain these units if they have an ErP efficiency rating of C or above. This work would futureproof the home's heating and hot water system. If it is rated lower than C, replacement with a higher efficiency model is recommended.

2. Replacement with a Heat Pump System

This scenario would benefit from the cylinder already being installed. To ensure efficient and effective hot water production, however, the unit would likely need upgrading to a model with a larger heat exchanger surface area. Fortunately, the presence of microbore system pipework in these systems is less likely when compared to use of combination boilers in newer housing.

Much like homes with combination boilers, the property would still need to have appropriate external space to accommodate the outdoor unit. Homeowners would also need to consider permitted development and planning if the size of the unit exceeds 0.6 m^3.

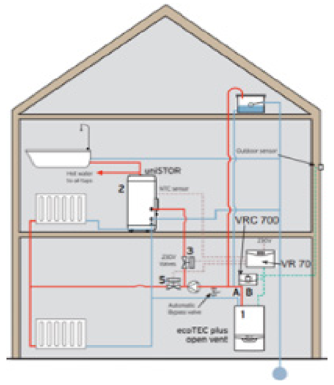
It appears homes with gas system boilers are more amenable to replacement with a heat pump as there is a lower chance of additional works required.

3. Upgrade to a Hybrid Heat Pump System

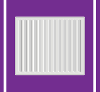
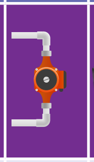
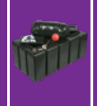
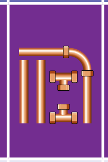
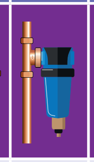
The solution in this scenario is very similar to homes fitted with combination boilers. However, with gas system boilers heat pumps can also be used to contribute to domestic hot water production as well as central heating.

Open Vent (regular) Boiler System – c. 4 million Installed

Open Vent Set Up Overview



Installed Base	2020 Volume
c. 4m (c. 15% on gas properties)	225k
Pros	**Cons**
• Good for larger homes • Good for low water pressure • Good for replacing an old open vent heating system	• Needs space for a separate water tank

System Type	Boiler Type	System Components									
Open Vent	Open vent	Hot Water Cylinder	Control	Radiator	Pump	Cold water storage	TRV	Pipework	Filter	Cleaner and inhibitor	
											• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100%	60%	80%	25%	80%	25%	25%	Boiler swap 2% Boiler change and new location = 15%	80%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

An open vented or regular boiler system has similar characteristics to a system boiler. These systems still have a DHW cylinder but, if unchanged since first install, could also be working under a head pressure from a cistern tank in the loft rather than mains pressure. Either way, the cylinder would still need to be upgraded for a heat pump installation. Fortunately, many of the original open vented installations have already been converted to a sealed system to create a 'dry loft' and minimise freezing issues associated with pipes and storage cisterns during winter.

It appears such systems are well positioned for replacement with a heat pump system as less additional preparation work is required. The option to utilise a hybrid heat pump system is also possible.

Hybrid Heating System – c. 11,000 Installed

Heat Pump / Hybrid Set Up Overview

Installed Base	2020 Volume
c. 11k	1,300
Pros	**Cons**
• Reduced CO_2 and improved air quality • Lowest possible running costs • Reduced peak electrical load for grid • Use of existing system • Best of both worlds – HP for low and medium heating requirements, boiler for high heating requirement and hot water boost • Low carbon heating solution for properties with high heat losses	• Capital investment for 2 x heat sources

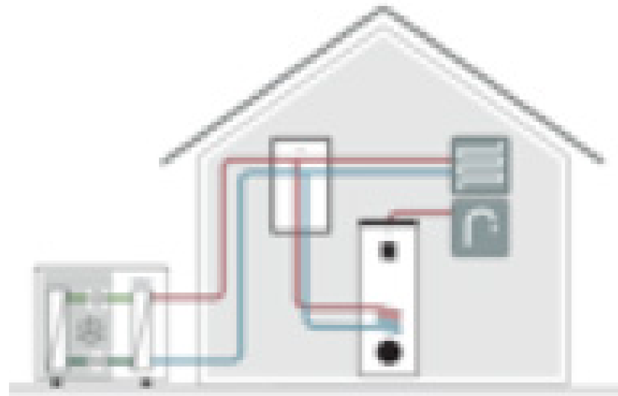
System Type	Appliance Type		System Components							
Hybrid	Heat Pump	Boiler (Combi or System)	Cylinder	Interface	Control	Radiator	Pipework	Filter	Cleaner and inhibitor	
										• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100% (either added to existing system or completely new)	80% (mostly replaced / distress, 20% remain)	95% alongside system boiler 0% with combi	100%	100%	50%	Boiler change and additional system piping = 20%	95%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

With a hybrid system, the heat pump can be added to an existing boiler system or installed when the boiler fails and needs replacing. There are a variety of hybrid units available that consist of a boiler, control system and an externally fitted heat pump. Also available is an integrated compact hybrid with no requirement for an outdoor unit. Hybrid systems can be installed when the heat loss of the fully insulated homes exceeds the output from a single-phase heat pump. The system controls work to optimise efficiency by choosing the most appropriate heat source for a given demand. As the boiler system remains in place, DHW provision is unchanged. With a combination system this can overcome the issue of siting and installing a DHW cylinder for a pure heat pump system. If the boiler is replaced due to failure, Boiler Plus requirements will apply.

It is possible to run an installed hybrid system on existing heat emitters. However, heat loss calculations should be carried out to check the radiator outputs at a lower operating temperature (50c MWt). If necessary, radiators will require replacement to provide the required output for a low-temperature system and increased efficiency.

Air Source Heat Pump – c. 275,000 Installed

Air to Water Heat Pump Set Up Overview



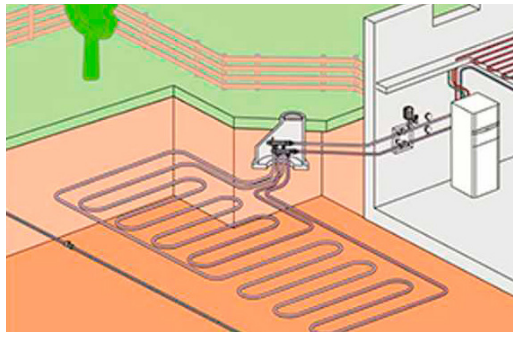
Installed Base	2020 Volume
c. 240k	43.5k
Pros	**Cons**
• Low running costs, which can help reduce energy bills • Homeowners could benefit from Government incentives • Removes the need for fuel to be delivered and stored at home • More environmentally friendly • They operate efficiently even in cold temperatures • 25% of energy used by heat pump is provided by electricity, with the remaining 75% being generated by the environment • Quiet operation • Heat pumps work well with both underfloor heating and radiators with low surface temperatures • Can be used as part of a climate controlled system within the home • Simple and robust technology with low maintenance and long service life	• Cost can be prohibitive • Possible unplanned disruption.

System Type	Appliance Type	System Components							
AWHP	Heat Pump	Cylinder	Interface	Control	Radiator	Pipework	Filter	Cleaner and inhibitor	
									• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100%	96%	100%	100%	50%	40%-100% (eg microbore)	95%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

Air source heat pumps (ASHPs) absorb heat from the outside air to heat the home and hot water, though they can still extract heat at low air temperatures. Heat from the air is absorbed at low temperature into a fluid. This fluid then passes through a compressor, increasing the temperature and transferring it to the home's heating and hot water circuits. Consideration should also be given to high temperature heat pumps as an alternative to fitting a hybrid

Ground Source Heat Pump – c. 50,000 Installed

Ground Source Heat Pump Set Up Overview



Installed Base	2020 Volume
c. 24.8k	3.9k
Pros	**Cons**
• Less noise than AWHP • Low maintenance and running costs • Generally longer lifespan • Government incentives available	• Cost can be prohibitive • Ground space required

System Type	Appliance Type	System Components								
GSHP	Heat Pump	Ground Loop	Cylinder	Interface	Control	Heat Emitters	Pipework	Filter	Cleaner and inhibitor	
										• Installation • Commission & Setup • Servicing / Maintenance
% replaced during new installation	100%	95%	95%	100%	100%	100%	40%-100% (eg microbore)	95%	100%	• Benchmark completion, customer handover. (x%) • Service and maintenance part of warranty T&C's

Ground source heat pumps (GSHPs) use pipes that are buried to extract heat from the ground. This heat can then be used to heat radiators, underfloor or warm air heating systems and hot water in the home.

07. Heat Loss Calculations – Benchmark

The whole house heat loss method can be used to calculate the kW output required to range rate a boiler – be it combination, open vented or system.

However, assessing the low-carbon potential of an existing heating system will require a room-by-room heat loss calculation, including minimum outside temperature and maximum mean water temperature. These calculations will identify emitter improvements that required for specific rooms and, importantly, identify individual spaces as 'hard to treat'. In turn, this will stop the entire property being classified as hard to treat.

These calculations should be included in the Benchmark along with the current mean water temperature and the potential energy saving mean water temperature. The results would then form part of a 'low-carbon readiness' indicator.

There are a number of heat loss calculation tools available. They should reference BS EN12831-1: 2017 and preferably be integrated into the digital Benchmark platform.

Actions

- Explore incorporating room by room heat loss calculations into Benchmark
- Explore regulatory options for mandating heat loss calculation and recording

08. Energy Performance Certification – EPCs/Benchmark and the Home Passport

The EPC plan was published in September 2020, setting out a series of actions following calls for evidence in July 2018. To maximise the effectiveness of improving the performance of the existing housing stock, EPCs should provide a trusted, accurate and reliable measure of energy performance and engage consumers on the issue of reducing their energy consumption. Consumers and third parties should also have access to the data to inform their decisions.

EPCs are currently a cost calculation methodology and it would be beneficial for an EPC to clearly state the difference between efficiency and running costs. The Building Regulations may also offer a guideline to change. Assessment of heating systems for low-carbon readiness is best suited to qualified installers. The Benchmark document could serve as the platform for not only recording completed works but also assessment of future energy saving heating system upgrades. The Benchmark has the potential to become the 'heating system' chapter of any future home energy passport.

Benchmark has been launched via a digital platform in Q1, 2021. It is planned to develop this platform further. This includes a consumer app, launching later in 2021 allowing homeowners to access records of services and maintenance.

This system does not propose to replace the EPC but rather develop it into a consumer-facing proposition. At the centre of Benchmark is the installer, who has been chosen by the consumer to work on their heating system. Future system improvements could be aggregated and incentivised. To minimise disturbance these improvements could be planned and a convenient time between consumer and installer.

Installer Upskilling

Installers are key part of the jigsaw for decarbonising heating and hot water systems. They are the main point of contact with the homeowner, providing the solution and cost for the method of delivery.

Hydrogen-ready appliances, heat pumps and hybrid systems will become more important as the government looks to cut carbon emissions. As such, it is vital heating engineers proactively include low-carbon technologies in their portfolio. Industry training from manufacturers will prepare them for consumer demand of these products. This not only applies to engineers already installing established technologies, like today's gas boilers, but also new entrants to the market. This training makes the apprentice a more valuable asset. The following details a selection of the current training available today or in development.

- **Low-Carbon Heating Technician Apprenticeship** – Level 3 'trailblazer' proposal is now approved, with a standard being developed for the next stage, i.e. defining knowledge, skills and behaviours required of the occupation. Three-year duration envisaged.
- **Plumbing and Domestic Heating Technician** – An overview of all heating technology and one chosen specialism, e.g. gas, oil, environmental technology, ASHP, solar etc. Typical four-year duration.
- **Gas Engineering Operative** – Typical 18-month duration, gas focus, will be impacted by IGEM IG/1,
- **Competence framework for hydrogen** – Training for gas operatives in low-carbon hydrogen

Further development should provide training for new starters and include recognised, staged development courses. This could include an accredited certification scheme, low-temperature heating system design/ heat pump introduction, and expert-level courses all supported by a suitable skills card. All of this has the potential to link to current legislation such as the home Energy Performance Certificate and the Benchmark scheme.

Homeowner Communication, Education and Incentivisation

Currently the majority of replacement gas boilers are 'distress purchases' due to the failure of the original appliance. Straightforward incentives need to be in place to encourage homeowners to improve levels of insulation and to upgrade their heating and hot water system. This paper has highlighted that adding three easily installed insulation measures, retaining hot water cylinders and upgrading the heating system can help the homeowner to reduce energy usage and prepare a plan for decarbonisation their heating and hot water system.

It is suggested that more information is required for the homeowner regarding options for improving their property. A suitable consumer hub is seen as important part of the process. Industry has also suggested the use of a 'home passport', building on the Energy Performance Certificate to more information and an achieve a true record of the home's carbon emissions performance and running cost.

09. Conclusion

Transitioning homes to low-carbon heating and hot water systems is a complex process and will require a range of different solutions. This challenge is only made more difficult by the UK's disparate housing stock, dominated by older properties using mains gas as the main heat generation source. These homes are also more likely to have insufficient levels of insulation when compared to new build and there is a high chance the original installed heating system was designed around high-temperature primary circulation with a lower degree of control.

Switching to low-temperature heating will raise efficiency and reduce carbon emissions but also support the use of key future technologies like heat pumps and hydrogen boilers. Designing for such systems from new is relatively straightforward but considerable work is needed to prepare legacy building stock for a net zero economy.

The Challenge of Newer Homes

Even more recent builds pose problems. Since the late 1980s there has been a move towards the use of combination boilers in small- to medium-sized properties, where domestic hot water is produced instantaneously. This eliminated the need for a hot water storage cylinder, leaving many newer property designs without space for one. Heat pump output powers do not support instantaneous heating of hot water, meaning upgraded systems will once again require the use of a hot water store (or means to store the thermal energy produced for hot water). This presents a major challenge for transitioning homes with combination boilers over to low-temperature systems.

Similarly, microbore circulating pipework has been widely used since the 1970s. In high-temperature systems the primary circulation flowrates are relatively low so the higher flow resistance generated by microbore pipes does not cause issues. However, low- temperature systems, like those using heat pumps, require much higher circulation rates. It is likely that many existing systems will require replacement of at least some pipework where new heating appliance are set to be installed. It is likely that radiators were also sized based on higher flow temperatures, meaning some will need replacing to achieve a sufficient heat output.

These kinds of major retrofit exercises will be expensive and disruptive for many people. Yet there is now an urgent need to transition existing building stock over to newer low-carbon heating and hot water systems. As such, homeowners will likely need incentivising so that proactive work can be carried out. This will mean appropriate consideration of heat pumps, hybrids and preparing for hydrogen boilers.

Preparing for the Future

Ensuring systems are suitable for heat pumps or other low-temperature heating systems will mean retaining the hot water store. In new build, it should be mandated that space be retained for future installation of a cylinder, while older properties should be encouraged to replace. As with many heating appliances, old cylinders are relatively inefficient, having a much higher heat loss, poor thermal transfer characteristics and a very simple interface with the heating system. The introduction of a cylinder scrappage scheme, or discounted purchase scheme for DHW cylinders or thermal stores, would not only make hot provision more efficient but equip homes with appliances necessary for future low-carbon technologies.

This paper highlights that hybrid approaches could be an effective way to accelerate the move to low-carbon heating. Use of a control system ensures that the most suitable technology is used, with a heat pump satisfying the majority of a home's demand. The remaining gas boiler would only be used for support during coldest days of the year when demand is highest. Again, homeowners will need incentives to take this step, not least sight of lower running costs.

This paper has also shown there remains a significant number of households using a mains gas combination boiler. In many cases, major changes to pipework, controls and heat emitters will be necessary in these properties, notwithstanding the lack of a hot water store. These systems are best suited to replacement with a hydrogen boiler but the infrastructure necessary to deliver this system is still in development. Clear commitment from the government in support of a hydrogen grid will be necessary to incentivise boiler manufacturers to develop H2-ready models. Projects like HyDeploy, the UK's first demonstration of hydrogen in homes, will be essential for proving the fuel's viability and more should be rolled-out across the country.

Opportunities

There are many challenges ahead but also a number of opportunities. Existing boilers are more efficient if operated at lower primary flow temperatures though this may require upgrades to system piping and controls. However, mandating low-temperature system retrofit measures would reduce the cost of adding a heat pump at a later date. Low-temperature heating systems with existing gas boilers can also deliver 6% to 8% efficiency improvements and should not be overlooked as part of a wider programme of change. This is especially relevant where properties have already received insulation upgrades.

Perhaps most important of all, this paper has shown that extensive retraining of the installer base will be necessary for any successful transition. This will ensure correct assessment of existing systems, as well as the identification of appropriate technologies and system improvements, including design, installation and commissioning. All low-carbon technologies require this to ensure the theoretical energy savings are realised in practice.

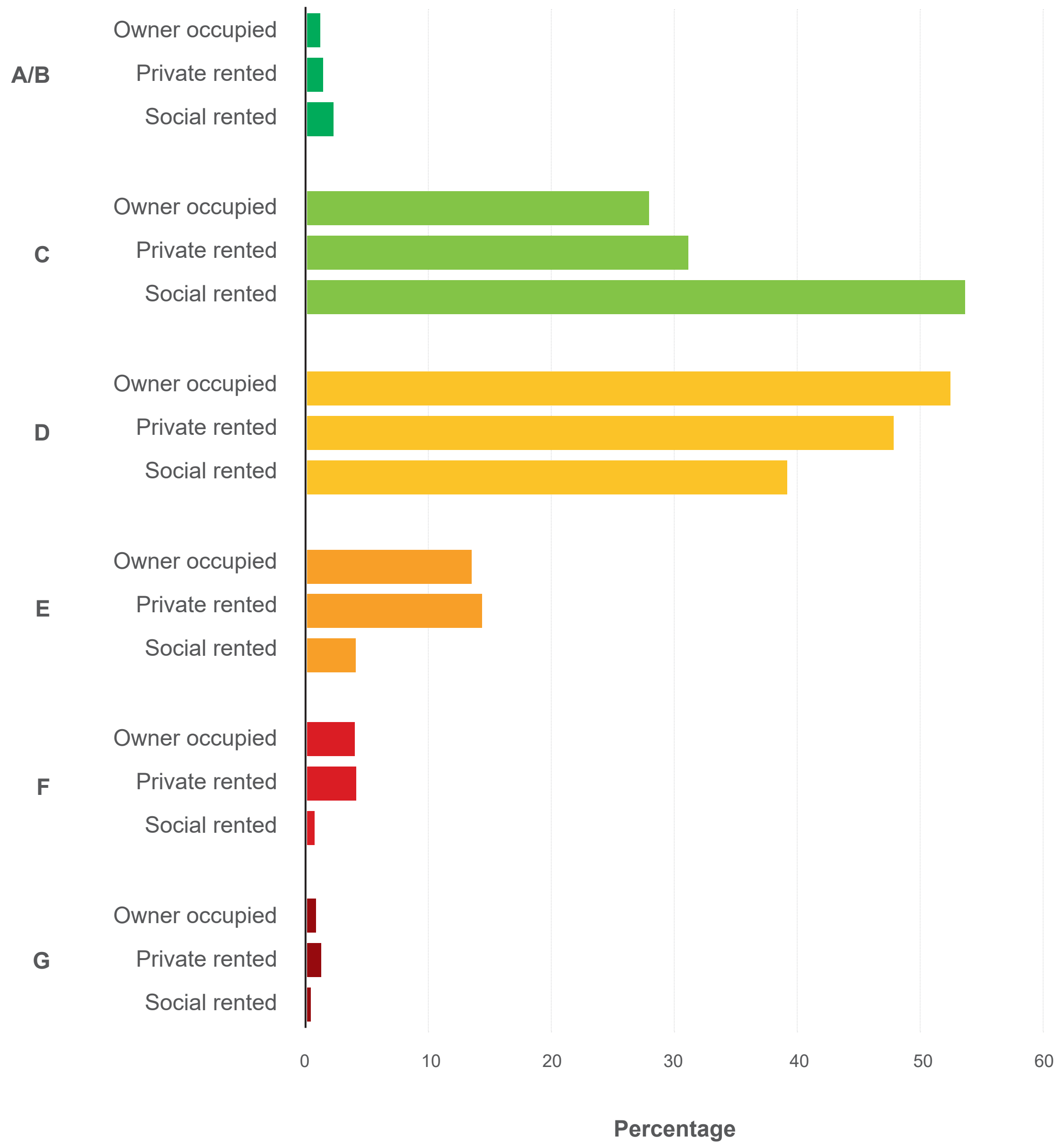
Consumer awareness campaigns will also be needed to help homeowners understand why transition is vital. This should include information about differences in performance and why behavioural changes are necessary to extract the best energy savings and carbon reductions. The campaign can be backed by installers but would benefit from targeted advice from trusted third-party consumer advice bodies.

10. Appendices

Appendix 1:

EPC Bands by Tenure

(Source: English Housing Survey – Reference 5)



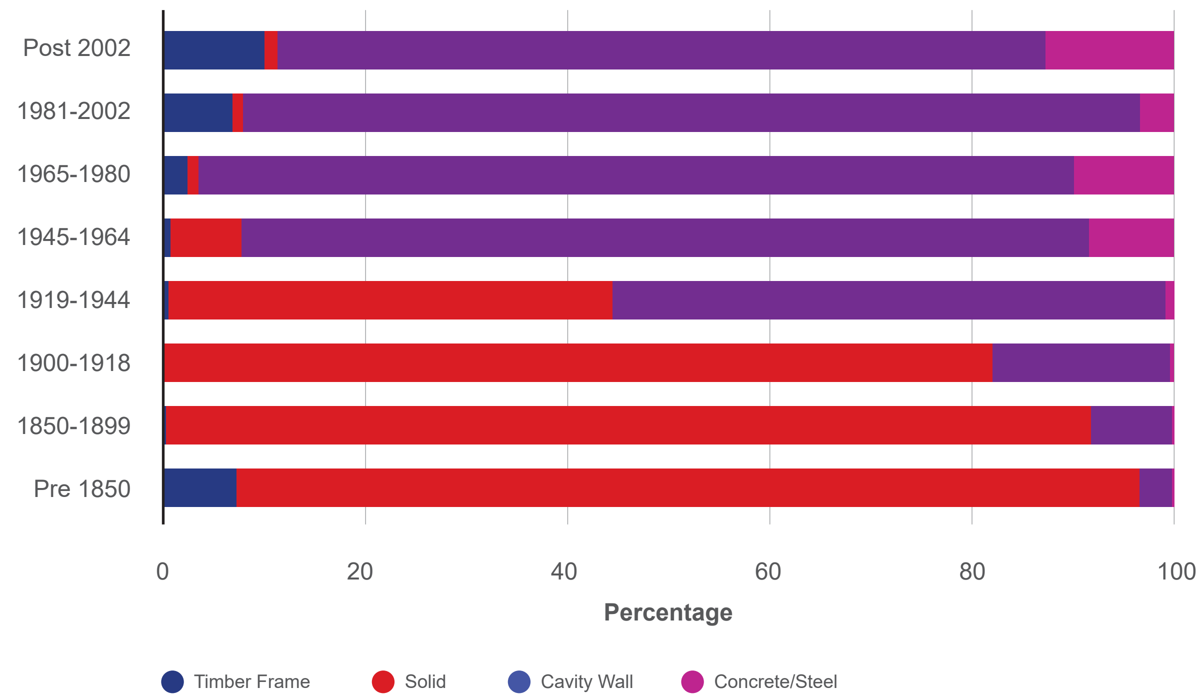
Appendix 2:

Housing Stock Data for the UK

(Source data for Figure 3 – From Reference 4)

	England	Scotland	Wales	Northern Ireland [1]	UK
Dwelling age					
Pre 1919	4,972	467	351	82	5,871
1919-1944	3,793	291	133	68	4,284
1945-1964	4,582	544	219	126	5,472
1965-1980	4,689	515	304	189	5,698
1981-1990	1,895	194	99	99	2,287
Post 1990	4,019	452	235	216	4923
Dwelling type					
Terrace	6,669	534	376	221	7,829
Semi-detached	6,100	481	369	180	7,129
Detached	4,093	554	296	164	5,107
Bungalow	2,195	inc. within other categories	154	164	2,512
Flat	4,864	895	147	52	5,958
Dwelling tenure					
Owner occupied	15,089	1,491	924	512	18,016
Private rented	4,789	346	180	146	5,460
Social rented	4,072	626	238	122	5,058
Location					
Urban	19,796	2,055	900	503	23,254
Rural	4,154	409	441	277	5,281
Total dwelling stock	23,950	2,464	1,342	780	28,536
Average dwelling size	94 m^2	98 m^2	102 m^2	105 m^2	95 m^2
Dwelling age					
Pre 1919	20.8%	19.0%	26.2%	10.5%	20.6%
1919-1944	15.8%	11.8%	9.9%	8.7%	15.0%
1945-1964	19.1%	22.1%	16.3%	16.2%	19.2%
1965-1980	19.6%	20.9%	22.7%	24.3%	20.0%
1981-1990[2]	7.9%	7.9%	7.4%	12.8%	8.0%
Post 1990	16.8%	18.4%	17.5%	27.7%	17.3%
Dwelling type					
Terrace	28.0%	21.7%	28.0%	28.3%	27.4%
Semi-detached	25.5%	19.5%	27.5%	23.0%	25.0%
Detached	17.1%	22.5%	22.1%	21.0%	17.9%
Bungalow	9.2%	inc. within other categories	11.5%	21.0%	8.8%
Flat	20.3%	36.3%	11.0%	6.7%	20.9%
Dwelling tenure					
Owner occupied	63.0%	60.5%	68.9%	65.6%	63.1%
Private rented	20.0%	14.0%	13.4%	18.7%	19.1%
Social rented	17.0%	25.4%	17.7%	15.6%	17.7%
Location					
Urban	82.7%	83.4%	67.1%	64.0%	81.5%
Rural	17.3%	16.6%	32.9%	36.0%	18.5%

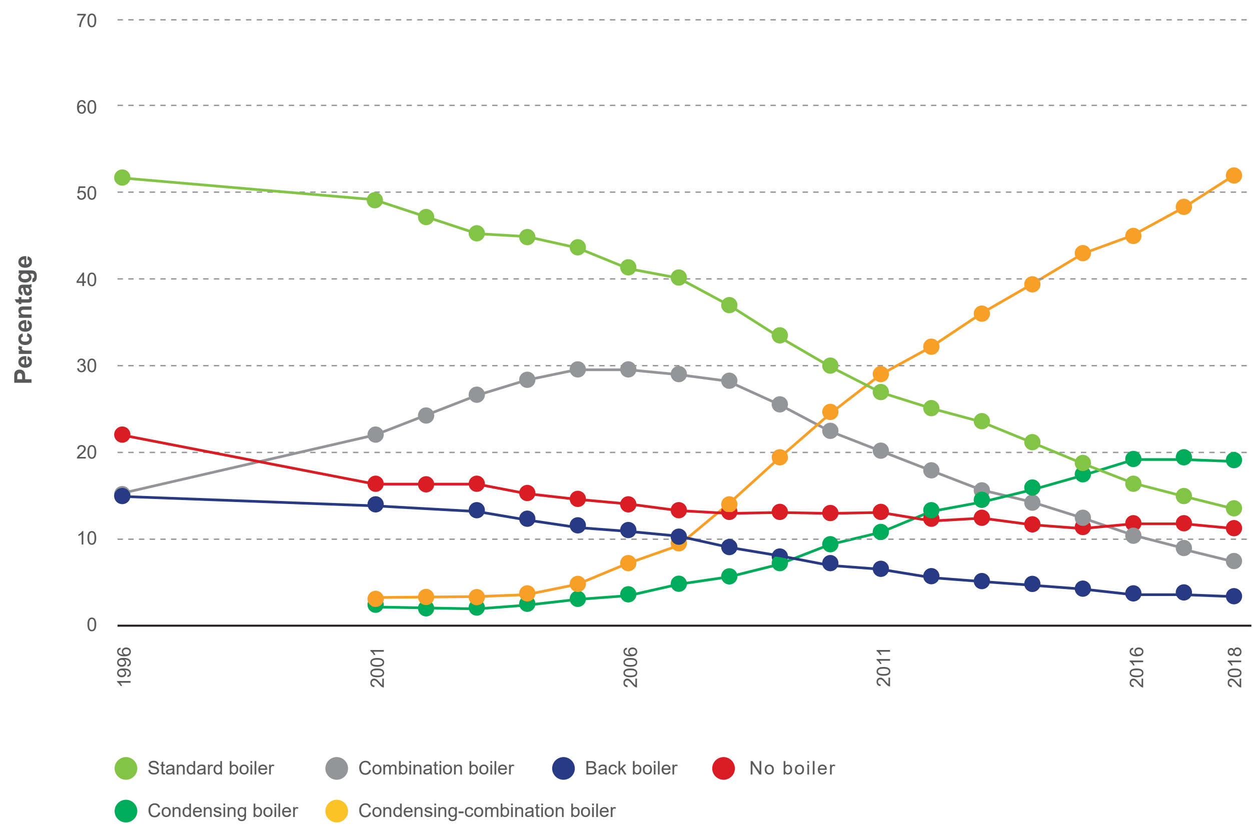
	England	Scotland	Wales	Northern Ireland	UK
Total population (thousands)	55,619	5,425	3,125	1,871	66,040
Total households (thousands)	23,272	2,464	1,350	742	27,828
Average household size	2.39	2.20	2.31	2.52	2.37
Average number of persons per occupied dwelling	2.43	2.20	2.33	2.49	2.41
Total population	84.2%	8.2%	4.7%	2.8%	100.0%
Total households	83.6%	8.9%	4.9%	2.7%	100.0%
Gas central heating	20,375	1,966	1,100	186	23,627
Oil central heating	929	143	135	526	1,733
Other central heating	716	105	35	61	917
Electric (storage heaters)	1,223	183	48	N/A	N/A
Fixed heating	707	67	23	N/A	N/A
Gas central heating	85.1%	79.8%	82.0%	23.8%	82.8%
Oil central heating	3.9%	5.8%	10.1%	67.5%	6.1%
Other central heating	3.0%	4.3%	2.6%	7.8%	3.2%
Electric (storage heaters)	5.1%	7.4%	3.6%	N/A	N/A
Fixed heating	3.0%	2.7%	1.7%	N/A	N/A



Appendix 3:

Boiler System Types in UK Housing Stock

(Source: English Housing Survey – From Reference 5)



Appendix 4:

Radiator Mean Water Temperature Reduction From 70°C to 50°C

(Source: Manufacturers Association of Radiators & Convectors)

Energy Calculation for Reducing Mean Water Temperature

New Build Property – 80m²

Energy saving moving from 70° to 50° mean temp. = 6.4%

CO_2 saving 73kG/year

	Units	70° Mean Heating	70° Mean Heating	50° Mean Heating
Technology Use		YES	YES	YES
		1	1	1
System Description		SAP 80m² new build standard control	SAP 80m² new build with compensating control	
Property Floor Area	M²	80	80	80
House Heating Requirement	kWh	3323	3323	3323
House DHW Requirement	kWh	1845	1845	1845
Total House Energy Requirement	kWh	5168	5168	5168
Product Efficiency	fraction	0.891	0.94	0.989
Product Efficiency DHW	fraction	0.891	0.891	0.891
Energy for Heating Required	kWh	3729.52	3535.11	3359.96
Energy for DHW	kWh	2070.707071	2070.707071	2070.707071
DHW Provided by Solar Thermal	kWh			
Total Energy		5800.22	5605.81	5430.67
Fuel Tariff	p/kWh	4	4	4
Fuel CO_2 Emission $kgCO_2/kWh$		0.198	0.198	0.198
CO_2 Emission kg/year		1148.44	1109.95	1075.27
Annual Cost	£	232.01	224.23	217.23
RHI Tariff	p/kWh	0	0	0
RHI Tariff Lifetime	Years	0	0	0
RHI Annual Benefit	£	0	0	0
Net Annual Fuel Cost	£	232.01	224.23	217.23

Energy Calculation for Reducing Mean Water Temperature

Older Property

Energy saving moving from 70° to 50° mean temp. = 7.85%

CO_2 saving 210kG/year

	Units	70° Mean Heating	70° Mean Heating	50° Mean Heating
Technology Use		YES	YES	YES
		1	1	1
System Description		Older Property standard control	Older Property compensating control	
Property Floor Area	M²			
House Heating Requirement	kWh	9500	9500	9500
House DHW Requirement	kWh	2500	2500	2500
Total House Energy Requirement	kWh	12000	12000	12000
Product Efficiency	fraction	0.891	0.94	0.989
Product Efficiency DHW	fraction	0.891	0.891	0.891
Energy for Heating Required	kWh	10662.18	10106.38	9605.66
Energy for DHW	kWh	2805.836139	2805.836139	2805.836139
DHW Provided by Solar Thermal	kWh			
Total Energy		13468.01	12912.22	12411.50
Fuel Tariff	p/kWh	4	4	4
Fuel CO_2 Emission $kgCO_2/kWh$		0,198	0,198	0,198
CO_2 Emission kg/year		2666.67	2556.62	2457.48
Annual Cost	£	538.72	516.49	496.46
RHI Tariff	p/kWh	0	0	0
RHI Tariff Lifetime	Years	0	0	0
RHI annual Benefit	£	0	0	0
Net Annual Fuel Cost	£	538.72	516.49	496.46

Energy Calculation for Reducing Mean Water Temperature

Larger Floor Area Property

Energy saving moving from 70° to 50° mean temp. = 7.8%

CO_2 saving 264kG/year

	Units	70° Mean Heating	70° Mean Heating	50° Mean Heating
Technology Use		YES	YES	YES
		1	1	1
System Description		Large Property Standard control	Large Property compensated control	
Property Floor Area	M^2			
House Heating Requirement	kWh	12000	12000	12000
House DHW Requirement	kWh	3200	3200	3200
Total House Energy Requirement	kWh	15200	15200	15200
Product Efficiency	fraction	0.891	0.94	0.989
Product Efficiency DHW	fraction	0.891	0.891	0.891
Energy for Heating Required	kWh	13468.01	12765.96	12133.47
Energy for DHW	kWh	3591.470258	3591.470258	3591.470258
DHW Provided by Solar Thermal	kWh			
Total Energy		**17059.48**	**16357.43**	**15724.94**
Fuel Tariff	p/kWh	4	4	4
Fuel CO_2 Emission $kgCO_2/kWh$		0.198	0.198	0.198
CO_2 Emission kg/year		**3377.78**	**3238.77**	**3113.54**
Annual Cost	£	682.38	654.30	629.00
RHI Tariff	p/kWh	0	0	0
RHI Tariff Lifetime	Years	0	0	0
RHI Annual Benefit	£	0	0	0
Net Annual Fuel Cost	**£**	**682.38**	**654.30**	**629.00**

Installed Base of Different Generic System Types in U.K. Homes in 2019

	2019
Gas Combi	15,000,000
Gas OV/System (with cylinder)	9,100,000
Heat Pump	250,000
Electric	1,450,000
Oil	1,700,000
LPG 300k included in Gas	
Other (inc H2)	900,000
Total	**28,400,000**

Reference

BRE Trust: **The-Housing-Stock-of-the-United-Kingdom_Report_BRE-Trust.pdf**

and

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Installed Base of Different Generic System Types in U.K. Homes – Forecast to 2025

	2019	2020	2021	2022	2023	2024	2025
Gas Combi	15,000,000	15,050,000	15,100,000	15,150,000	15,200,000	15,200,000	15,200,000
Gas OV/System (with cylinder)	9,100,000	9,153,000	9,238,000	9,296,000	9,328,000	9,365,000	9,304,000
Heat Pump	250,000	285,000	355,000	474,000	641,000	875,000	1,226,000
Electric	1,450,000	1,465,000	1,480,000	1,495,000	1,510,000	1,525,000	1,540,000
Oil	1,700,000	1,683,000	1,649,000	1,608,000	1,560,000	1,505,000	1,445,000
LPG 300k included in Gas							
Other (inc hydrogen)	900,000	914,000	928,000	942,000	956,000	970,000	985,000
Total	28,400,000	28,550,000	28,750,000	28,965,000	29,195,000	29,440,000	29,700,000

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