Task 1: Market Overview

IEA-HPT Annex 45: Hybrid Heat Pumps

United Kingdom

December 2017

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1.1 Overview of main challenges in the UK

The characteristics of the UK building stock create one of the main challenges with regards to the use of heat pumps:

- The high average age of the building stock means there is comparatively low thermal quality of the building envelopes.
- There is an increasing trend towards removing storage tanks from UK homes because of lack of space, and the dominance of combi gas boilers.

The availability of relatively low cost gas and gas boilers creates a strong challenge for heat pumps – limiting the potential heat pump market size. The heating system stock in the UK is dominated by gas, which heats 85% of all dwellings. Even with the introduction of the domestic Renewable Heat Incentive in Spring 2014 it is expected that heat pumps will only pay back in off-gas grid buildings (i.e. replacing oil or electric heating). In 2020 heat pumps will therefore still only reach a very low penetration of the building stock.

The characteristics of UK buildings, combined with the current high proportion of gas use for domestic heating, provide a potential opportunity for hybrid heat pumps utilising gas boilers.

1.2 UK Housing Stock Characteristics

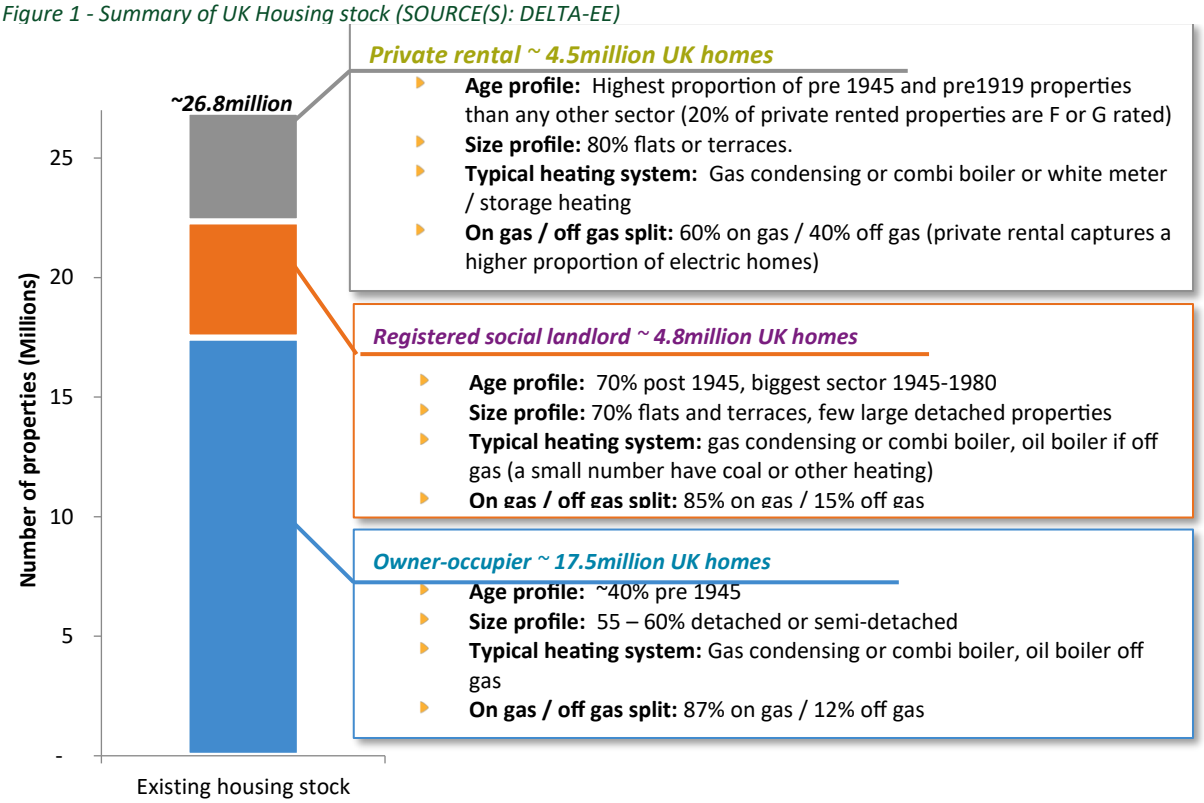
1.2.1 Customer types

In 2011 the dwelling stock in Great Britain comprised ~26.73 million dwellings[1]. **The dwelling stock is dominated by owner-occupied dwellings**, making up 65% of the total housing market. Social housing (18%) and privately rented property (17%) account for the rest of the dwellings.

- **The social housing sector has been the most important sector for heat pumps** - social housing providers are a major customer for heat pumps, driven by a need to overcome fuel poverty issues through reducing monthly energy charges for their tenants.
- **The owner-occupier sector is increasingly important for the heat pump market** (and is expected to see the fastest growth driven by the RHI). Owner-occupiers are able to make their own decisions regarding a heating system (unlike in the rented sector) - however, the upfront cost of a heat pump is still a strong barrier for investment in this sector.
- **The rented sector is not significant for heat pumps** – generally private landlords are not willing to make an investment which will benefit the tenant in running cost savings.

[1] Of these, 86% (22.98 million) were located in England, 8.88% (2.37 million) in Scotland and 5.17% (1.38 million) in Wales

Figure 1 - Summary of UK Housing stock (SOURCE(S): DELTA-EE)



1.2.2 Age of the building stock

In both the English and the Scottish dwelling stock more than 50% of dwellings have been built before 1965. In both regions approximately 78% of dwellings have been built before or in the early 1980s. This means that **a large share of the UK's building stock is has a relatively low thermal inertia, which requires constant heating and therefore significantly reduces the useability of the thermal mass of a building as energy storage.**

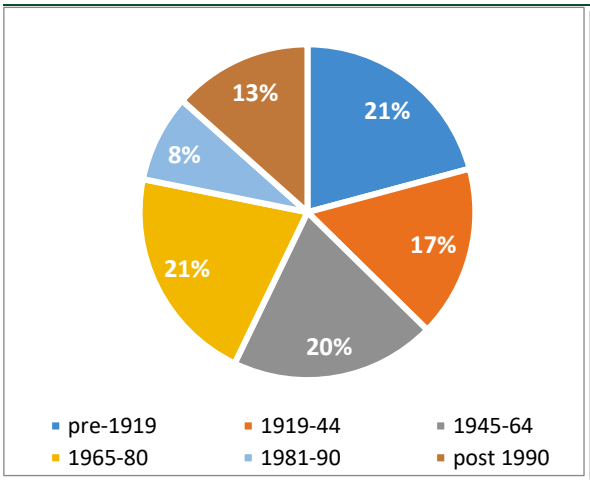


Figure 2 - England's Dwelling Stock 2011 by age

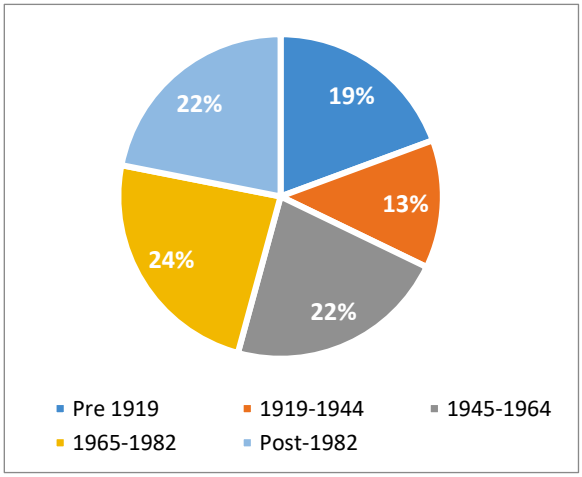


Figure 3 - Scotland's Dwelling Stock 2011 by age

Source(s): English Housing Survey 2013, DA1101: stock profile
Scottish House Condition Survey: Key Findings 2011

1.2.3 Thermal Performance

In terms of thermal performance, the UK building stock still requires some significant investment. As of 2013, a potential of 20.35 million energy efficiency improvement measures remains to be delivered:

Source(s): *DECC, Estimates of Home Insulation Levels in Great Britain: July 2013 (Experimental Statistics)*

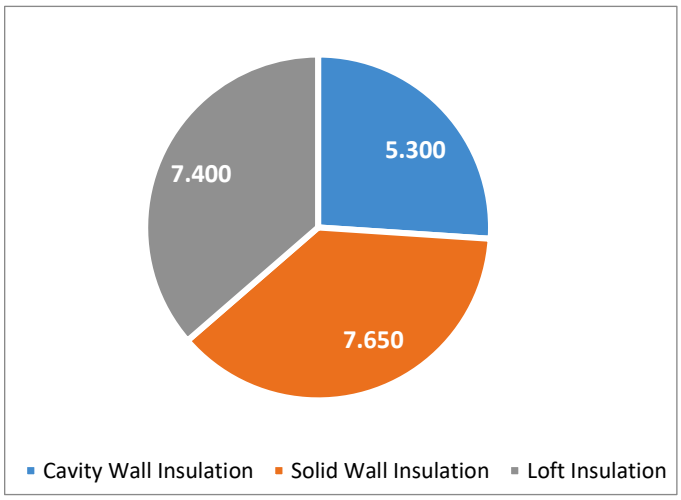


Figure 4 - Remaining potential for themal improvements in the UK building stock (000s)

The thermal efficiency of buildings in the UK is rated via the Standard Assessment Procedure (SAP). The SAP rating is based on a scale of 1-120, with 1 the worst and a score of 100 representing no net costs for water and heating (ratings >100 indicate a net benefit, e.g. through the feed-in of renewable electricity). The share of buildings in each rating band in England and Scotland can be seen below. **Less than 25% of homes in England achieve a "C" rating or above - underlining the need for improvements to be made in the energy performance of the UK building stock.**

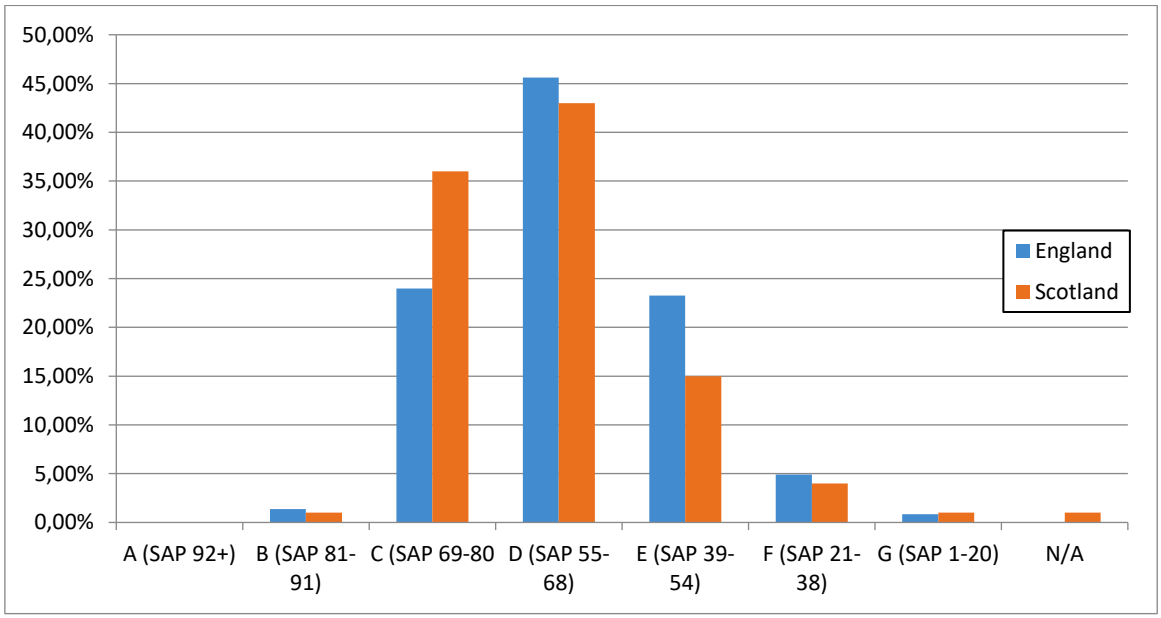


Figure 5 - ENERGY PERFORMANCE OF BUILDINGS IN ENGLAND AND SCOTLAND BY EPC RATING

Source(s): *DECC, Final Project Report, An investigation of the effect of EPC ratings on house prices, June 2013; Scottish House Condition Survey: Key Findings 2011; Delta-ee*

1.3 Trends in the Heating Market

The UK heating system stock is dominated by (relatively low cost) gas boilers, which account for 85% of the installed systems (and >90% of heating systems sold per year). This is currently the greatest barrier to the uptake of heat pumps in the UK – the electricity / gas price ratio (where gas is approximately a third of the price of electricity), combined with the availability of low cost gas boilers, makes it difficult for electric heat pumps to compete against gas economically.

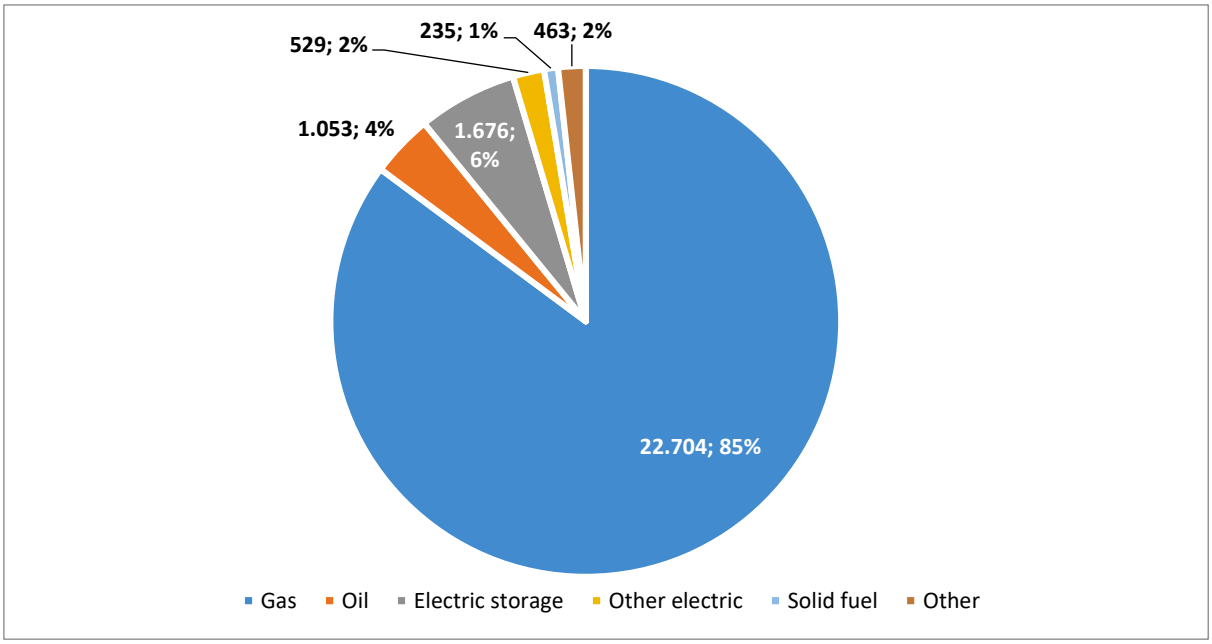


Figure 6 - INSTALLED CENTRAL HEATING SYSTEMS IN THE UK IN 2011, BY FUEL TYPE (IN '000 AND %)

Source(s): ***DECC, Energy Consumption in the UK, 2013 Update***

The heat distribution in the UK building stock is dominated by high flow temperature radiator systems, running at 70°C and above – creating a challenge for heat pumps. Due to the high flow temperatures they have been sized for, radiators in UK homes are usually small and flow temperatures may not be able to be reduced by much[2]. It is estimated that 90-95% of existing buildings are equipped with such radiator systems, making the existing property market in the UK particularly challenging to penetrate for heat pumps.

The average size of new build UK homes is one of the smallest in Europe (see for example the 2011 study by the Royal Institute of British Architects[3] or the 2001 study the French Office of National Statistics, INSEE[4]). Further, unlike homes in e.g. Germany, UK homes rarely have basements and heating systems are typically installed within the living space. **There is therefore an increasing preference to not use hot water storage tanks. This lack of storage space could significantly reduce the flexibility potential from heat pumps in UK homes – especially when combined with the low thermal inertia of the building stock.** With an average of only 85m² per home in the building stock and the average new build home being only 75m² in size, there is a trend towards removing hot water storage tanks in the UK in order to maximise useable space in the property. Only 51% of households in the UK were estimated to have a hot water tank in 2011, a reduction of 7% since 2008 – and a downward trend which is

[2] There is some debate as to whether flow temperatures as high as 70°C are necessary across the whole building stock (e.g. it is thought there is a portion of dwellings with over-sized radiators in the UK whose flow temperatures could potentially be reduced – but it is not clear how many dwellings this refers to)

[3] Royal Institute of British Architects, 2011, *The Case for Space: The Size of England's new homes*, http://www.architecture.com/Files/RIBAHoldings/PolicyAndInternationalRelations/HomeWise/CaseforSpace.pdf

[4] ÉCONOMIE ET STATISTIQUE N° 343, 2001-3, Page 32

expected to continue. This trend reflects the increasing use of combination boilers (without tanks) which in 2010 made up more than 73% of the total gas boiler market.

1.3.1 Historic heating market trends

Key characteristics of the UK heating market evolution are as:

- About 1.5 million gas boilers are installed per year – making the UK the biggest boiler market in Europe
- A growing dominance of wall-hung gas combi boilers over the last decade
- A growth in condensing boilers since 2005 (by 2020, most boilers in the UK will be condensing.
- Renewables emerging since mid-2000s – but still account for <2% of the annual heating sales (and heat pumps <1%).
- Most renewables replace oil or electric heating – not gas.

What does this mean for heat pumps?

The preference for wall-hung combi boilers means that UK homes have increasingly little space available for renewable heating such as heat pumps, which usually require tanks. The heat pumps which will be able to penetrate this part of the market will have to be very compact and work without storage. This means flexibility from heat pumps will be limited.

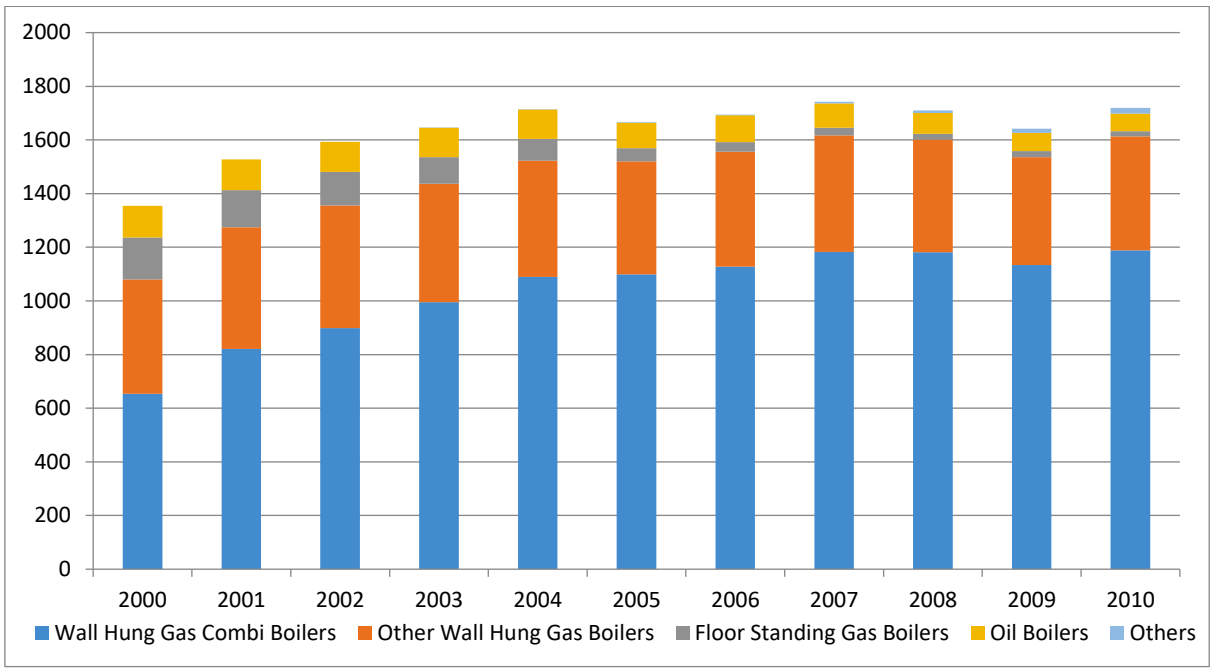


Figure 7 – Historical Heating System Sales in the UK, 2000-2010, excluding electric storage heaters (IN '000 PIECES) Heat pumps and other renewable technologies are within "others" and account for less than 2% of the market.

Source(s): ***BRG; Delta-ee***

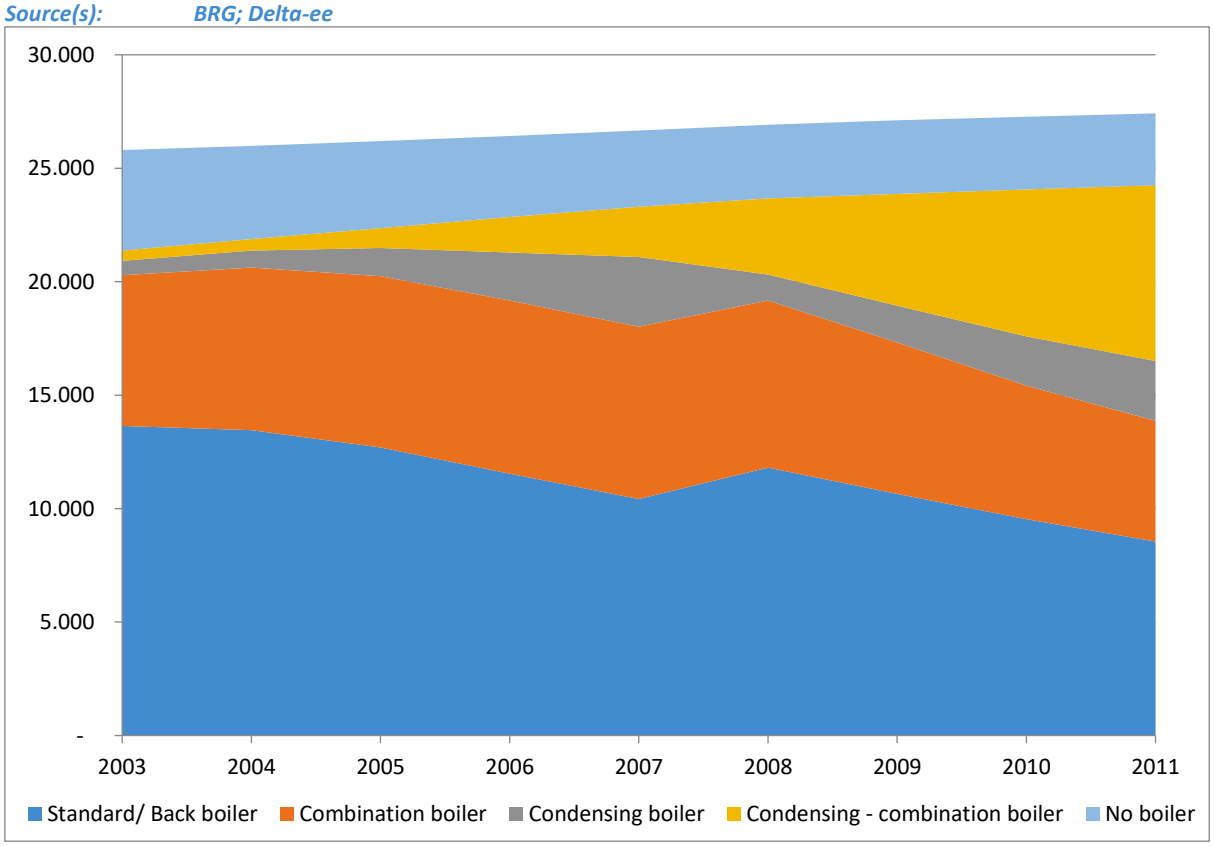


Figure 8 – Evolution of installed boilers UK 2003-2011 ('000 PIECES)

Source(s): ***DECC, Energy Consumption in the UK, 2013 Update (there was a change of data source in 2008, responsible for the discontinuity in the dataset)***

1.4 Customer Preferences

Typical operating patterns of UK heating systems differ from those in many other countries in Europe – instead of keeping the home at a relatively stable temperature, customers in the UK tend to use their heating systems in "bursts". Essentially the heating is only switched on when the customer is at home. This operation mode requires high flow temperatures at the start of the heating period, in order to reduce the time required to increase the temperature in the dwelling to a comfortable level.

Such an operation strategy is not well suited for a heat pump.

- It would lead to significant peaks in electric demand in the mornings and evenings
- It would result in poor heat pump performance – as illustrated by some of the challenges experienced during the UK Energy Saving Trust heat pump field trials.

The graph below shows an actual temperature profile measured in an Edinburgh home, illustrating the occupancy-led control of the heating system.

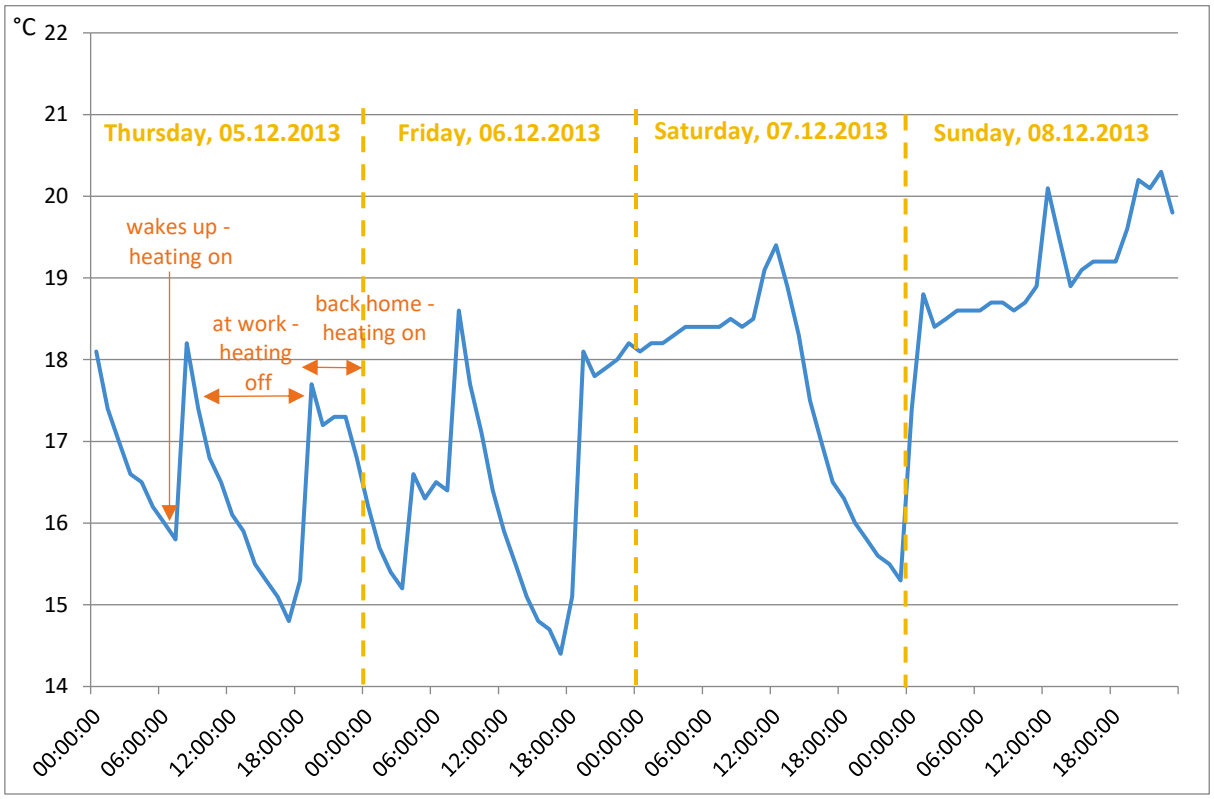


Figure 9 – Occupancy led heating profile for a home in the UK, 05-08.12.2013

The graph shows that the heating system is only run when the occupant is at home. During week-days the heating system is switched on in the morning for a period of 1-2 hours, it is then switched off until the occupant returns in the evening and switched off for the night. On weekends the heating system usually remains switched on as long as the occupant is in the house.

Source(s): ***Temperature measurement in an Edinburgh home, via www.ic-meter.com, live data from the home, as well as the Delta-ee offices can be seen via the website's demo account***

2 UK Heat pump market

2.1 Trends in the Heat Pump Market

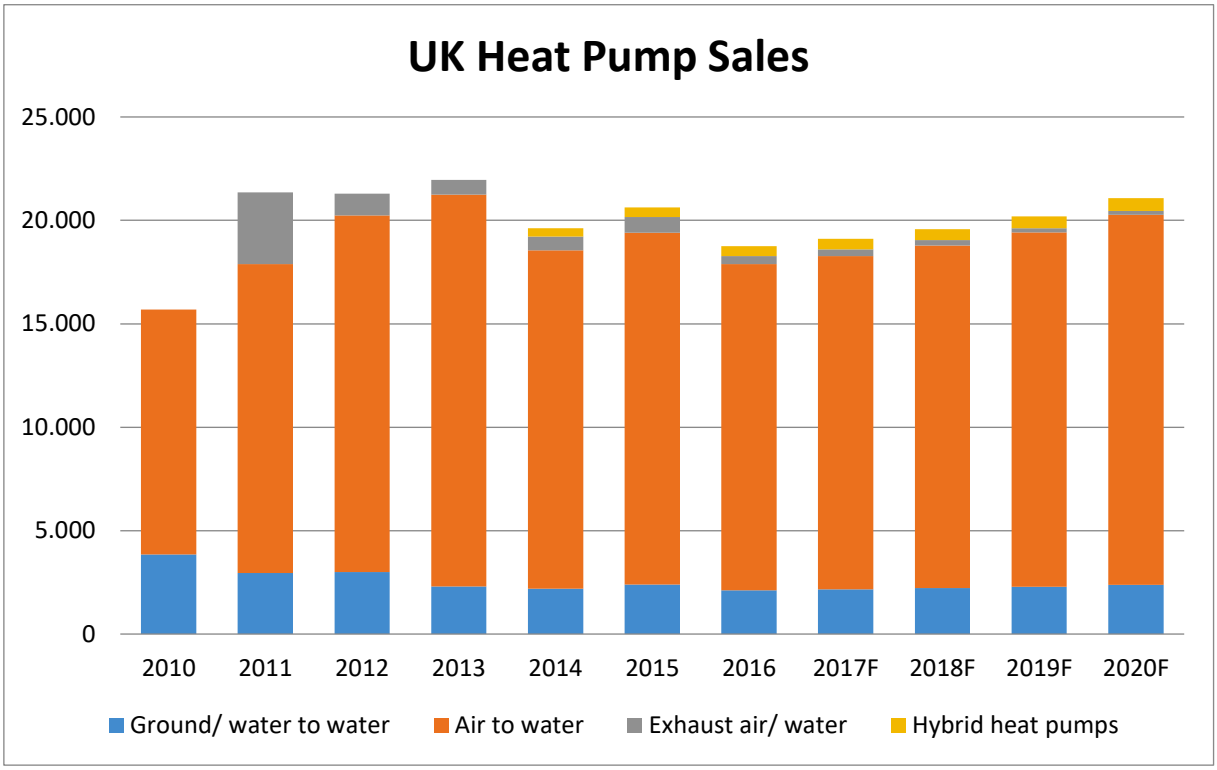


Figure 10 - UK heat pump sales and forecasts (2017). Source BSRIA (2017)

The UK heat pump market has been relatively stable since 2011. There has been a small shift from sales of GSHPs to ASHPs as illustrated in Figure 10. Overall there is dominance of new air to water heat pumps. Hybrid heat pumps entered the market as a designated product in 2014 (rather than simple bi-valent systems) and have seen a small amount of growth. Continued support for heat pumps from the Renewable Heat Incentive feed-in tariff until 2020 results in a growth forecast for sales in ASHPs.

2.2 Hybrid Heat Pump Market Review

2.2.1 Market size and potential

In the UK the overall domestic heat pump market is still small. The heating market is dominated by boilers (which make up 85% of the market[5]), and by far the most widely installed type of boiler is the gas condensing boiler. Heat pumps have gained more traction in other countries.

The current UK heat pump market suffers from high capital cost, a low awareness of the product and some mistrust in the technology, especially when the competing technologies are so well established.

Stakeholders reported they have been selling domestic hybrid heat pumps since 2009 but they have been recorded by BSRIA in UK market statistics since 2011. Since then market growth has been slow. The current domestic hybrid market in the UK is still very limited[6]. The estimated current market size in the UK is summarised in Table 1. BSRIA figures estimate that the total domestic heat pump market is around 17,700 a year. It has been estimated from stakeholder interviews and feedback that about 18% these sales are of gas boiler assisted heat pumps. This value includes both domestic and commercial

[5]RHI Evidence Report: Gas Driven Heat Pumps, *BEIS, 2014*

[6] Hybrid renewable energy technologies hit the market, *BSRIA, 2013*

heat pumps but as the market is so dominated by domestic products (estimated to be around 90%) it seems fair to assume that 18% of the domestic market are hybrids.

It is important to note that market data for heat pumps with a gas boiler collected from literature and through stakeholder engagement is likely to include some 'bivalent' systems (a system without an intelligent controller). The figures for 'true' hybrid technology is therefore lower, but there is a lack of reliable data to estimate by how much.

Similarly, hybrid ground to water heat pumps are mainly used in properties off the gas grid. In this case, the heat pumps are often used with existing oil boilers, and so are outside the scope of this study.

The proportion of heat pumps that were combined with boilers was reported to have fallen from 21% in 2012 to 18% currently[7]. With these factors in mind the values in Table 1 are at the upper limits of the current market size.

Table 1 Estimated sales of hybrid heat pumps in the UK 2014

Heat pump category	Annual heat pump sales volume (domestic & commercial)	Annual domestic sales volume	Estimated proportion hybrid	Estimated sales volume hybrid
Air to water	16,500	~ 15900	18%	~2860
Ground/water to water	2,200	~ 1800	18%	~325

2.2.2 Market potential

Despite trends in the UK, hybrid demand across Europe is increasing and was estimated to reach 8,500 units per year in 2015[8]. As UK has an established domestic gas infrastructure, there is potential for an increasing market for these products in the UK.

In 2013 BSRIA forecast sales of hybrid heat pumps of 120,000 units or less between 2012 and 2020, if the technology received no financial support[9]. This technology has received financial support since April 2014 but according to manufacturers and suppliers this has had little effect.

2.2.3 Potential in current applications

The Committee on Climate Change has suggested that hybrid heat pump technology could provide a bridging technology from current consumer choices to low carbon technologies[10]. For this to become a reality the technology will have to grow out of its current market niche.

The current markets for domestic hybrid heat pumps are quite well defined because of the cost. Purchasers tend to be energy conscious consumers or housing associations that are aiming for better energy performance for their residents. This is a limited market which may explain why the market is not increasing.

[7] BSRIA statistics
[8] European heat pump markets and statistics report, *Thomas Nowak, EHPA, 2015*
[9] Hybrid renewable energy technologies hit the market; *BSRIA; 2013;*
https://www.bsria.co.uk/news/article/hybrid-renewable-energy-technologies-market/
[10] Pathways to high penetration of heat pumps, *Committee on Climate Change, 2013*

2.2.4 Potential for diversifying the end user

The key to the growth of this market relies on diversifying away from the current niche application and for hybrid heat pumps to become a viable and accepted alternative for gas boiler replacements, or adding to existing gas boilers.

There are many factors which influence the competitiveness of hybrid heat pumps but fundamentally system types are similar in size and application. The potential market size for domestic hybrid heat pumps in the UK could, in theory, be as large as the number of existing gas boilers.

The cost of a hybrid add-on heat pump can be lower than a standard electric heat pumps. The consumer would need to be convinced that hybrid heat pumps are a high quality, lower energy product which can deliver an attractive fuel bill savings to diversify away from standard practice which is replacing their boiler with another boiler.

Another market for hybrid packaged heat pumps is for new build properties or retrofit where the boiler has reached the end of its life, usually as an alternative to a condensing gas boiler. The competitiveness of hybrid packaged heat pumps compared to other products is explored in **Error! Reference source not found.**. This compares hybrid heat pumps with gas boilers, and also with standard electric heat pumps, along with gas driven heat pumps which are potentially a direct competitor.

	Gas boiler	Domestic packaged hybrid heat pump	Standard electric air source heat pump	Gas driven adsorption/ absorption
Capital cost	Low cost	Moderate cost	Fairly high cost	High cost
Installation cost	Low cost	Moderate cost (may need to upgrade some radiators)	Fairly high cost (often need radiator upgrade and new hot water cylinder)	Absorption moderate cost Adsorption high cost (as ground source)
Running costs	Fairly low cost, dependent on gas prices	May be lower cost than gas boiler depending on relative gas/electricity prices	Often higher cost than gas boiler depending on relative gas/electricity prices	Lower cost than gas boiler or hybrid heat pump depending on relative gas/electricity prices
Consumer familiarity	High familiarity and favourability	Low familiarity	Some familiarity	Not yet available in the UK (at domestic scale)

Table 2 - Hybrid packaged heat pump competiveness versus competing domestic heating technologies

A utility company (E.ON) noted that they had seen interest in hybrids from gas networks, heat pump manufacturers, gas boiler manufacturers and other utilities. They see a potential mass market for retrofitting a heat pump alongside an existing boiler to create a hybrid system and are interested in the link with dynamic tariffs and demand management. A 'smart' connected hybrid could be advantageous in the future due to its ability to help balance the grid and assist with load shifting. The ability to use a hybrid heat pump for load shifting does not necessarily require a form of thermal inertia (such as a hot water tank) because the system can switch between heat sources.

One target market for hybrid add-on products is retrofit to existing boilers. They have been described as a bridging or transition technology[11], if a consumer wants to reduce the costs of their bills or the energy use then an add-on technology could meet these needs. Through this purchase consumers could become more familiar with heat pump technology reducing the barrier to installing a full heat pump system when they next replace their heating systems.

Another advantage of hybrid add-ons is that the consumer does not have wait for their boiler to fail, with modern boilers typically having long lifetimes of 10-15 years.

2.2.5 Estimate of effective market potential

In order to estimate the potential size of the market opportunity for heat pumps, Delta EE undertook a high level assessment of the impacts of property type, property age (i.e. to create an estimate driven by property physical space limitations), and the composition of annual heating replacements in the market. Given the coarse nature of this assessment they sought to establish a range of possible outcomes.

There are approximately 27 million domestic dwellings in the UK (excluding NI) and in approximately 23 million (85%) of these, gas boilers are used to provide heating and/or hot water[12]. Heating and hot water for the remaining dwellings are supplied through off-gas-grid means such as solid fuel, oil or electricity.

The analysis suggests that between 3.4 and 7.3 million domestic dwellings may be suitable for hybrid or gas driven heat pumps when gas availability and internal or external property space limitations are taken into account. Advances in technology that reduce heat pump equipment size or reduce the noise emitted from outdoor units are likely to steadily increase number of dwellings for which heat pump technology could be used.

The annual market for domestic heating replacements is approximately 1.67 million units[13] of which 1.5 million units are of gas boilers[14]. Comparison with the total stock of UK domestic dwellings gives an annual replacement rate of 6.5% of the installed base. However, analysis of research undertaken by Ipsos MORI and the Energy Saving Trust[15] on drivers for homeowners' desire to purchase a new heating solution (e.g. distress purchases, replacement parts hard to find for existing solution, refurbishment) indicates that only 44% of the time would the heat pump supply chain be likely to meet the customer's needs.

Factoring in the annual replacement rate and the drivers for heating system purchases, to the size of the addressable market gives an annual market potential of between 100,000 and 210,000 dwellings per annum.

[11] Pathways to high penetration of heat pumps, *Committee on Climate Change, 2013*
[12] Sub-national consumption statistics, *BEIS, 2014*
[13] Report IEA HPP Annex 42: Heat Pumps in Smart Grids. Task 1 (i): Market Overview United Kingdom, *Delta Energy & Environment, 2014.*
[14] Gas driven heat pumps: Market potential, support measure and barriers to development of the UK market, *R.E Critoph Warwick University, 2013*
[15] Homeowners' Willingness To Take Up More Efficient Heating Systems, *Ipsos MORI and the Energy Saving Trust, 2013.*

This potential is shared between gas driven and hybrid heat pumps, which mostly share a common target market. The likely relative uptake of the two technologies will depend on a variety of factors. Some of these are explored in the summary report in this series[16].

2.2.6 Product availability

There are a number of products on the market and so product availability does not seem to be a limit on the market. However, many of the manufacturers with products listed do not directly market their heat pumps as hybrids, but simply include 'hybrid function' in a list of many features. The most frequent reasoning given for this was that it was difficult to justify the extra cost of a hybrid system above that of a standalone boiler or single heat pump unit. This has had the effect that whilst the products are available, the products are not understood or not known by the consumer.

2.3 Market segmentation and competition

Manufacturers mostly market their products towards consumers who are already considering entry into the heat pump market, rather than competing directly with conventional gas boilers. That said, three of the major suppliers offer both component parts of a hybrid system: conventional gas boilers and heat pumps.

Apart from standalone gas boilers and standalone heat pumps, manufacturers showed no consensus on competitive technologies. One manufacturer identified other hybrid systems as direct competitors such as heat pump/solar systems. A natural competitor would be gas driven heat pumps, as these combine the cost competitiveness of natural gas as a fuel with the energy and carbon savings of heat pump technology. Micro-CHP is also a potential competitor.

2.4 Current hybrid products available

There are many domestic hybrid heat pump products currently available on the market in the UK, ranging from 'true' hybrid packages to standard heat pumps that can simply be retrofitted into an existing boiler heating system. A sample of the manufacturers and products can in be seen in Table 3. All these products use single phase electricity. Where possible we have included the range of COPs quoted at A7/W55 (i.e. outdoor ambient air temperature of 7°C and hot water delivery at 55°C) or B0/W55 (i.e. brine supply from ground loop at a temperature of 0°C and hot water delivery at 55°C) tested at full load to EN14511 and the SSHEE at 55°C under average climatic conditions (tested at part load to EN14825) for each product range.

[16] Evidence Gathering – Low Carbon Heating Technologies, Domestic High Temperature Heat Pumps, Hybrid Heat Pumps and Gas Driven Heat Pumps: Summary Report, BEIS, 2016

Table 3 - Summary of hybrid heat pump products in the UK

Manufacturer	Product range	System design	Refrigerant	Controller	Rated output range (kW)	Bivalent temp. (°C)	Monobloc or split	Ground or air source	COP (A7/W55; B0/W55)*	SSHEE range (%)**	Additional information
Daikin	Altherma Hybrid	Hybrid packaged	R410A	Four modes and built in weather compensation	5 or 8	Not given	Split	Air	N/A***	127 - 129	This is the only integrated boiler/heat pump package.
Glow-Worm	Clearly Hybrid	Hybrid packaged	R410A	Uses weather compensation Fuel/electric prices must be inputted to optimise the system.	4, 6, 7 or 9	-5 or -8	Monobloc	Air	2.2 – 2.7	112 – 121	This is similar to the Vaillant range below, as both are owned by one company.
Hitachi	All Hitachi ranges/ models	Hybrid add-on	R410A or R134a	Allows a bivalent point to be set and has in built weather compensation	7.5 – 17.5	-7 or -10	Monobloc and split models available	Air	3.16 (data for a sample of products)	127 – 129 (data for a sample of products)	Products are 'hybrid ready' rather than hybrid products. DHW, stored at 54˚C, is given priority.

Manufacturer	Product range	System design	Refrigerant	Controller	Rated output range (kW)	Bivalent temp. (°C)	Monobloc or split	Ground or air source	COP (A7/W55; B0/W55)*	SSHEE range (%)**	Additional information
IDM	TERRA	Hybrid add-on	Not given	Can control 6 separate heating circuits and operating data can be accessed and monitored.	15, 21 or 31 (air source) 5, 9, 13 or 24 (ground source)	-5, -10 or -15	Monobloc	Air or ground	N/A***	169 – 173 (air); 160 – 201 (ground)	The IDM TERRA range is not marketed as hybrid, but the products can be used for hybrid systems.
Mitsubishi Electric	Ecodan	Hybrid add-on	R410A	Switches between the heat pump and boiler based on temperature, cost, CO2, unit failure or external command.	5, 8, 10 or 16 (mono) 4, 7 or 12 (split)	-7	Monobloc and split models available	Air	2.17 – 2.68	125 – 128	These systems can produce domestic hot water if combined with a hydrobox and hot water cylinder.

Manufacturer	Product range	System design	Refrigerant	Controller	Rated output range (kW)	Bivalent temp. (°C)	Monobloc or split	Ground or air source	COP (A7/W55; B0/W55)*	SSHEE range (%)**	Additional information
Samsung	EHS	Hybrid add-on	R410A	Uses an outdoor weather sensor to decide which system should operate at any one time.	5, 6, 8, 9 or 10 (mono) 4, 5, 6, 8, 9 or 10 (split)	-10	Monobloc and split models available	Air	N/A***	108 – 128	The Samsung range is not marketed as hybrid, but as 'hybrid compatible'.
Stiebel Eltron	Hybrid range	Hybrid add-on	R407C, R410A or R134a	Uses external air temp., 'kelvin minutes', weather compensation and considers the building's thermal mass.	5 – 66	Not given	Monobloc	Air or ground	2.47 – 3.23 (air); 2.9 – 3.41 (ground)	104 – 130 (air); 124 – 133 (ground)	'Kelvin minutes' determine the speed of system response. E.g. if radiators need to reach 60˚C and the heat pump can supply 59˚C, it starts counting down before using the boiler.

Manufacturer	Product range	System design	Refrigerant	Controller	Rated output range (kW)	Bivalent temp. (°C)	Monobloc or split	Ground or air source	COP (A7/W55; B0/W55)*	SSHEE range (%)**	Additional information
Vaillant	Aro THERM	Hybrid packaged	R410A	The controller has load compensation, weather compensation and tariff control (new model to be released in 2016)	4, 6, 7 or 9	-5 or -8	Monobloc	Air	2.55 – 2.97	105 - 113	This is similar to the Glow-Worm range, as both are owned by one company.

3 Drivers & barriers for hybrids

While hybrid heat pumps have a positive impact on some barriers to the uptake of standard heat pumps, it is not clear whether this impact is sufficient to overcome the major barriers

- Hybrid heat pumps could have a positive impact on consumer inertia – for example where consumers are able to keep their existing boiler.
- They could help to overcome lack of confidence in heat pumps as they can demonstrate how a heat pump operates to provide satisfactory heating and modest cost savings based on current fuel prices.
- However, hybrid heat pumps have some additional barriers to overcome compared to standard heat pumps, such as a lack of awareness and limited measured performance data to an agreed standard,
- Hybrid heat pumps also suffer many of the same barriers as standard heat pumps such as concerns over performance of earlier heat pump installations, and the need for additional space.

This section first gives a brief overview of the drivers for the uptake of this technology, and then discusses the barriers for uptake.

Research shows that many of the same barriers which prevent the rapid uptake of conventional heat pumps are also applicable to this technology. The findings on barriers are therefore presented in terms of the well-known barriers to conventional heat pumps; and then the impact of hybrid technology is described for each barrier (i.e. whether it mitigates or exacerbates this barrier).

This section was compiled from a review of literature, along with discussions with all of the stakeholders interviewed.

3.1 Drivers for deployment

Hybrid heat pumps have a number of advantages over standard heat pumps that mean they could find a market in the UK. These strengths include:

- The boiler is used to reach higher temperatures (compared to a standard heat pump) needed to provide hot water
- The heat pump can provide baseload low temperature heating at high efficiency
- The technology is suitable for the UK housing stock and could be fitted with existing high temperature radiators if the boiler is used to top up the space heating
- They can be suitable for installation in new build properties
- The intelligent controller can optimise running costs, energy efficiency or carbon emissions by switching between the two sources
- Add-on products can be combined with an existing boiler and water tank, or with a combi boiler, reducing costs and allowing heat pump installation before the end of the boiler's useful life
- They can overcome customer inertia where customers are used to gas heating, and the dual system provides a sense of security
- Hybrid heat pumps can be used for electricity grid demand management - switching to the gas boiler at times of high electricity demand

3.2 Summary of key barriers

Standard heat pump barriers are summarised in Table 4, which gives a brief summary of the barrier, and the impact of gas technology on that barrier, along with an indication of the strength of the barrier. The barrier strength is our assessment based on a combination of expert opinion, and how frequently the barrier was mentioned by stakeholders and highlighted in the literature search.

Our assessment of the impact of gas technology relative to standard heat pumps is colour coded, where green shading designates a positive impact and red a negative impact. Items shaded blue mean that the barrier is not significantly different for gas heat pumps compared to standard products.

The barriers where hybrid heat pumps have an impact compared to standard heat pumps (red or green) are then discussed further in the following sections, segmented into consumer, technical, installation, and market barriers. It should be noted that some barriers may fall across one or more of these categories. Further details of the other barriers (blue) are shown in Annex B.

Table 4 Summary of standard heat pump barriers and the impact of domestic hybrid pumps

Key:
Technology's impact on standard heat pump barrier: **Green - positive impact; blue - no impact; red - negative impact**
Barrier Strength: * - Minor barrier; * * - Moderate barrier; * * * - Major barrier

Barrier	Description	Technology's impact on standard heat pump barrier	Barrier strength
High upfront cost	High up-front cost is the major barrier for demand	Hybrid heat pump packages may be a little more expensive than standard HPs as both the boiler and heat pump unit must be purchased – although the requirement for radiator upgrades may be reduced.	* * *
		When used with an existing boiler, hybrid heat pump prices are lower than replacement with standard HPs as the kW size of the heat pump can be smaller.	* * *
Consumer inertia	Consumers are reluctant to move away from the convenience of gas boilers	Consumers will retain the familiarity of a gas boiler given that hybrids are a made up of a heat pump and gas boiler	* * *
Low technology awareness	Low level of knowledge / awareness about heat pumps on the demand-side	Awareness of hybrid heat pumps is lower than that of standard heat pumps	* * *
Lack of confidence	Lack of robust / comparable performance data and previous negative experiences with heat pumps	Similar to standard heat pumps however the gas boiler element could be installed quickly with the rest of the system installed later making a hybrid an option when the system is a 'distressed' purchase	* * *
Aesthetics	Aesthetics are a major barrier for consumers	Similar to standard heat pumps	* * *

Barrier	Description	Technology's impact on standard heat pump barrier	Barrier strength
Space constraints and planning permission	Space constraints (for the heat pump unit and hot water tank), including planning requirements	Hybrids require less space than standard heat pumps as the shared load means that the heat pump required is smaller. If the boiler provides DHW, no additional hydrobox is required. Planning issues are similar to standard heat pumps.	* * *
High electricity price / low gas price	A large differential between electricity and gas per unit of energy reduces potential savings compared to other countries	The hybrid heat pump can switch between the gas boiler and the standard heat pump to achieve the most cost effective means of generating heat.	* * *
Uncertainty over performance / savings	Current performance metrics are not reflective of in-use performance and it is difficult to calculate savings	Only limited trials of hybrids have occurred and so there is less system performance data than standard heat pumps.	* *
Number of players in supply chain	Given the large number of players in the supply chain, it is not clear who is incentivised to ensure proper installation	Similar to standard heat pumps.	* *
Thermal efficiency of housing stock	The UK's existing housing stock includes a significant proportion of thermally inefficient properties	Hybrids help to meet increased heat demand as the gas boiler tops up where the heat pump can't meet the demand.	* *
Suitability of incumbent heating distribution systems	Widespread use of high flow / return temperature heating systems which are not suitable for heat pump retrofit	Hybrids can be used with existing high flow / return temperature heating systems as gas boiler tops up the heat pump deficiency.	* *
Shortage of necessary skills	Lack of skilled and experienced technicians / engineers to install and maintain systems	Hybrid systems also require installers to be 'Gas Safe' registered. F-gas competence is required to	*

Barrier	Description	Technology's impact on standard heat pump barrier	Barrier strength
		install split systems, although this is the same as for standard heat pumps.	
Speed of installation	Heat pumps take considerably longer to install than gas boiler	Similar to standard heat pumps.	*
Noise	Heat pumps can be noisier than other heating types such as gas boilers	Similar to standard heat pumps.	*
Low replacement opportunities	Existing gas boilers have long useful lives of 10-15 years.	Hybrid heat pumps can be coupled with an existing boiler if it is compatible with a smart controller. There therefore isn't a need to wait for the gas boiler to need replacing.	*
Network electricity capacity	Heat pumps will add significant demand to the electricity network (both at a local and national level)	Hybrid heat pumps are able to ease the pressure on electricity demand at peak times by switching to the gas boiler.	*

Key:
Technology's impact on standard heat pump barrier: **Green - positive impact; blue - no impact; red - negative impact**
Barrier Strength: * - Minor barrier; * * - Moderate barrier; * * * - Major barrier

3.3 Consumer Barriers

3.3.1 High up-front cost

In general, high up-front cost compared to gas-condensing boilers is a **major barrier** for standard heat pumps, especially when considered alongside uncertainty on in-use savings. However, the effect of cost varies depending on the market segment considered:

- **Housing developers** – cost is a major barrier for housing developers. The cost of a heat pump is not fully reflected by a proportionate increase in the value of a property. For this reason, housing developers are more likely to install gas-condensing boilers to maximise their return. Housing developers told us that there are more cost-effective ways for architects/engineers to increase the score in the Standard Assessment Procedure (SAP) or meet other building regulations, such as improving the building fabric and installing solar technology.
- **Buy-to-let landlords** – cost is a major barrier for landlords due to the landlord-tenant divide. Landlords are not incentivised to pay the high up-front cost as the tenant will be the financial beneficiary (through lower heating bills).

- **Homeowners** – cost is a major barrier for homeowners, although they do benefit from the ongoing savings.
- **Housing associations** – cost is also significant for housing associations, however, they are often eager to reduce the ongoing cost of living for occupiers.

While prices have become more competitive, the total installed cost of a boiler remains significantly lower than a hybrid heat pump as the hybrid unit contains both a heat pump and boiler. One housing association said that even with financial incentives available for heat pumps it wouldn't be cost effective to update the system in comparison with the installation of a gas boiler. This was echoed by another stakeholder that said that the performance benefits were not great enough to overcome the cost. Housing developers reported this as a significant barrier as they see little if any return on investment as heat pumps don't increase the value of the property.

Interestingly, one manufacturer decided to withdraw their hybrid package product from the market in July 2015, despite significant R&D and having been on the market for years. They stated that their product was no longer cost competitive.

For hybrid and controller add-ons, where the system operates with an existing boiler, up-front costs can be lower than a standard heat pump, because the heat pump can be smaller in a hybrid system as the boiler can produce DHW and some high temperature space heating. In addition, there can be reduced need for radiator upgrades as the boiler can provide high temperature space heating top-up when required.

3.3.2 Consumer inertia

Consumer reluctance to switch from the familiarity and convenience of incumbent technology (mainly gas boilers) is a **major barrier** to the uptake of standard heat pumps. This reluctance is reinforced by the ability of gas boilers to quickly heat a home and provide hot water on demand. Consumers are often concerned about the 'quality' of the heat from standard heat pumps (i.e. a concern that low heat levels are insufficient to heat a home). The complexity of heat pump control systems compared to gas-condensing boilers adds to this inertia. Research has suggested that for the choice of system the 'key determinant was the technology itself (dictating 54% of choices)'[17].

Several stakeholders felt that current messaging around heat pumps would benefit from highlighting convenience benefits (such as longer product lifespans and lower maintenance requirements) alongside potential cost savings.

Hybrid heat pumps may be more successful at overcoming consumer reluctance to part with their familiar and trusted gas boilers given that they combine a heat pump with a gas boiler. One housing association said that if the hybrid heat pump is positioned as an extra piece of equipment attached to the boiler, to make it cheaper and more efficient, that will generally gain consumer acceptance. Despite this however, they said that the harder sell was to the asset management team who were fundamentally quite conservative as a result of previously perceived negative experiences with heat pumps. The interviewee felt that this could be overcome if asset managers worked work closer with manufacturers at the time of specification and installation.

3.3.3 Consumer awareness, confidence and trust

Consumer awareness of heat pumps in general is very low and is therefore a **major barrier**. In a survey of householders, 12% had heard of air source heat pumps and understand what they are, with the figure being 28% for ground source heat pumps[18]. Similar scales of awareness have been found in other studies[19].

Feedback from manufacturers is that they cannot justify the funding to run significant awareness raising campaigns themselves – that the current heat pump market in the UK is not large enough. In Germany, for example, utilities have been very successful in driving awareness[20].

[17] Homeowners' willingness to take up more efficient heating systems, *Ipsos MORI and the Energy Saving Trust, 2013*
[18] Pathways to High Penetration of Heat Pumps, *Frontier Economics, 2013*
[19] Homeowners' willingness to take up more efficient heating systems, *Ipsos MORI and the Energy Saving Trust, 2013*

That said, one manufacturer interviewed has placed standard heat pump advertorials in magazines to raise consumer awareness as, until this happens, they cannot warrant the cost of marketing their hybrid compatible heat pumps as such. The low awareness of standard heat pumps therefore has a knock on effect on the success of hybrid heat pumps.

Of the consumers that are aware of standard heat pumps, not all of them are necessarily aware of hybrid heat pumps. In interviews, a number of demand side interviewees, such as housing associations and housing developers, revealed that they were not aware of the technology. However after the technology was explained to them they expressed that it was something that they would like to further investigate. This demonstrates that awareness even within the already engaged standard heat pump user group is potentially lacking.

3.3.4 Uncertainty over performance/savings

Lab performance metrics can never be fully reflective of in-use performance and it is difficult for consumers to calculate savings. This is a **moderate barrier**. Since 26th September 2015, the Ecodesign Directive has stipulated that seasonal performance data for heat pump units (which should more closely represent in-use performance) must be published and readily available to consumers. However, this data is currently difficult to locate and the level of technical knowledge required to use this performance data is high.

3.4 Technical Barriers

3.4.1 Space

Lack of space is a **major barrier** (and could also be considered a market barrier due to the nature of UK housing stock). External space is usually required for the heat pump unit, as well as internal space for a water tank if required. The effect of this barrier will vary by property type. Non-urban properties are less likely to have space restrictions than high-density urban dwellings. This is a major barrier in parts of the market with space constraints.

Hybrid systems can take up less space than a standard heat pump. This is because the size of the required heat pump is often smaller in a hybrid system, as it does not need to be sized to meet all heating requirements in a property, as the boiler can provide very high temperature space heating and DHW.

3.5 Installation and Maintenance Barriers

According to a number of the stakeholders interviewed, poor installation of standard heat pumps had a negative impact on their reputation in the market. However, some demand-side stakeholders such as housing associations reported to us that this issue has decreased over the last five years. To avoid a similar situation with hybrid heat pumps (if the market is able to distinguish between them), it is important that similar poor installation is avoided as the market grows.

3.5.1 Shortage of necessary skills

There has been a lack of capacity of trained installers for electric heat pumps[21]. This is a **minor barrier** that could hold back supply once demand grows. Given the importance of installation quality on in-use performance[22], poor performance of early installations could be a barrier to further uptake of heat pumps (as has proved to be the case with standard heat pumps). Consumers may also be concerned about a skills shortage for maintenance.

The skills shortage has improved and many manufacturers run training courses or have special relationships with groups of installers. However, some stakeholders still raised this as an issue during interviews for this research.

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[20] **http://www.delta-ee.com/images/downloads/pdfs/2015/ARTICLES_HPT_Jan15.pdf**, *Delta-EE, 2015*

[21] Pathways to High Penetration of Heat Pumps, *Frontier Economics, 2013*

[22] Expert interviews

This barrier is exacerbated by hybrid heat pumps as installers also need to be 'Gas Safe' registered. One manufacturer that we spoke to did not actively market their hybrid compatible products as they only had one 'Gas Safe' approved installer and given that it was a new product they didn't want to burden their other installers with having to get registered at that time. Even though they were impressed by the product they hadn't carried out a full market evaluation and hadn't had requests from installers for the product. This is an example of how installer skill sets are reactive to the market rather than proactive to how the market may evolve.

3.6 Market Barriers

3.6.1 Readily accessible and low-cost gas network in UK

The extensive gas network and relatively high cost of electricity per unit of energy compared to gas in the UK is a **major barrier** as it means that in-use cost savings from heat pumps are potentially lower compared to other countries[23]. Volatility around energy prices adds to uncertainty around savings.

This barrier is overcome with hybrid heat pumps as the system (depending on the capability of the controller) can switch between the gas boiler and the electric heat pump to achieve the most cost effective means of generating heat.

3.6.2 Low replacement opportunities

Gas boilers have long useful lives of 10 – 15 years, and consumers are reluctant to replace them unless they are coming to the end of their life. This is a **minor barrier** that is not limiting the market.

Add-on hybrid heat pumps overcome this barrier as they are able to be connected to an existing boiler.

3.6.3 Suitability of incumbent heating distribution systems

Widespread use of heating distribution systems with high flow / return temperature which are not suitable for heat pumps is a **moderate barrier** for retrofit of standard heat pumps[24]. Heat pump suppliers commented that a high proportion of customers are reluctant to change their radiators to low temperature alternatives.

Due to the high temperatures that hybrids can achieve, as a result of being 'topped up' by the boiler, they have a positive impact on this barrier as they can be retrofitted to incumbent heating distribution systems.

3.6.4 Electricity grid constraints

This is a **minor barrier** that may limit deployment with increased uptake of heat pumps. This barrier can be a constraint on both the capacity of a local grid connection, as well as a longer term constraint due to limitations on total electricity generation capacity if a significant proportion of the UK's heating demand were electrified. In addition, the single phase supply in the UK means that many international products designed for three phase supply are unsuitable. The single phase supply also places a maximum on the heat pump capacity that can be installed so that in some situations not all of the load can be met.

Hybrid heat pumps help to overcome this barrier as they are able to switch to the gas boiler at times of peak demand, for example first thing in the morning and early evening.

3.6.5 Thermal efficiency of housing stock

The UK's existing housing stock includes a significant proportion of old properties, which tend to be thermally inefficient. In 2012, nearly 60% of dwelling were built before 1964, and over 20% aged before 1919[25]. The lower the thermal efficiency of a property, the lower the performance of a standard heat pump is. Standard heat pumps work best in well insulated, thermally efficient properties, so maintenance work to increase the efficiency of a property is often carried out before fitting a standard heat pump. This adds cost and disruption to the project, and so is a **moderate barrier**.

[23] IEA HPP Annex 42: Heat Pumps in Smart Grids – Market Overview, *Delta-EE, 2014*
[24] The Future of Heating: Meeting the Challenge, *BEIS, 2013*
[25] English Housing Survey Headline Report 2010-11, *DCLG, 2012*

Hybrid heat pumps have a positive impact on this barrier as the boiler is able to attain higher temperatures where the heat pump cannot meet the demand, therefore heat loss is not such a significant issue.

3.6.6 Planning and space

Planning constraints exist but are not insurmountable, therefore this is a **minor barrier**. For an installation outside, the space used must not exceed 6m^3, noise level restrictions apply and there are regulations stipulating how close to a boundary line the unit can be sited. For listed properties, more stringent regulations apply.

Lack of space can be a **major barrier depending on the property type and location.** External space is usually required for the heat pump unit, as well as internal space for a water tank. The effect of this barrier will vary by property type. Non-urban properties are less likely to have space restrictions than high-density urban dwellings.

For hybrid systems the impact of this barrier is lower, as the heat pump unit can be smaller than a standalone unit, which leads to fewer problems associated with noise and siting.

4 Standards & regulations Standards Review

UK and EU performance standards are available for electrically driven heat pumps, but do not currently cover hybrid systems.

- There are no specific performance standards for electrically driven hybrid heat pumps (only for sorption hybrid heat pumps).
- Applying the current standard for seasonal performance for electrically driven heat pumps to hybrid heat pumps is likely to give inaccurate results.
- Hybrid products must meet the requirements for minimum performance, labelling and the provision of technical data of the ErP Directive.

4.1.1 Space heating

There are currently no standards specifically covering electric vapour compression hybrid heat pumps.

However, there is a standard, BS EN 12309, for determining the performance at standard rating conditions and the seasonal performance of both standard and hybrid sorption heat pumps. For sorption heat pumps the same standard rating conditions are applied to both standard and hybrid products if the source is air or water but for ground source products a higher source temperature is assumed for the hybrid. This is because the heat extraction regime is different with the extraction rate for hybrid appliances tending towards zero at peak demand as the boiler takes over. For determining the seasonal performance the calculation method for standard and hybrid products is the same but the part load conditions representing performance over the reference heating seasons are different. As the hybrid is sized to meet less than 100% of the load its part load ratio is higher than the standard product at any given temperature.

Work is needed to develop specific standards for determining the performance at standard rating conditions (COP) and seasonal performance (SCOP) of electric vapour compression heat pumps. At present the performance standards for standard electrically driven heat pumps are sometimes being used for hybrid products. If BS EN14511, the standard for determining COP for electric heat pumps, is used for hybrids it is likely to give representative values for air and water source products but to underestimate the performance for ground source products. If BS EN 14825, the standard for calculating seasonal performance of electric heat pumps, is used for hybrids it is likely to underestimate the performance of air, water and ground source products.

4.1.2 Performance for water heating.

Where a packaged hybrid heat pump provides domestic hot water as well as space heating the standard BS EN 16147:2011 is used to assess the performance for water heating. Again this doesn't take account of the fact that the hot water is more likely to be delivered by the boiler.

The standard covers water heaters and combination water heaters connected to or including a water storage tank. The COP_{dhw} and the water heating energy efficiency η_{wh} are determined using a range of standard load profiles. This standard is currently being revised to align fully with ErP legislation.

4.1.3 Design of heat pump systems

General guidance on the design of heat pump systems is given in BS EN 15450:2007 Heating systems in buildings. Design of heat pump heating systems.

4.1.4 System efficiency

BS EN 15316-4-2:2008 Heating systems and water based cooling systems in buildings. Method for calculation of system energy requirements and system efficiencies. Part 4-2. Space heating generation systems, heat pump systems.

This calculates the energy efficiency of a heat pump heat generating system. This standard is being revised to cover hourly and monthly calculation.

There are a number of standards which cover specific aspects such noise, safety and environmental issues etc. Details of these are included in a more comprehensive list of standards in Appendix B.

IEA HP Annex 45 Hybrid Heat Pumps, which started in September 2015 will look at technical procedures to be included in future standards for determination of the performance of hybrid heat pumps and methods to evaluate primary energy consumption of the systems.

4.2 Ecodesign for energy related products directive (ErP)

All products must meet the requirements of the Ecodesign Directive (2009/125/EC). The directive requires manufacturers to produce products that meet minimum performance standards and that these products are clearly labelled using a standard methodology. This is implemented through specific Ecodesign regulations and the Energy labelling regulations. The regulations covering electric (and therefore hybrid) heat pumps are:

- Commission regulation (EU) No 813/2013 Ecodesign requirements for space and combination heaters setting minimum performance requirements for heat pumps for water based space heating up to 400 kW.
- Commission delegated regulation (EU) No 811/2013 Energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device setting requirements for energy labelling and product data for heat pumps providing water heating up to 400 kW
- Commission regulation (EU) No 814/2013 Ecodesign requirements for water heaters and hot water storage tanks setting minimum water heating energy efficiency requirements for products with a rated output up to 400 kW and hot water storage tanks with a volume up to 2000 l.
- Commission delegated regulation (EU) No 812/2013 Energy labelling of water heaters, hot water storage tanks and packages of water heater and solar device setting requirements for energy labelling and product data.

These regulations came into force on 26th September 2015.

Reversible heat pump products that can also provide cooling will also need to meet minimum performance requirements for cooling. These come under Lot 21 of the Ecodesign regulations and the final draft of these regulations has been sent out for public consultation. It is proposed that they come into force on the 1st January 2018.

Details of the current and proposed requirements are given in Table 5.

Table 5 The minimum energy performance requirements that hybrid air to water, water to water and ground to water heat pumps need to meet

Implementation date	Minimum heating requirement SSHEE		Minimum cooling requirement SSCEE	
	Low temperature*	Other	GWP>150	GWP≤150
26 Sept 2015	115%	100%		
26 Sept 2017	125%	110%		
1 Jan 2018			149%	134%
1 Jan 2021			161%	145%

*Low-temperature heat pump means a heat pump space heater that is specifically designed for low-temperature application, and that cannot deliver heating water with an outlet temperature of 52 °C at an inlet dry (wet) bulb temperature of -7°C (-8°C) in the reference design conditions for average climate.

4.3 Building Regulations

There are no specific requirements with respect to heat pumps in the Building Regulations but recommendations on heat pumps are provided in the Domestic Building Services Compliance Guide. This recommends that the supply water temperature for radiators should be in the range 40 – 55°C for air to water, water to water and ground to water heat pump systems.

Standard assessment procedure (SAP) Appendix Q is a database of product performance which allows the use of specific performance data in the SAP (2012) calculations of building performance to confirm the building meets meet Part L of building regulations and to calculate building energy performance certificates. Appendix Q is currently being updated to accept Ecodesign data and to use the methodology proposed in the revised version of EN 15316-4-2 which proposes an hourly calculation method rather than the current bin method. The changes are likely to be implemented early in 2016 and should also incorporate hybrid heat pumps.

4.4 Microgeneration Certification Scheme (MCS)

MCS was set up to provide assurance on microgeneration technologies used to produce electricity and heat from renewable sources, and on the standard of installation of these technologies. It provides product certification for heat pumps not exceeding 45 kWth and individual installer and company certification. Participation is voluntary and fees are charged. There are initial fees for the assessment of product eligibility and initial and annual fees for assessment of installers. The assessment is carried out by an independent accredited certification body. The product certification scheme includes hybrid heat pumps and products have to meet the minimum energy performance requirements set by Ecodesign. MCS requires manufacturers to use a spreadsheet they have developed to calculate the SCOP and SSHEE, and products must have weather

compensation. Evidence of actual testing to determine the rating and performance at defined conditions must be provided[26].

MCS in collaboration with industry has developed an installer standard for heat pumps[27] which covers supply, design, installation, set to work, commissioning, and handover of heat pump systems. To be eligible to receive the Renewable Heat Incentive (RHI), systems need to be installed according to this standard and in addition the renewable heat output from hybrid heat pumps needs to be metered. This is often done by monitoring the total heat produced by the hybrid using a heat meter and subtracting the metered gas and electricity inputs.

The MCS heat pump installer guidance states that:

> "A heat pump shall be selected that will provide at least 100% of the calculated design space heating power requirement at the selected internal and external temperatures in Tables 1 and 2, the selection being made after taking into consideration the flow temperature at the heat pump when it is doing space heating".

And:

> "When selecting an air source heat pump, the heat pump shall provide 100% of the calculated design space heating power requirement at the selected ambient temperature and emitter temperature, after the inclusion of any energy required for defrost cycles."

This applies for products where the heat pump and boiler are purchased as a package. However the installer guide also says:

> "For installations where other heat sources are available to the same building, the heat sources shall be fully and correctly integrated into a single control system. A heat pump shall be selected such that the combined system will provide at least 100% of the calculated design space heating requirement at the selected internal and external temperatures. For installations where other heat sources are available to the same building, it shall be clearly stated by the MCS Contractor what proportion of the building's space heating and domestic hot water has been designed to be provided by the heat pump."

Therefore, to comply with the MCS guidance, where the heat pump and boiler are integrated into a single unit the heat pump component must be sized to meet 100% of the design load, however for hybrid add-on systems the combined capacity of the boiler and heat pump must meet the design load.

4.5 UK heat pump product test facilities

BSRIA have accreditation by the UK Accreditation Service (UKAS) to test heat pumps up to about 30 kW capacity according to EN14511 and are seeking UKAS accreditation for testing at part load to EN14825. Their facilities can test over a wide range of temperatures. They have two chambers so can test split or monobloc products.

BRE have test facilities for heat pumps and are accredited to EN14511 for air source heat pump testing (including conditions for the Home-heating Appliance Register of Performance, HARP, in Ireland) and also can test to EN14825 and EN16147 (Domestic Hot Water units).

KIWA provide MCS certification for air and ground source heat pumps.

[26] MCS007 Product Certification Scheme Requirements – Heat pumps, Microgeneration Certification Scheme, accessed December 2015 found here:
http://www.microgenerationcertification.org/admin/documents/MCS%20007%20-%20Issue%202.1%20Product%20Certification%20Scheme%20Requirements%20-%20Heat%20Pumps%202011.10.26.pdf

[27] Microgeneration Installation Standard: MIS 3005, BEIS updated 2015, accessed December 2015 found here:
http://www.microgenerationcertification.org/images/MIS_3005_Issue_4.3.pdf

4.6 European standards

A number of European countries have developed national standards especially relating to the design and installation of heat pumps. They will not be listed here except for the guidance produced by the Association of German Engineers as this has been widely used throughout Europe.

The Verein Deutscher Ingenieure; VDI 4650 -1 2009 calculation of the seasonal performance of heat pumps - Electric heat pumps for space heating and domestic hot water (DHW). This is currently under revision. This has a simplified approach to bivalent operation with a table showing demand coverage which is a function of bivalent point and the mode of operation (alternate, parallel, or partly parallel).

4.7 Product certification.

A number of other countries have set up their own product certification schemes for heat pumps

4.7.1 Eurovent Certita

This voluntary, fee-based scheme covers a wide range of HVAC products. Reversible air to water heat pumps have been included under the Liquid Chilling Packages and Heat Pumps (LCP-HP) programme for some time but coverage has increased since the incorporation of the French NF Heat Pump Mark which is now offered alongside the Eurovent Certification mark and a Euro Heat Pump programme was started in 2015. Eurovent product certification is based initially on self-verification but then subject to independent surveillance. It covers air to water, water to water and ground to water electrically driven or sorption heat pumps (since 2014) (air to water up to 100 kW at -7°C, water to water up to 1500 kW). They publish or are about to publish SCOP, SEER and SPER and the next regulations will include Seasonal space heating energy efficiency (SSHEE) and seasonal space cooling energy efficiency (SSCEE).

4.7.2 CEN Heat pump Keymark

The European Heat Pump Association agreed in December 2015 to set up the Heat Pump Keymark, a product certification scheme which is expected to be recognised throughout Europe. It will initially cover heat pumps included in Ecodesign Lot 1.

5 Hybrid Heat Pump Performance

A range of SSHEE and COP data has been analysed for the heat pumps component of hybrid heat pumps and there is a wide spread of performance. A number of trials are now underway to examine in-use performance but there is a lack of data to date.

- Since September 2015 it has been required for manufacturers to publish seasonal performance information to support the more commonly published COP information.
- Lab tested performance data (from the heat pump component of hybrid heat pumps) was collected from product brochures, ErP data fiches and manufacturer interviews.
- The average COP at A7/W55 of the air source products reviewed was 2.67 and ranged from 2.17 to 3.23 with no apparent dependence on capacity.
- The average Seasonal space heating energy efficiency (SSHEE) at 55°C (at average climate conditions) was 119%.
- Data from in-situ trials is limited because products have only been on the market in the UK for about two years.
- In-situ trials have shown that products can operate satisfactorily with conventional radiators but the economics are more challenging because the price differential between gas and electricity.

5.1 Laboratory-Tested Performance

The rated performance of hybrid heat pumps is tested according to BS EN14511. The test conditions for air to water heat pumps are shown in **Error! Reference source not found.**. It should be noted that the standard only c overs performance of the heat pump, not the whole hybrid system. Therefore the COP and SSHEE values presented below refer only to the heat pump component.

Table 6 - Test conditions for air to water heat pumps shows the Coefficient of Performance (COP) at A7/W55 (outside air at 7°C and the water out at 55C) for a selection of the hybrid products identified in this study

Heat pump type	Outdoor heat exchanger		Indoor heat exchanger	
	Inlet dry bulb temperature °C	Inlet wet bulb temperature °C	Inlet temperature °C	Outlet temperature °C
Air to water, low temperature	7	6	30	35
Air to water, medium temperature	7	6	40	45
Air to water, high temperature	7	6	47	55
Air to water very high temperature	7	6	55	65

Ground to water heat pumps and water to water heat pumps are tested with the same indoor heat exchanger temperatures as for air to water heat pumps but the outdoor heat exchanger temperatures are different. For

ground to water heat pumps the outdoor heat exchanger temperatures are inlet temperature 0°C and outlet temperature -3°C and for water to water they inlet temperature 10°C and outlet temperature 7°C. Hybrid heat

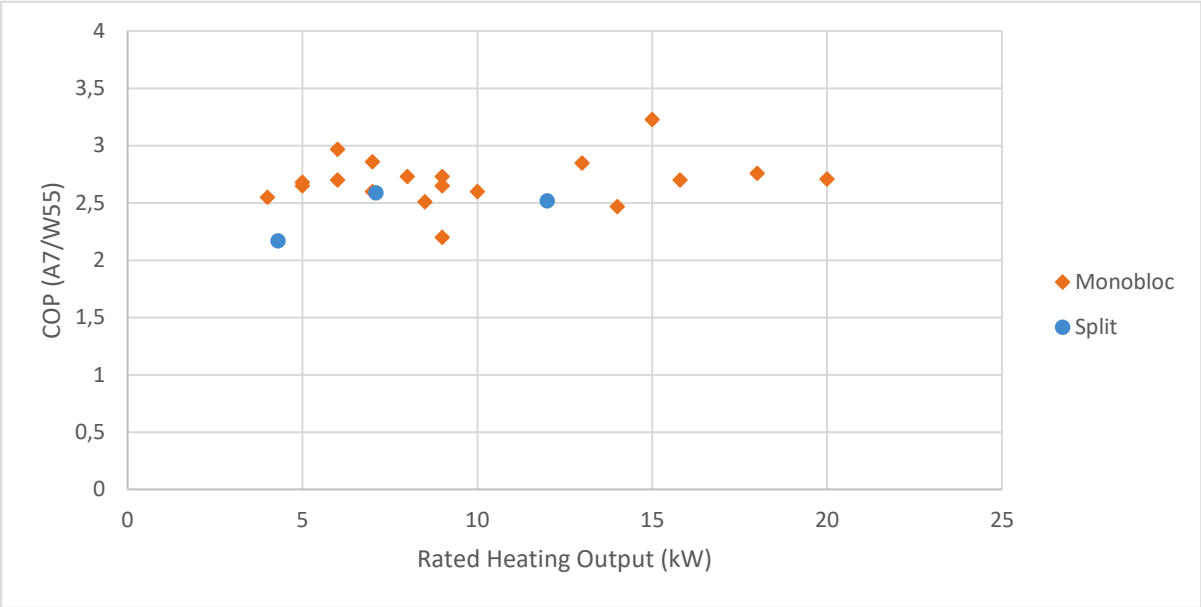

Figure 11 - COP values measured at A7/W55 for a selection of air source hybrid heat pumps

pumps are predominantly air to water products.

The average COP (heat pump component only) for the products in the sample was 2.67 and the minimum and maximum respectively 2.17 and 3.23. There is a substantial spread in performance among air to water products. The COP varies significantly because these tests are carried out at a single test point. Previously, heat pumps might have been designed to be optimised to perform well at this test point but now under Ecodesign test methodology products are optimised over a range of operating conditions. Based on this limited sample of products the rated COP does not appear to be dependent on the heat pump capacity.

The Ecodesign legislation setting minimum performance and labelling requirements came into force on the 26th September 2015. This requires manufacturers to provide data on the seasonal performance of products measured as the seasonal space heating energy efficiency (SSHEE) according to BS EN 14825. The SSHEE values for the same products as above (and some additional larger products) are given in Figure 12. Although there is still significant spread with a difference of between 20% and 25% between the lowest and highest values, the spread in performance when measured as a seasonal average is lower than when measured at the single rating condition. The SSHEE should be a more accurate measure of actual performance.

Figure 13 and Figure 14 show the SSHEE values for warm, average and cold climates for these products; split and monobloc products have been shown separately. They show an increase in seasonal performance for warmer climates as would be expected. The gradients do vary, possibly because products have been optimised for operation in different climate regions. The performance of split and monobloc products is similar.

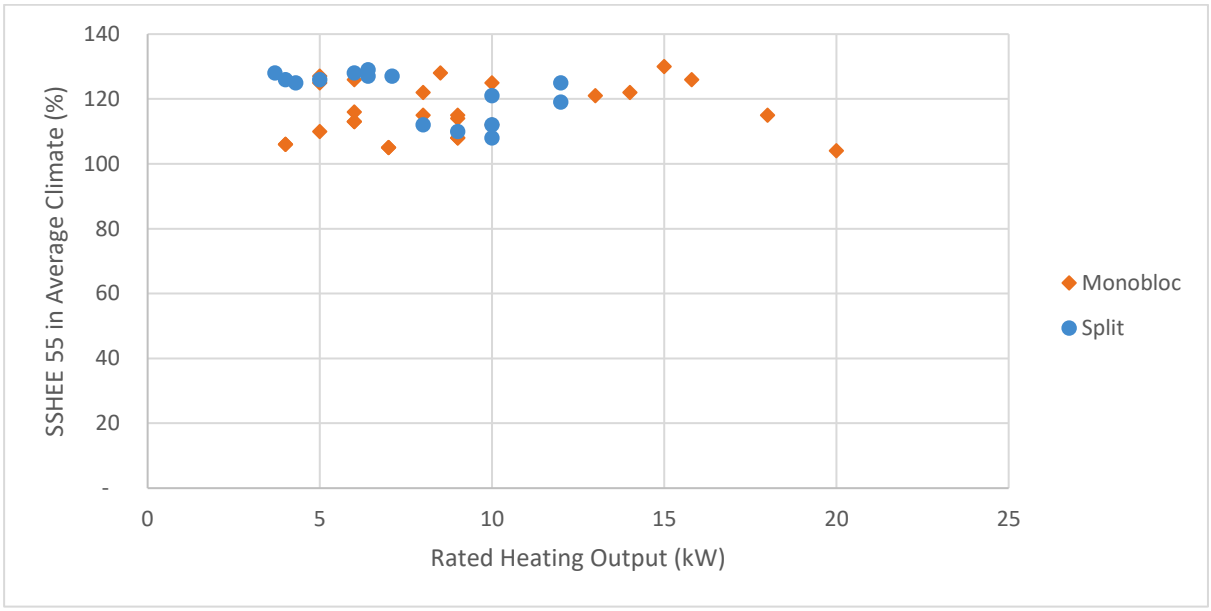

Figure 12 - SSHEE values for a selection of air source hybrid heat pumps with different capacities

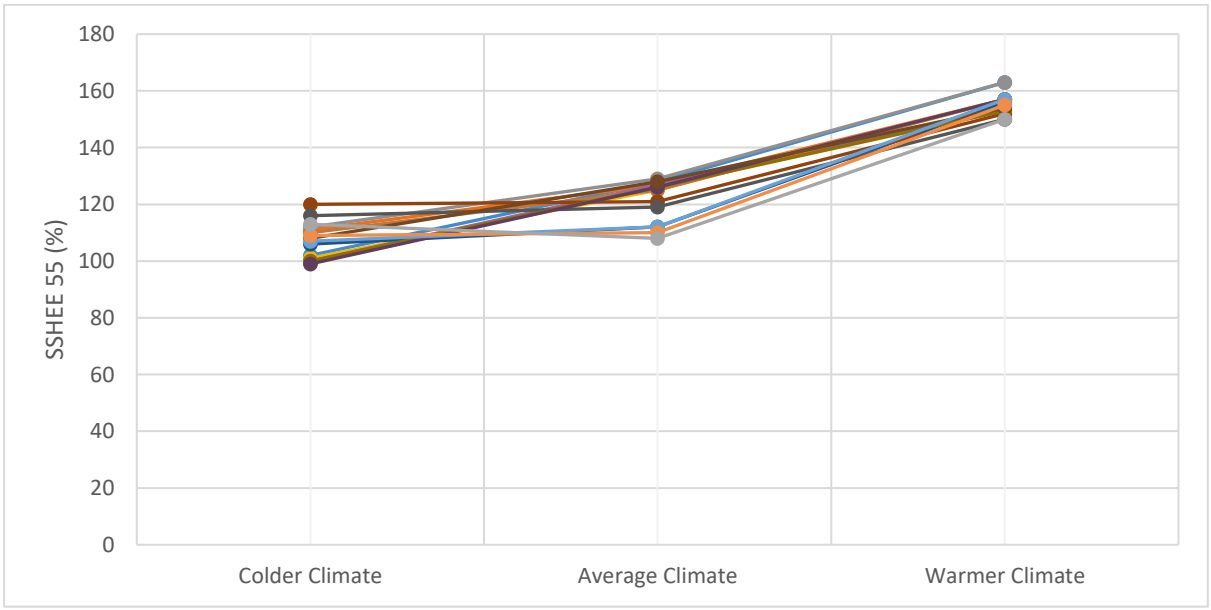

Figure 13 - SSHEE values for a selection of split air source hybrid heat pumps

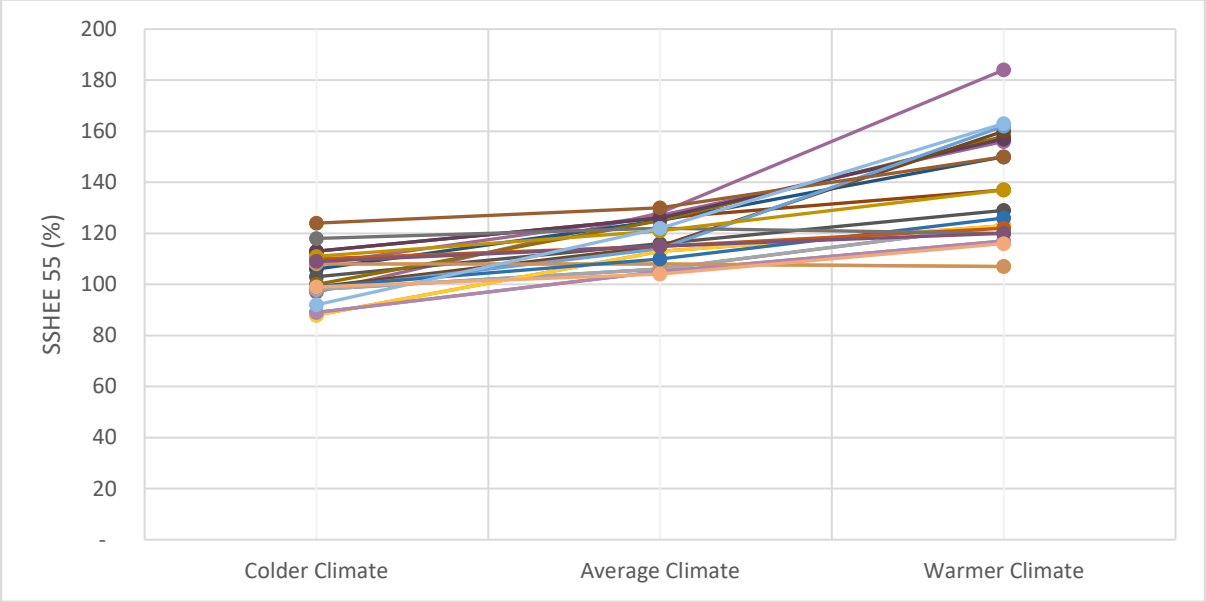

Figure 14 - SSHEE values for a selection of monobloc air source hybrid heat pumps

The average SSHEE at 55˚C for air to water heat pumps at average climate conditions was 119% and the maximum and minimum 133% and 108% respectively. The SSHEE value gives the performance in primary energy terms and converting these to performance in terms of delivered electricity by multiplying by 2.5/100 implies approximate seasonal performance factors (SPF) ranging from 2.6 to 3.75 which are all greater than the minimum SPF of 2.5 required for renewable energy.

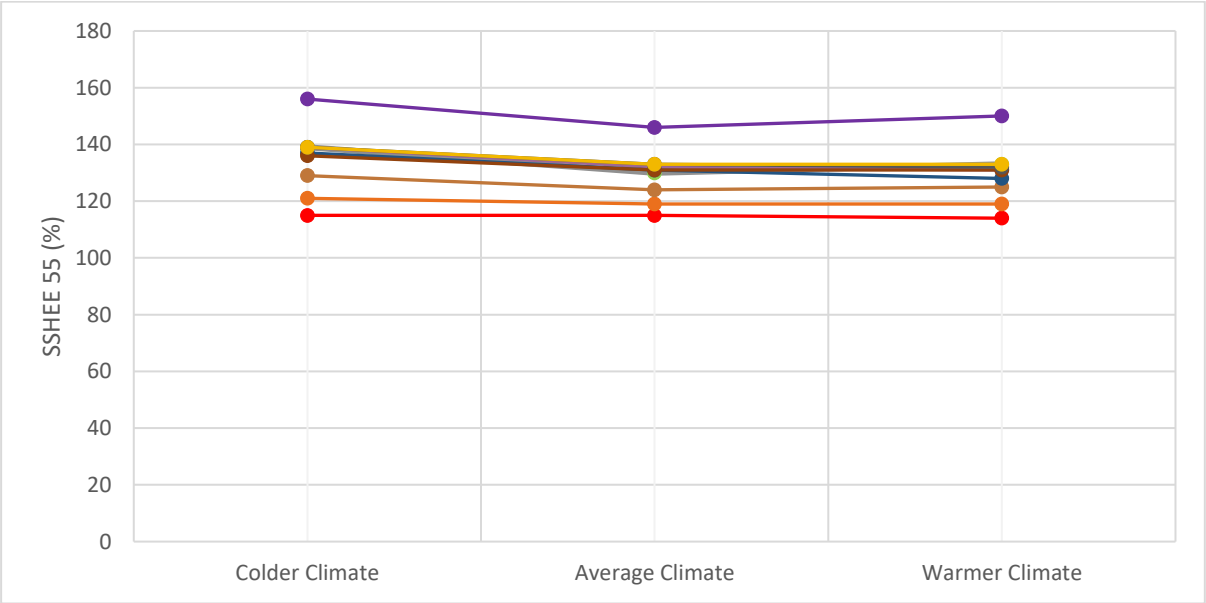

Figure 15 - SSHEE values for a selection of ground source hybrid heat pumps

5.2 In-Use Performance

Hybrid heat pumps have only been available in the UK for around five years and so in-use performance data is limited. Manufacturers have carried out some trials on their products but information is commercially sensitive and they can be reluctant to release detailed results.

Nine hybrid installations have been monitored by one manufacturer (Daikin) and the results from these are being analysed at Leeds Beckett University. Results released so far show that the SCOPs during the heating season varied between 3.1 and 4.0 but no seasonal figures are available yet.

One manufacturer, Vaillant, has monitored the performance of a single 5kW system providing space heating only and measured an SPF of 2.94 for the heat pump only. The savings compared to gas and electricity were about £200 to £250 a year plus an additional financial incentive payment.

Both gas and electricity utilities have shown interest in the technology. British Gas has run a detailed trial where ten systems were installed at the homes of staff members and the performance monitored over 12 months. They found that the systems, which were operated with conventional radiators, all operated reliably and that the users were very satisfied with the heating provided. Reasonable energy savings were achieved but the economics were more challenging because of the large differential between gas and electricity prices. They concluded that high running hours were needed as the running cost savings were small.

During this trial it was found that some users adjusted the programming in the controller which gave some erratic results for the run hours for the air source heat pump. With hybrid heat pumps, performance is very dependent on the control settings, and the need to reset controllers after users had altered them was identified as a major reason for call-outs by several manufacturers.

E.ON has also looked at hybrids and gathered information on a large number of products but have not conducted trials. The utility has carried out extensive modelling as a way of exploring the wide variation in system types and controls. They found the control system and control strategy were critical. The modelling showed that a reasonably priced system would pay back within its lifetime, but even after factoring in low carbon policy support, savings were small.

E.ON found that the largest size of the heat pump component of the hybrid system that made economic sense was about 5 kW and the average was about 3 kW, but this result was sensitive to changes in low carbon policy support and the ratio between gas and electricity prices. They also suggested that an incremental bolt-on system was most likely to be cost effective, for example retrofitting a hybrid heat pump and small thermal store to an existing gas boiler with the gas boiler providing the water heating. Their conclusions were not the same as the British Gas trial, but the studies were very different – with one based on modelling and the other on physical trials.

A number of Housing Associations and District Councils have also shown an interest in hybrid heat pumps but their focus is often on reducing energy costs and alleviating fuel poverty. Their results are often more qualitative than quantitative however Fyne Homes in Scotland, whose housing stock consists mainly of solid stone buildings, is just starting a trial of 9 hybrid heat pumps and Manchester University will assist with the monitoring of these. They have already installed some air source heat pumps and tenants have been very happy with these.

5.2.1 Relevant European trials

The Danish Technological Institute, funded by the Danish Energy Agency, have recently carried out detailed in–situ performance trials on 12 domestic hybrid heat pumps, 7 of which were installed in individual houses and 5 were in multi-family buildings. Overall for the 7 single houses the hybrid heat pumps had an efficiency of 114% and the seasonal performance factor was 2.95. On average the heat pump provided 70% of the heating and this resulted in a reduction in gas of 59%. The results for the multi-dwelling properties were similar with marginally higher savings. The conclusion from the trials was that although compatibility between products could be a problem, and correct installation and dimensioning were critical, heat pumps were a very successful way to reduce gas usage.

5.2.2 System sensitivities

Table 7 Overview of system sensitivities

Sensitivity	Description	Scale of sensitivity	Comment
Design	Sizing	* *	Because systems are only designed to provide a proportion of the load, sizing is less critical than for a full heat pump system however sizing will have a significant impact on cost For add-on hybrids it may be difficult to predict performance accurately
Installation	Poor installation will significantly affect the performance	* * *	Installation can require more skills than for just a boiler or heat pump Systems should be easy to install to minimise installation costs
Maintenance	The system will require more maintenance than either gas or heat pump only systems	* * *	Personnel with both F-gas and Gas Safe qualifications will be needed
Controls	The controller is a key component of the hybrid heat pump. More sophisticated control increases to potential benefits from the system	* * *	Advanced features include adaptive control and 'smart' functionality Benefits include: User – improved performance, reduced cost, lower emissions, access to preferential tariffs Utility – peak shifting Manufacturer – preventative maintenance, feedback on performance
User interaction	System performance is very sensitive to control settings which can easily be inadvertently changed by the user	* *	More automated control or the ability for settings to be adjusted remotely by the manufacturer could mitigate this

Key: *** = performance very sensitive to variable * = little sensitivity to variable

Feedback from stakeholders, and from the trials carried out to date, highlighted the importance of compatibility of the component products and that this could be better ensured when products are sold as a system. The trials indicate that the controls and control settings are key to optimising performance.

5.2.3 Expected technology lifetimes

The expected lifetime for the heat pump is 15 to 20 years and a view from stakeholders was that boiler life would be longer than the life of the heat pump. The possibility was raised that the life of the heat pump might be reduced when working in a hybrid system because the run hours were likely to be longer as it would be providing the base load. Likewise the demand on the boiler would be less than usual. If there was a significant difference in the lifetimes this would need to be taken into consideration when purchasing highly integrated systems.

5.2.4 Energy and Carbon Performance

The energy extracted from an ambient source can be considered as renewable. What fraction this forms of the delivered heat will depend on the efficiency of the hybrid heat pump.

Assuming that the electricity used by the heat pump is generated using fossil fuels, then the fraction of delivered heat that will be renewable will be given by (1-1/SPF), where the SPF is the seasonal performance factor.

For hybrid heat pumps the average SSHEE found from our product survey was 119% for air source hybrid heat pumps. This equates to a SPF of 2.975 (multiply SSHEE by 2.5/100 to account for electricity generation losses). The proportion of energy supplied by the hybrid system that is considered renewable will depend on the proportion of total energy usage covered by the heat pump. If the hybrid heat pump has been sized to meet 80% of the overall heating demand, then the fraction of heating energy that will be renewable will be 53%

5.2.5 CO2 savings

In order to estimate indicative CO_2 and cost savings, we have developed a generic scenario, and considered two possible counterfactuals – a gas condensing boiler, and an electric air to water heat pump.

The potential CO_2 reduction can be found by comparing the CO_2 emissions for two products to meet the annual space heating and water load for a typical building.

5.2.6 Assumptions

For this example we have assumed 12,000 kWh space heating and 2,000 kWh domestic hot water. Based on a typical load factor of 17%, this would require a hybrid heat pump of around 5kW or larger. The output water is assumed to be medium temperature (as defined by Ecodesign regulations), as we have used SSHEE at 55°C as the performance measure.

Carbon conversion factors and energy prices are shown in Table 8, taken from BEIS Green Book guidance[28].

We have assumed that the hybrid heat pump will provide 80% of the space heating needs and the remaining 20%, plus all of the DHW, is provided by the gas boiler component. We have assumed the gas boiler counterfactual provides 100% heating and DHW, but that the standard electric heat pump only provides 80% of the hot water, with the rest provided by direct electric back-up (because it will not reach the temperatures required to protect against legionella bacteria).

As a simplification, we have assumed that SSHEE is all allocated to the primary fuel (e.g. we have not accounted separately for the electricity use by the gas boiler).

The SSHEE and also Water Heating Energy Efficiency (WHEE) data in Table 9 has been extracted from our review of heat pump products and a brief survey of a sample of gas and oil boilers.

The simplified £/tCO_2 calculation has been calculated assuming an average installed cost of £8,000 for a hybrid package heat pump and £2,300 for a gas boiler counterfactual. For simplicity, a product lifetime of 15 years has been assumed for both. Annual running costs have not been included due to uncertainties over future energy prices.

[28] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, Data tables 1-20: supporting the toolkit and the guidance, BEIS, 2016, Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483282/Data_tables_1-20_supporting_the_toolkit_and_the_guidance.xlsx

Table 8 Carbon conversions and energy prices from BEIS green book guidance[28]

Carbon conversion factors		
Gas*	0.185	$kgCO_2/kWh$
Burning oil	0.247	$kgCO_2/kWh$
Electricity**	0.333	$kgCO_2/kWh$
Energy prices		
Gas*	4.11	p/kWh
Burning oil***	3.61	p/kWh
Electricity	14.83	p/kWh

* Fuel factors and prices based on kWh calculated based on gross calorific value
** Long run marginal factor used for electricity
*** Calculated from an oil price of 37.1p/litre

Table 9 Min, Max and average SSHEE and WHEE values across a range of heat pumps and boilers (from survey of Ecodesign fiche data)

	Minimum	Maximum	Average
SSHEE55 (%) / SPF			
Hybrid heat pump	104	133	119
Gas boiler			92.5
Oil boiler			90
Standard electric heat pump			119
WHEE (%) / SPF			
Hybrid heat pump	96	116	100
Gas boiler			82
Oil boiler			76
Standard electric heat pump			101

5.2.7 Energy use and savings

In Table 10 below the energy use, cost and carbon emissions are calculated for hybrid heat pumps, based on the range of SSHEEs and WHEEs found in our survey of available products. The equivalent results for a gas boiler counterfactual and a standard electric heat pump counterfactual and the savings for the hybrid heat pump relative to the counterfactual are also shown. The ranges of savings relate solely to the range of hybrid heat pumps efficiencies used. All other variables (such as the counterfactual efficiencies) are averages and are constant. Negative values denote that the savings are greater for the counterfactual.

Table 10 Energy use, carbon emissions and savings for hybrid heat pumps versus gas boilers and standard electric heat pumps

	Hybrid heat pump	Condensing gas boiler counterfactual	Standard electric heat pump counterfactual
Total space heating consumption, kWh/yr	5,480-6,290	12,970	4030
Total water heating consumption, kWh/yr	2,440	2,440	1,030
Total energy consumption kWh/yr	7,920 to 8,730	15,410	5,070
Total carbon emissions, kg/CO_2/yr	1,890 to 2,160	2,840	1,690
Total energy cost £/yr	640 to 760	630	750
		Savings using a hybrid heat pump:	
Energy saving kWh/yr		6,690 to 7,490 (43 to 49%)	-3,660 to -2,850 (-77 to -56%)
Carbon saving, kgCO_2 /yr		690 to 950 (24 to 34%)	-470 to -200 (-28 to -12%)
Cost saving £/yr		-120 to -2 (-19 to 0%)	-3 to 120 (0 to 15%)
Simple £/tCO_2 saved relative to counterfactual		450	

Nb indicative values only, subject to rounding errors

In the scenario modelled the hybrid heat pump results in approximately the same annual energy costs as a gas fired boiler, with a small energy and carbon saving.

There are cost savings of between 0% and 15% compared to a standard electric heat pump because of the price differential between gas and electricity. However, carbon emissions are a little higher (approximately 10-30%) for the hybrid heat pump in this case.

A simple carbon abatement cost £450/tCO_2 has been calculated i.e. the additional cost of purchasing and running a hybrid heat pump compared to a gas boiler, per tonne of CO_2 saved over the product lifetime.

It should be noted that the carbon emissions factor for electricity is expected to fall in subsequent years and so the carbon emissions associated with the standard electric heat pump are likely to come down over time.