Department for
Business, Energy
& Industrial Strategy

Evidence Gathering – Low Carbon Heating Technologies

Domestic Hybrid Heat Pumps

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Prepared for BEIS by:

The Carbon Trust and Rawlings Support Services

The views expressed in this report are those of the authors, and do not necessarily reflect those of the Department of Business, Energy and Industrial Strategy.

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Acronyms

CCC	Committee on climate change
COP	Coefficient of performance
BEIS	Department of Business, Energy and Industrial Strategy
DHW	domestic hot water
ErP	Energy related products (Ecodesign)
EVI	Enhanced vapour injection
GWP	Global warming potential
HARP	Home-heating appliance register of performance
LPG	Liquefied petroleum gas
MCS	Microgeneration certification scheme
SAP	Standard assessment procedure
SCOP	Seasonal coefficient of performance
SEER	Seasonal energy efficiency
SPER	Seasonal primary energy ratio
SPF	Seasonal performance factor
SSCEE	Seasonal space cooling energy efficiency
SSHEE	Seasonal space heating energy efficiency
VDI	Verein Deutscher Ingenieure

Contents

1. Executive summary

Introduction

Most low carbon pathways suggest that heat pumps will play a large role in decarbonising the UK economy. The Committee on Climate Change (CCC) has suggested that the overall cost-effective uptake of heat pumps in UK homes could reach 2.3 million by 2030[1].

This study was undertaken by the Carbon Trust for the Department of Business, Energy and Industrial Strategy (BEIS) to inform their evidence base on domestic hybrid heat pumps. The purpose is to help explore the role hybrid heat pumps may play in the market and inform future UK policy intervention relating to low carbon heating technologies.

This study was conducted from September 2015 to December 2015 using desk-based research, interviews with experts and stakeholders, and a stakeholder workshop. Experts from 40 organisations were interviewed across both the demand and supply side.

The Technology

A hybrid heat pump system is defined here as an electric air to water or ground to water heat pump combined with a gas boiler; a means of inputting the heat into an existing heat distribution system; and a dedicated control system to switch between the two sources. There are 2 types of product considered:

- **Hybrid package heat pumps** – sold as a single package, including heat pump unit, gas boiler and intelligent controller.
- **Hybrid add-on heat pumps** – sold as a heat pump unit with an intelligent controller which can be retrofitted to an existing gas boiler.

A hybrid heat pump system can meet the full heating and hot water needs of a domestic property. The boiler is used to reach higher temperatures needed to provide domestic hot water, whilst the heat pump can provide base load low temperature heating at a lower cost and using less energy. An intelligent hybrid heat pump system can optimise running costs, energy efficiency or carbon emissions of the heating system by switching between the two sources.

[1] Sectoral scenarios for the Fifth Carbon Budget, Technical report, *Committee on Climate Change, Nov 2015*

Current state of market and future market potential

Hybrid heat pumps have a wide range of potential applications. When used in conjunction with existing high temperature radiators, the boiler can top up the space heating. They can be combined with an existing boiler and water tank, or with a combi boiler, reducing costs. They can also be suitable for installation in new build properties.

There are many domestic hybrid heat pump products currently available on the market in the UK. However, many of the manufacturers do not directly market their heat pumps as hybrids, but simply include ‘hybrid compatible’ or ‘hybrid function’ in a list of many features.

Hybrid heat pumps currently have about 18% of heat pump market share (however, this includes simple bivalent heat pumps).

Stakeholders were positive about the future of hybrid heat pumps due to the reducing cost differential between hybrids and alternative technologies, but they currently remain a niche market. The estimated potential annual market is 100,000 to 210,000 units.

Costs and performance

The current cost of replacing a gas boiler with a hybrid heat pump can be around three times higher. The price of hybrid air source heat pumps ranges from under £2,000 to over £7,000 depending on the size, type and make of product. The fully installed price identified in this study is consistent with studies focussed on standard heat pumps, ranging from £4,000 to £11,300 for air source products.

In terms of running costs, most stakeholders agreed that hybrid heat pumps make little saving compared to a good quality, well-installed gas-fired condensing boiler, for example 0-5% cost savings, although they can achieve good carbon savings.

It is difficult to provide a definite indicator of performance for hybrid systems as a whole as there are no specific performance standards for electrically driven hybrid heat pumps. Published performance data is for the heat pump component only.

At A7/W55 (ambient air source at 7°C and water output at 55°C), the Coefficient of Performance (COP) for the products looked at varied significantly, with a range of 2.17 to 3.23. The average Seasonal Space Heating Energy Efficiency (SSHEE) at 55°C was 119% and varied from 104% to 133%.

Information gathered from a number of trials has shown that hybrid heat pumps generally perform well, however particular care is needed with controls. It is hard to draw quantitative conclusions on the relationship between lab and in-use performance, due to the lack of a performance standard and limited availability of trial data.

Barriers and drivers for deployment

A number of barriers exist to large scale uptake of heat pumps, however hybrid heat pump technology can help to mitigate some of the traditional barriers.

Hybrid add-on heat pumps have the benefit of being cheaper than a standard electric heat pump due to the smaller size requirements. They may reduce customer resistance to heat pumps as consumers are used to gas powered heating. They can also be used to deliver a high temperature heating output (using the boiler for back up) and domestic hot water.

However they have some additional barriers to overcome such as lower awareness compared to standard heat pumps. They are new to the market and there is a lack of trial information, and so the cost benefits and performance are unproven.

Hybrid heat pumps also suffer from other commonly quoted barriers to heat pumps, such as concerns over performance of earlier heat pump installations, and the need for additional space.

Gap Analysis

In general, confidence in the information collected is good. However, performance information is limited and site specific.

Stakeholders have been willing to share information across the full range of topics considered, and this information has been cross-checked against previous studies (with good consistency across different sources).

As this technology is new to market, although there is good published performance information based on standard conditions, in-situ verified results are limited. Furthermore, published information relates only to the heat pump performance, and not to the full system.

Further trials and modelling would be helpful to more accurately determine the potential cost and carbon savings across the range of different property types in the UK. This information may also help to stimulate demand (by convincing end-users about real-world performance).

Conclusions

Hybrid heat pumps could be a competitive low-carbon transition technology, delivering the carbon saving benefits of an electric heat pump with the performance of a gas boiler when required. Having a system that is capable of performing like a gas boiler may help to overcome consumer inertia (as consumers show a strong preference for gas boilers due to their familiarity with this technology).

The technology is suitable for the UK housing stock and can potentially be fitted with existing, high temperature radiators, although replacing some radiators may be preferable in some cases to improve overall system performance.

2. Introduction and context

This study for the Department of Business, Energy and Industrial Strategy (BEIS) serves to inform their evidence base on domestic hybrid heat pumps, to help inform future UK policy intervention relating to low carbon heating technologies. It has been carried out by the Carbon Trust, who have consulted widely with demand and supply side stakeholders.

Specifically, this report seeks to:

- Give an overview of the current state of the art
- Review the current UK market and future market potential
- Review relevant technical standards
- Gather information on system performance (rated and in-use)
- Gather evidence on current costs and the potential for future cost reduction
- Discuss the barriers to deployment
- Identify where major gaps in evidence currently exist and measures to fill these gaps

The above topics form Chapters 4 to 10 of this report.

Scope

Geographical scope

The focus of this report is on products that are already available in the UK market. However, as this is a relatively new technology application, we also considered products that are available in Europe. In our literature review we examined sources from across the world to inform our research approach, particularly uptake in the European market.

Technology scope

The technology category addressed by this project is hybrid heat pumps designed for domestic use.

A heat pump is: a device that can transfer heat from a low temperature source, such as ambient air, water, the ground or waste heat, and raise it to a higher useful temperature.

Domestic hybrid heat pumps

For the purposes of this study, domestic hybrid heat pumps have been defined as electric air to water or ground to water heat pumps heat pumps either integrated with, or sold as a package with a dedicated gas boiler; or designed to operate with an existing boiler. In either case, they include a dedicated, intelligent control system to operate and switch between the two sources. For this study products of up to 45kW (for the heat pump capacity) have been considered.

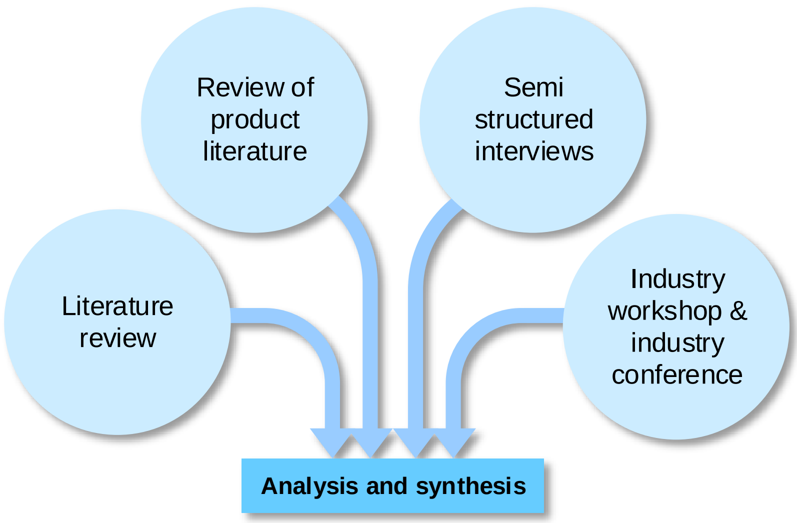
A hybrid heat pump system can meet the full heating and hot water needs of a domestic property. The boiler is used to reach higher temperatures needed to provide domestic hot water, whilst the heat pump can provide base load low temperature heating at a lower cost and using less energy. An intelligent hybrid heat pump system can optimise running costs, energy efficiency or carbon emissions of the heating system by switching between the two sources.

3. Methodology

Research and Analysis

Our approach to this study was to divide the work into four activity streams. We began with a desk-based literature review to gather insights from published material. We also undertook an in-depth study of supplier product information (sales material and technical data). We then spoke to key stakeholders in a series of semi structured interviews. This was followed up with an industry workshop to present the initial findings and seek feedback. Using these different sources of information allowed the project team to triangulate the data and strengthen the confidence in the resulting project findings. Figure 1 summarises the research process.

Figure 1 Summary of the research process



The four activity streams were used to inform the main study areas defined by BEIS which can broadly be summarised as:

- State of the art
- Market potential
- Technical standards
- System performance
- Costs
- Barriers
- Gap analysis

Figure 2 summarises the activities employed in the research stages and which key study areas they informed.

Figure 2 An outline of the key activities and focus areas for each research method

	Desk based research	Review of product literature	Semi structured interviews	Industry workshop
Activities	• Extract publicly available information • Review academic research • Access current and applicable standards • Source field trial information	• Access manufacturer's websites and catalogues and Ecodesign information	• Talk to key stakeholders from the supply side, demand side and other stakeholders	• Present interim findings to key stakeholders • Encourage discussion between manufacturers and end users
Key study areas	• Technical standards • Barriers • Technology	• Technology • System performance • State of the art	• Barriers • Costs and market • System performance	• Market potential • Barriers • Gap analysis

Evidence gathering process

Literature review

We reviewed over 150 documents relating to both hybrid heat pumps and general heat pump technology. These provided information on the technology variants, claimed performance, market information and standards. The amount of information specifically relating to hybrid products was limited, but we have extrapolated from general heat pump information where appropriate.

Product review

We also collated product information and performance data from supplier sales brochures, technical and installation brochures, and technical data sheets. These were obtained from manufacturer and supplier websites, and from direct contact with suppliers.

During the course of the project the deadline for manufacturers to publish technical performance information under the Ecodesign (ErP) regulations passed. We therefore hoped to be able to obtain standardised manufacturer SSHEE (see section 7) data from manufacturer websites. However, this information was difficult to locate, and often not immediately accessible through manufacturer websites. In many cases it was necessary to identify and speak to relevant people within the organisation to find the information.

Semi-structured interviews

The Carbon Trust interviewed 40 key stakeholders for this study. In the interviews we critiqued our findings from the literature reviews and collected commercial information (e.g. product costs, sales), and data on in-use performance. We also discussed the current status of the market and potential for hybrid heat pumps.

The interviews were structured to examine each of the key study areas. Figure 3 shows an outline topic guide for the demand side and supply side interviews.

Figure 3 Example of interview structure according to the stakeholder's experience with the technology.

Supply side (e.g. manufacturers; installers)	Demand side (e.g. housing developers)
Products on sale and in the pipeline Lab and in situ performance Installation process Product maintenance schedules Costs Market structure and demand Innovation and R&D Barriers	Discussion of experience with heat pumps in general In situ performance Installation process Product maintenance schedules Costs, running costs and payback periods Barriers Discussion of specific experience with the technologies

We interviewed a wide range of stakeholders including; housing associations, utility companies, installers, trade associations and manufacturers (see Figure 4). Our sampling was structured, using existing Carbon Trust contacts and establishing contacts with manufacturers that have relevant heat pumps in the UK or international markets. We particularly sought out stakeholders that had supplied, installed or carried out field trials of hybrid heat pumps.

Figure 4 shows the distribution of 40 interviews carried out

		Interviewees
Supply side	Installers	14
	Manufacturers	
	Distributors	
Other stakeholders	Test houses & standards bodies	10
	Utility companies	
	Researchers/academics	
Demand side	Local authorities	16
	Housing associations	
	Housing developers	
	Total	40

Stakeholder workshop

At the workshop we brought together supply and demand side stakeholders from across the heat pump sector to present our interim findings and sought to capture their feedback. The workshop was attended by 14 stakeholders.

As stakeholders were aware that the final outputs from this study could inform future policy there was a risk of gaming and bias from the participating stakeholders. To mitigate this, all figures provided have been sense checked, and compared with published information e.g. market studies, performance data, price lists etc. We sought opinions from a wide variety of stakeholders to ensure triangulation of the feedback.

4. Current State of the Art

Hybrid heat pumps deliver the carbon saving benefits of an electric heat pump with the performance of a gas boiler when required. The key to hybrid operation is the intelligent controller.

- **Hybrid heat pumps are air or ground to water heat pumps, packaged with a gas boiler or designed to operate with any boiler, with a dedicated, intelligent control system.**
- **The heat pump can provide baseload low temperature heating at high efficiency. The boiler is used to reach higher temperatures needed to provide hot water and meet peak heating loads.**
- **The intelligent controller can optimise running costs, energy efficiency or carbon emissions by switching between the two sources. It can also allow for remote operation, allowing electricity grid demand management.**
- **Hybrid heat pumps have a wide range of potential applications.**
- **When used in conjunction with existing high temperature radiators, the boiler can top up the space heating. They can be combined with an existing boiler and water tank, or with a combi boiler, reducing costs.**
- **They can also be suitable for installation in new build properties.**
- **Hybrid heat pumps can help overcome customer inertia, where customers are used to gas heating, and the dual system provides a sense of security.**

Available Systems and System Diagrams

Within this section we describe the design and operation of hybrid heat pumps, along with their typical configurations and applications, and pros and cons. The principle of heat pump operation is described first, using a standard electric heat pump to illustrate.

Standard heat pumps

A heat pump transfers heat from a low temperature source such as ambient air, water, the ground or waste heat, and raises it to a higher useful temperature. Most heat pumps use a mechanical vapour compression cycle with the compressor driven by an electric motor. They make use of the fact that:

- When a substance evaporates it absorbs a large amount of energy which is then emitted as it condenses
- The temperature at which a liquid boils increases as the surrounding pressure increases
- The amount of energy required to transfer the heat is relatively small compared to the total energy transferred. Heat pumps can therefore provide an energy efficient, low carbon form of heating

Standard vapour compression heat pumps work by alternately evaporating and condensing a refrigerant. The main components are shown in The COP is measured in terms of delivered electricity. The SSHEE is a measure of performance averaged across a defined load profile, which is designed to represent real life use. SSHEE is measured in primary energy terms (before any conversion or delivery losses, for example electricity generation losses) which allows comparison of different technologies using different energy sources.

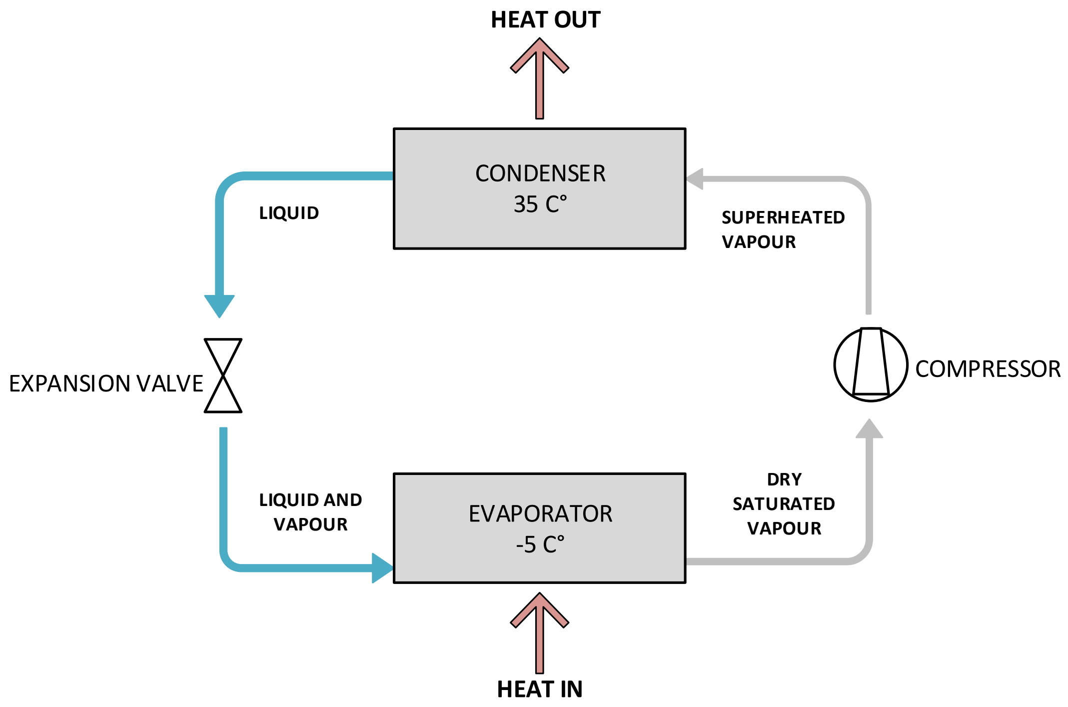
Figure 5 and include: an evaporator, a compressor, a condenser, an expansion valve and a refrigerant such as R410A. Standard heat pumps are able to efficiently provide water flow temperatures of up to 55°C.

The performance of a heat pump is limited by the source and output temperatures which respectively need to be as high and as low as possible to minimise the amount of temperature lift the heat pump has to provide. For example a heat pump system using the ground (which has a higher average temperature than the air in winter) as a source, supplying underfloor heating at an output temperature of 35°C, will have a higher efficiency than one using ambient air as the source and supplying radiators at an output temperature of 55°C.

The steady state performance of a heat pump is measured by the coefficient of performance (COP) which is the ratio of the heating capacity to the effective power input of the unit. The COP is measured in terms of delivered electricity. The SSHEE is a measure of performance averaged across a defined load profile, which is designed to represent real life use[2]. SSHEE is measured in primary energy terms (before any conversion or delivery losses, for example electricity generation losses) which allows comparison of different technologies using different energy sources.

[2] As explained in Commission regulation (EU) No 813/2013 which can be found here: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0813&from=EN

Figure 5 Standard vapour compression heat pump circuit



Hybrid heat pumps

A hybrid heat pump is defined here as an electric air to water or ground to water heat pump either: integrated with, or sold as a package with, a dedicated gas boiler; or designed to operate with an existing boiler. It includes a means of inputting the heat into an existing heat distribution system, and a dedicated control system to switch between the two sources. The heat pump provides the lead heating and typically meets about 80% of the heating demand. The heat pump is typically sized to meet 50% of the capacity which will provide 80% of the annual heating needed in a dwelling as shown in Figure 6[3].

Hybrids will typically operate in one of two ways (see

Figure 7). The left hand side shows balance point operation, where the boiler kicks in with supplementary heating and acts as additional support to 'top up' the heat pump. The balance point is the temperature below which the heat pump cannot meet the full heating load. Two modes of operation are possible below this point; the heat pump can continue to operate and the boiler provides additional 'top-up' heat (parallel operation) or the heat pump switches off and the boiler takes over to provide all the heating (alternative operation).

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[3] Illustrative curve, produced by the Carbon Trust

The balance will move according to the capacity and size of the heat pump. In addition, consumers have a certain level of choice as to where the balance point is.

Figure 6 A typical domestic hybrid heat pump sizing curve showing the heat pump size and how much of the annual heating it will provide

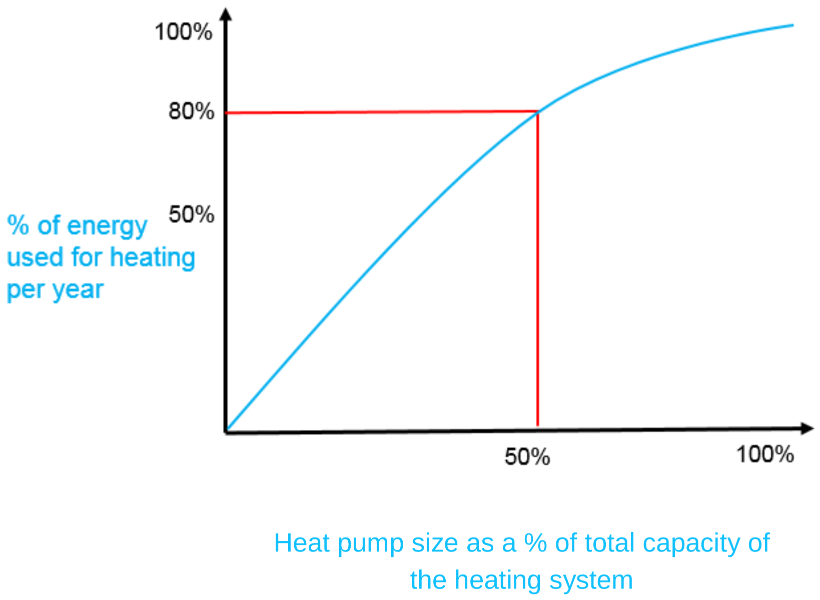
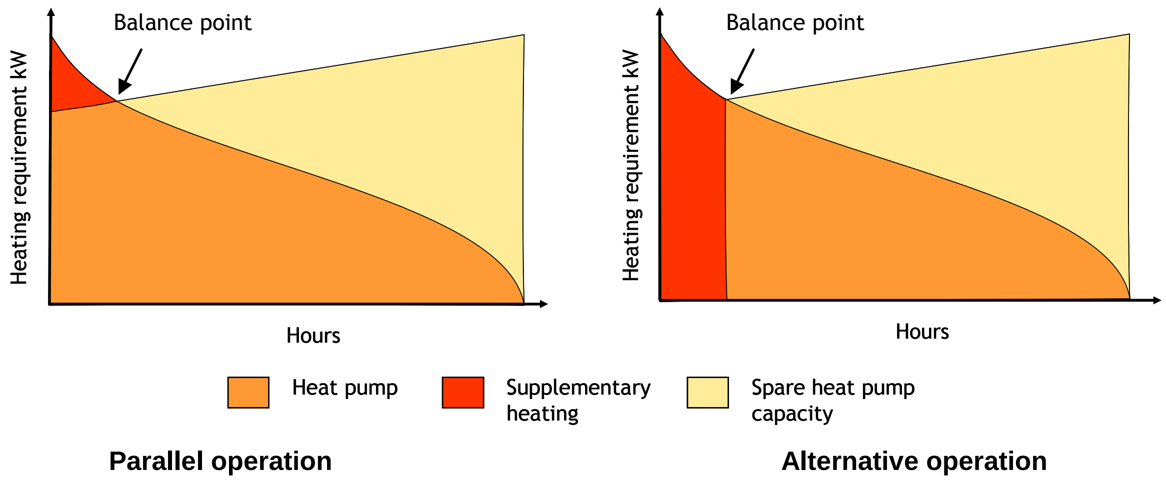


Figure 7 Hybrid heat pump operation types – parallel operation (left) and alternative operation (right)[4]



[4] Illustrative curves, produced by the Carbon Trust

Intelligent controllers can be set for a range of functions including optimisation of running costs, energy efficiency, and carbon emissions or potentially to allow control of the heat pump by a utility company to manage demand. They are able to intelligently regulate the system based on factors such as weather.

Hybrid heat pumps within the scope of this study have been divided into two categories; hybrid package heat pumps and hybrid add-on heat pumps as shown in Table 1. Hybrid package heat pumps are sold as a complete package. The components may be integrated into a single product - or supplied together as a set of matched products. The second category, hybrid add-on heat pumps, can be retrofitted to an existing gas boiler.

Simple bivalent heat pumps which can switch between a gas boiler and the heat pump, but where the units do not work together intelligently to optimise the system, can also be considered hybrid heat pumps but are outside the scope of this project.

As ‘hybrid’ can essentially be defined as any two different systems working together, some other technologies are marketed as hybrid products. These include solar/boiler hybrids, two different heat pumps working together, and heat pumps with oil boilers. This study specifically focusses on heat pump/gas boiler hybrid technology so other hybrid technologies will not be included in this report.

Table 1 Components of the two hybrid systems considered

Hybrid system	Components	Application
Hybrid package heat pumps	• heat pump unit • gas boiler • intelligent controller	Replacement system
Hybrid add-on heat pumps	• heat pump unit • intelligent controller	Can be retrofitted to an existing gas boiler

The heat pump can be either monobloc or split. With a monobloc product the heat pump is a single unit, usually mounted outside. Heat is transferred to the house using water which contains glycol to protect it from freezing, so a heat exchanger (mounted in the ‘hydrobox’ - see Figure 8) is used to transfer the heat from the heat pump into the heating system and keep the two circuits separate. The hydrobox also usually incorporates the system controller and contains the expansion vessel and pump.

In a split hybrid system the heat pump is in two parts; an outdoor unit comprising of the outdoor heat exchanger and the compressor, and an indoor unit comprising the indoor heat exchanger. Refrigerant circulates between the two parts. Some of the indoor components can be housed together, for example, in some products the heat pump indoor unit and hydrobox are combined and mounted with the boiler.

The heat pump may or may not provide water heating. Figure 8 shows a monobloc heat pump in a simple system where the heat pump just provides space heating and the boiler provides any top-up space heating needed and all the domestic hot water. The boiler can be a standard boiler or a combi-boiler. Figure 9 shows a split heat pump and a system where the heat pump contributes to both the space heating and the domestic hot water.

Some manufacturers recommend that the system also includes a buffer tank. The buffer tank is a thermal store which decouples the supply of heat from the heat pump and the demand from the heating system. A buffer tank can be used to:

- Ensure minimum flow through the heat pump
- Ensure a minimum run time and so reduce cycling
- To provide heat if the heat pump is unavailable

A buffer tank can be added either in parallel or in series. If it is added in series it is usually added in the return to the heat pump rather than the flow from the heat pump, to avoid slowing down the heating response time.

Figure 8 Monobloc hybrid heat pump with buffer tank mounted in parallel providing space heating only

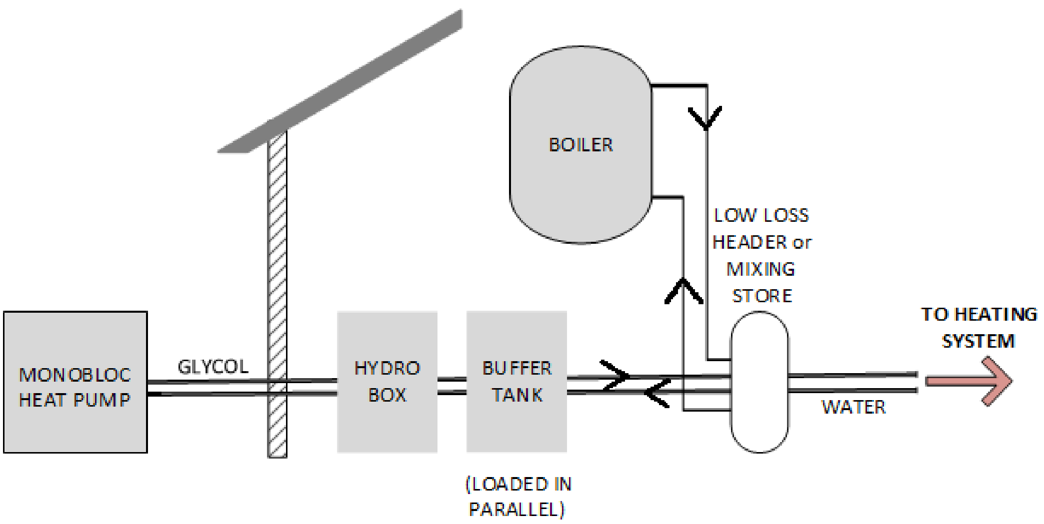
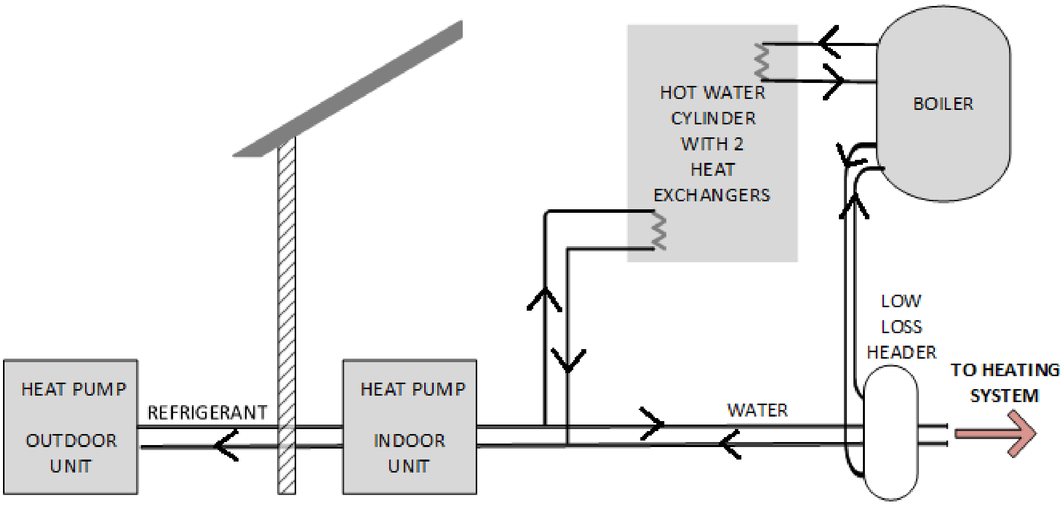


Figure 9 Split hybrid heat pump providing space heating and domestic hot water pre heating



Hybrid heat pump control

The intelligent controller for a hybrid system can be set for a range of functions including optimisation of running costs, energy efficiency, and carbon emissions.

Intelligent controllers are able to switch between the heat pump and boiler to optimise the system based on a number of external factors. Ideally it should be possible to enter the cost of fuel, CO_2 conversion factors and the efficiency of the alternative heat source. Weather compensation and load compensation should be inbuilt. It should be possible to set a floating (variable) bivalent point based on lowest cost, lowest emissions or lowest energy.

The controller may also be Wi-Fi enabled with "smart" capability, including two-way communication allowing external control of the system. This could be used by utility companies in future for demand management (i.e. demand side response[5]: shifting the time of electricity demand). Not all controllers on the market currently offer this level of functionality but this should be seen as the current attainable level of technological development.

The control system is usually compatible with a common two channel controller and capable of linking with the customer's existing heating and hot water controller.

The maximum temperature provided by the heat pump component of a domestic hybrid heat pump system is usually up to 55˚C. Whilst these high temperatures are feasible, it is much more common for the heat pump component to run at low temperatures to provide a constant low temperature baseload, whilst the boiler provides high temperature heating (when required) and domestic hot water.

[5] See for example: Why energy companies will need smart heat pumps, *Delta-ee, Sept 2013*

System Applications

Domestic hybrid heat pumps can be applied to either the new build or retrofit market due to the flexibility of the options and combinations available. It is in the retrofit market however, where they show their largest potential. This technology could bridge the gap between accepted gas-fired boiler heating systems and the requirement for electric heating which will become progressively lower carbon as electricity supply becomes decarbonised.

The applications marketed for domestic hybrid heat pumps are varied. Some manufacturers specify their hybrid systems most frequently for small, on grid properties as a replacement for a standalone gas boiler or as an add-on to an existing gas boiler with a reasonable remaining lifetime. Others named older properties as the target market, with high heat loads and existing high temperature radiators, and where a heat pump large enough to cover the full load cannot be used because of the restriction of a single phase electricity supply. Another application was thermally efficient buildings where a lower investment option is sought than a standard electric heat pump – where a smaller heat pump can be sized and a low cost combi boiler can continue to provide all domestic hot water.

Due to the boiler being able to meet the high temperature heating and hot water requirements of a property, in some cases the existing high temperature heating distribution system can remain unaltered. However this will not optimise the contribution from the heat pump. By modifying some key heat emitters (e.g. radiators) to allow the space heating to operate at lower temperatures the heat pump can deliver a higher proportion of the heating load, maximising the system efficiency. Some manufacturers have told us they do not market their systems as suitable for high temperature distribution systems as they are not competitive with a standalone boiler heating system.

Table 2 explores the relative advantages and disadvantages of the two different categories of hybrid heat pumps.

Table 2 Advantages and disadvantages of the two categories of hybrid heat pump addressed in this report.

System type	Advantage(s)	Disadvantage(s)
Hybrid package	• Ease of purchase and installation as supplied as one package • Manufacturers can ensure performance of the system as they have created all component parts • If the product is a distress purchase, the boiler could be connected straight away in advance of the full system being commissioned. • Some products combine the heat pump indoor unit and boiler in one box, which can make the product more compact	• Higher capital cost as package includes a boiler • Less flexibility as units cannot be 'mixed and matched'
Hybrid add-on	• Can be retrofitted to any existing boiler • User doesn't have to wait until boiler needs replacing to add the heat pump, and gain the efficiency benefits • Can be paired with any new boiler, allowing for low cost options to be considered	• There is less certainty over the efficiency of the system when the boiler is unspecified • Problems of compatibility could occur between the heat pump, boiler and control system

Potential Innovation

No major technology innovations have been identified. Additional manufacturers are thought to be investigating producing integrated packaged products

There is considerable scope for general heat pump efficiencies to increase. One major compressor manufacturer, has recently developed a new range of compressors incorporating enhanced vapour injection (EVI) which show an improvement of over 12% in efficiency, and the efficiency of heat exchangers is also steadily increasing. These improvements can help to reduce the size of equipment and more efficient fans can help to reduce noise.

Development of the controller is where the main innovation for hybrid heat pumps is likely to come. Manufacturers are building more sophisticated controls into their standard heat pumps which allows them to act as a ‘hybrid compatible’ products i.e. when combined with a boiler they operate as a hybrid system.

Further developments in “smart” controls are likely to allow remote control of heat pumps by utility companies, in order to manage demand (as discussed in section ‘Hybrid heat pump control’).

5. Market and Product Review

Despite positivity from stakeholders about the future of hybrid heat pumps, hybrids remain a niche market.

- **There are three packaged solutions but a large number of add-on hybrid heat pumps on the market.**
- **Hybrid heat pumps currently have about 18% of the heat pump market share (if all bivalent systems are included)**
- **The main market for packaged hybrid heat pumps is the new build or boiler replacement market.**
- **The largest market for add-on hybrids is retrofit to existing boilers.**
- **Hybrids are a potential 'bridging' technology from fossil fuels to low carbon technologies**
- **We have estimated the potential annual market at 100,000 to 210,000 units.**

Product Review

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.

Table 3 Manufacturers and product ranges

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.

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
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.
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, CO_2, unit	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

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
				failure or external command.							water cylinder.
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’.

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
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.
Vaillant	Aro THERM	Hybrid packaged	R410A	The controller has load compensation, weather compensation and tariff control (new model to be released in	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.

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
				2016)							

* Coefficient of Performance (COP) is at the standard rating condition measured according to EN14511

** Seasonal performance is the Seasonal Space Heating Energy Efficiency (SSHEE) for an output water temperature of 55˚C and average climate conditions measured according to EN14825

***Data available at other ambient/out-put temperatures and/or measured at part load conditions from the Ecodesign data fiche

Market Review

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[6]), and by far the most widely installed type of boiler is the gas condensing boiler. Heat pumps have gained more traction in other countries. According to the European Heat Pump Association heat pump sales (of all types) in key European markets in 2014 were[7]:

- France – 193,100 units
- Sweden – 95,500 units
- Germany – 68,400 units
- UK – 18,700 units

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[8]. The estimated current market size in the UK is summarised in Table 4. 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 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) which is out of scope for this research (as explained in section 4). The figures for 'true' hybrid technology will be 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. Stakeholders reinforced this point, claiming

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

[7] European heat pump markets and statistics report, *Thomas Nowak, EHPA, 2015*

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

hybrid heat pumps installed in the UK were often retrofitted to oil boilers rather than gas.

In interview most manufacturers commented that sales were low and stable or, according to one supplier, in decline. The proportion of heat pumps that were combined with boilers was reported to have fallen from 21% in 2012 to 18% currently[9]. With these factors in mind the values in Table 4 are at the upper limits of the current market size.

Table 4 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

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[10]. As UK has an established domestic gas infrastructure, there is potential for an increasing market for these products in the UK. However, a more recent BSRIA prediction was for 2,500 -3,000 hybrid heat pumps per year in the UK out of a total heat pump market of 35,000 in 2017[11] which suggests only a small growth or market stagnation until then.

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[12]. This technology has received financial support since April 2014 but according to manufacturers and suppliers this has had little effect.

However, in meetings and interviews stakeholders were positive about the future of hybrid heat pumps because the cost differential between this and alternative technologies is not insurmountable. One manufacturer commented that they are

[9] BSRIA statistics

[10] European heat pump markets and statistics report, *Thomas Nowak, EHPA, 2015*

[11] Heating trends by 2020, UK. *Krystyna Dawson, BSRIA, 2014*

[12] Hybrid renewable energy technologies hit the market; *BSRIA; 2013;* https://www.bsria.co.uk/news/article/hybrid-renewable-energy-technologies-market/

currently working on cost reduction but that increased sales volumes are really needed to bring costs down.

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[13]. 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. Limits to market uptake are discussed further in section 9.

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.

As discussed in section 8, 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 Table 5. 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.

[13] Pathways to high penetration of heat pumps, *Committee on Climate Change, 2013*

Table 5 Hybrid packaged heat pump competiveness versus competing domestic heating technologies

	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)

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[14], if a consumer wants to reduce the costs of their bills or the energy use (the balance between these factors is explored in section 10) 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.

Estimate of effective market potential

In order to estimate the potential size of the market opportunity for heat pumps, we 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 we 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[15]. Heating and hot water for the remaining dwellings are supplied through off-gas-grid means such as solid fuel, oil or electricity.

Our 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[16] of which 1.5 million units are of gas boilers[17]. 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[18] on drivers for homeowners' desire to purchase a new heating solution (e.g. distress purchases, replacement parts hard to find for existing solution,

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[14] Pathways to high penetration of heat pumps, *Committee on Climate Change, 2013*

[15] Sub-national consumption statistics, *BEIS, 2014*

[16] Report IEA HPP Annex 42: Heat Pumps in Smart Grids. Task 1 (i): Market Overview United Kingdom, *Delta Energy & Environment, 2014.*

[17] Gas driven heat pumps: Market potential, support measure and barriers to development of the UK market, *R.E Critoph Warwick University, 2013*

[18] Homeowners' Willingness To Take Up More Efficient Heating Systems, *Ipsos MORI and the Energy Saving Trust, 2013.*

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.

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[19].

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 in the Product Review 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.

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.

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

6. 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.**

Overview of standards

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.

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.

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.

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.

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 6.

Table 6 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.

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.

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[20].

MCS in collaboration with industry has developed an installer standard for heat pumps[21] 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.

[20] 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

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

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.

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.

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).

Product certification.

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

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).

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.

7. System 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.**
- **A major field trial looking at the use of the technology to manage peak demand is being carried out in Manchester and is due to finish in March 2017.**

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 Table 7. It should be noted that the standard only covers 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.

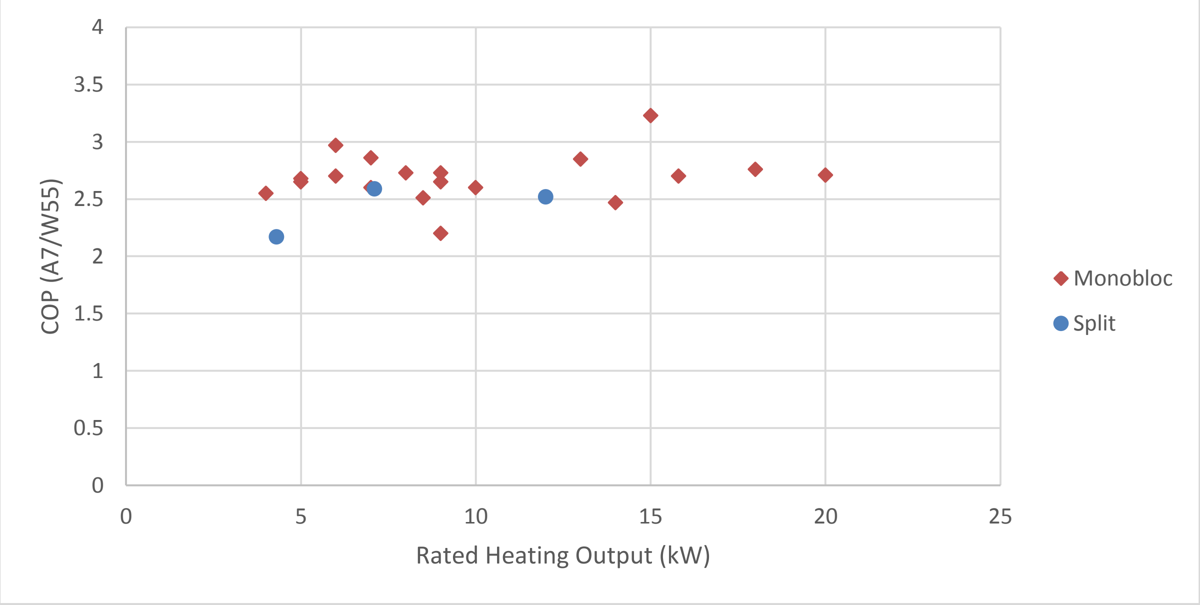
Table 7 Test conditions for air to water heat pumps

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 pumps are predominantly air to water products.

Figure 10 shows the Coefficient of Performance (COP) at A7/W55 (outside air at 7°C and the water out at 55˚C) for a selection of the hybrid products identified in this study.

Figure 10 COP values measured at A7/W55 for a selection of air source hybrid heat pumps



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 11. 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 12 and Figure 13 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 11 SSHEE values for a selection of air source hybrid heat pumps with different capacities

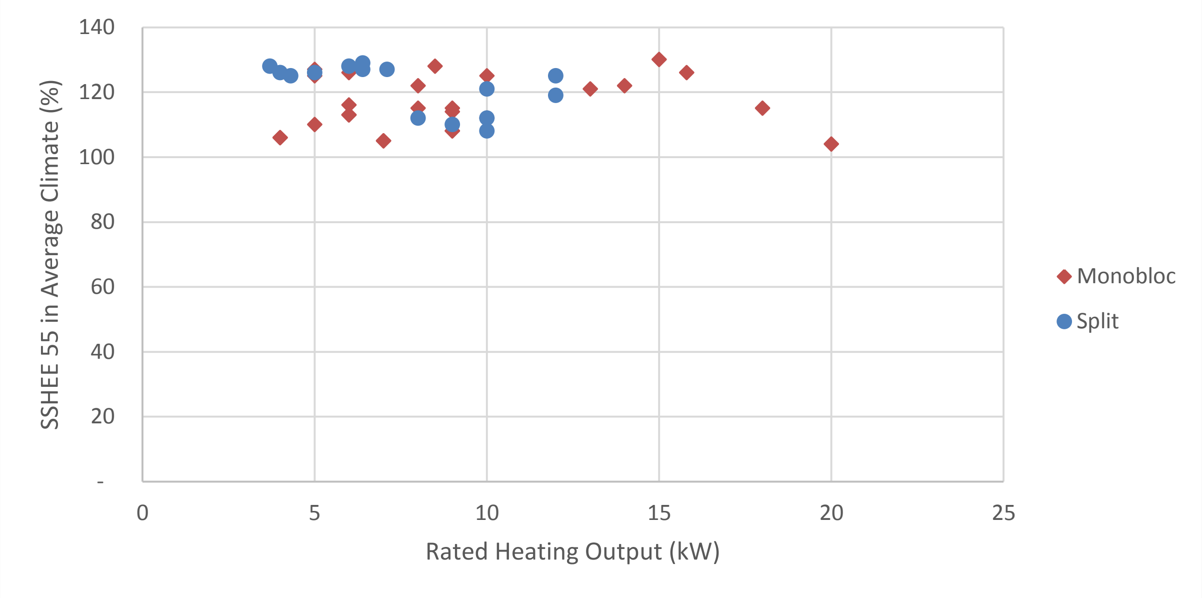


Figure 12 SSHEE values for a selection of split air source hybrid heat pumps

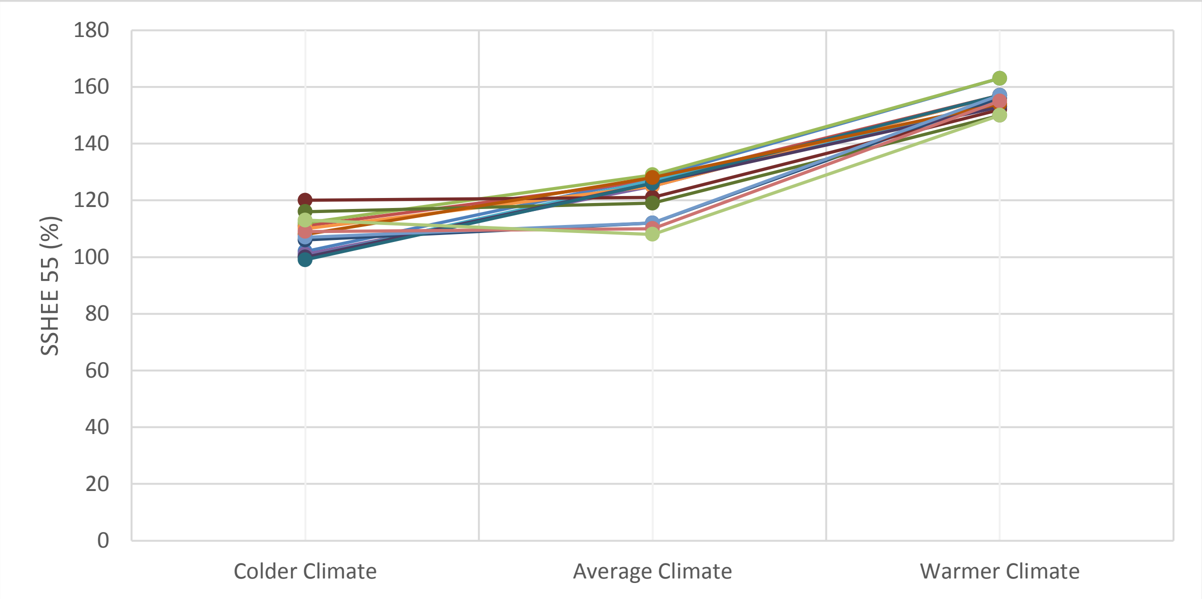
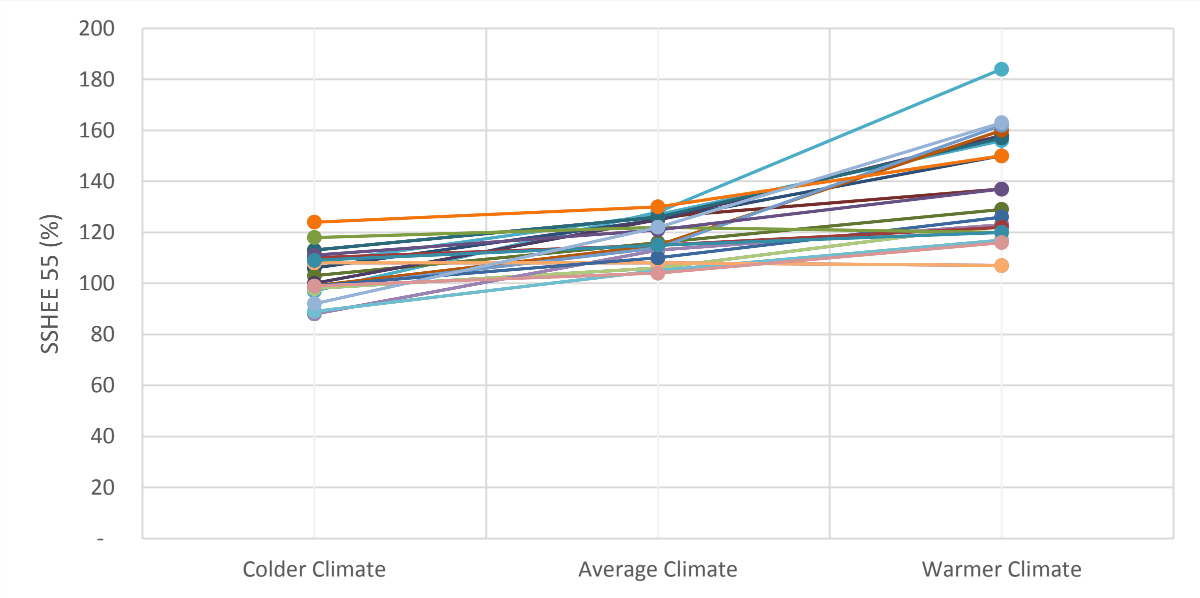


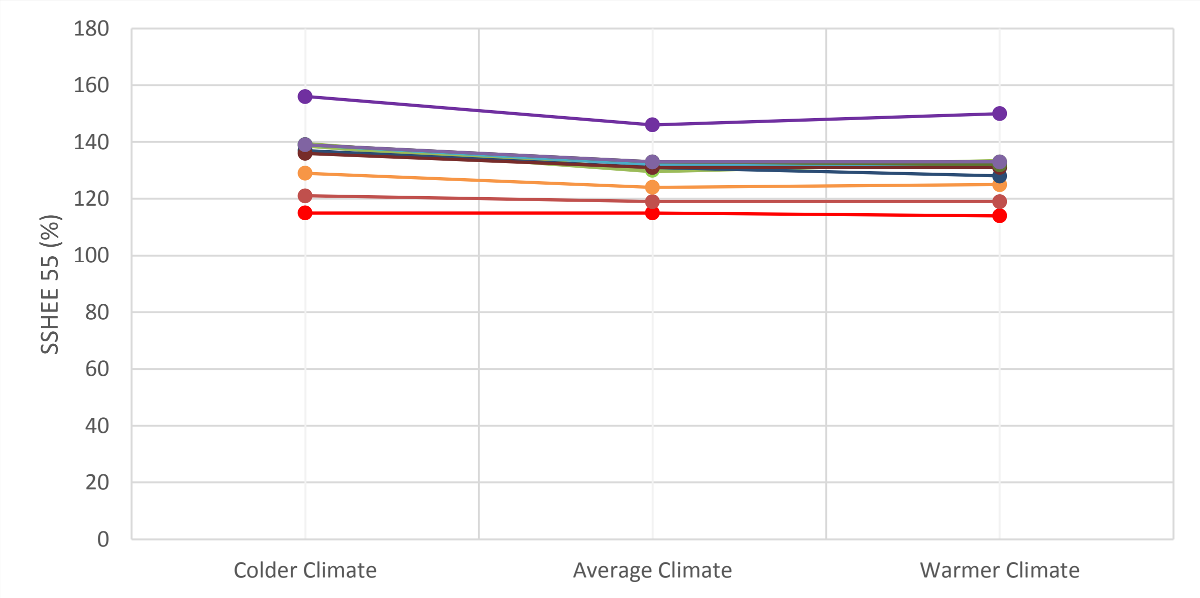
Figure 13 SSHEE values for a selection of monobloc air source hybrid heat pumps



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.

The spread of SSHEE for brine to water (ground source) hybrid heat pumps (for different climates) is much smaller than air to water, as ground temperature is more constant than air temperature in the UK. In the data from one manufacturer shown in Figure 14, the SSHEE increases as the kW output of the heat pump units increase.

Figure 14 SSHEE values for a selection of ground source hybrid heat pumps



In-Use Performance

Hybrid heat pumps have only been available in the UK for around two 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.

One reason that utilities are interested in the technology is that smart control of hybrid systems could be used to manage peak demand. The Smart Community Demonstration Project Greater Manchester, set up by the Japanese New Energy Development Organisation (NEDO) will study this. They also plan to develop a business model in which excess energy supplied from multiple users is aggregated and sold. This major field trial project involves installing and monitoring 600 heat pumps 185 of which are hybrids. The three year project will run until March 2017. No results are available yet.

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.

System sensitivities

The system sensitivities are summarised inExpected 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.

Table 8. 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 indicates that the controls and control settings are key to optimising performance.

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.

Table 8 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

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%

CO_2 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.

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 9, taken from BEIS Green Book guidance[22].

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 10 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

[22] 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

both. Annual running costs have not been included due to uncertainties over future energy prices.

Table 9 Carbon conversions and energy prices from BEIS green book guidance[22]

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 10 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

Energy use and savings

In Table 11 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 11 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.

8. Costs

The current cost of replacing a gas boiler with a hybrid heat pump can be around three times higher than a straight replacement boiler. However, hybrid heat pumps can be added on to an existing boiler, reducing the capital and installation costs. There is reduced need for radiator replacement compared with a standard heat pump, which also keeps costs down.

- **The price of hybrid air source heat pumps ranges from under £2,000 for a 5kw stand-alone heat pump and controller to over £7,000 for a 16kW heat pump packaged with a boiler, depending on the product type and manufacturer.**
- **The fully installed price identified in this study is consistent with studies focussed on standard heat pumps, ranging from £4,000 to £11,300, for air source products.**
- **As packaged hybrids are likely to be used in place of a boiler replacement, it may be most appropriate to consider the marginal cost, which ranges from £4,000 to £10,000 for the total additional installed cost, compared with a gas fired condensing boiler. Add-on hybrids, fitted to an existing boiler, have around the same cost range.**
- **Installation costs may include replacing radiators as these products operate at lower temperatures than boilers. Installation costs can be reduced by using heat pumps which deliver higher temperatures or, commonly, by allowing the boiler to top up the heating demand.**

Heat pump costs

Hybrid heat pump systems have the same cost elements as conventional heat pumps as shown in Table 12.

Table 12 Cost items for hybrid heat pumps

Capital cost	Installation cost	Running costs
• The heat pump itself • For a split system, the refrigerant pipework between the units • A domestic hot water tank – if needed • Controls and meters • Pipework, insulation, pumps etc. associated with any heating and hot water system • Upgrades to some heat emitters (radiators) – although this is not always required if the boiler is used to raise the heating water temperature • For ground source heat pumps, the ground collector	• System design • Installation of the heat pump • Installation of refrigerant pipework • Installation/replacement of hot water tank- if needed • Installation of pipework and electrical connection • Installation of heat emitters if required • For ground source heat pumps, the ground works (trenches etc.)	• Annual maintenance • Gas and electricity cost

Various components of costs have been identified but it has not been possible to accurately break down the costs for all the components separately, given the data collected. Nevertheless, the typical overall product and installation costs identified within this study are consistent with those from other studies, as described below. Within this study we focus on the costs for air source products. Ground source heat pumps can be used as hybrids, but this would tend to be in conjunction with oil fired boilers within off-grid properties which is outside the focus of this study.

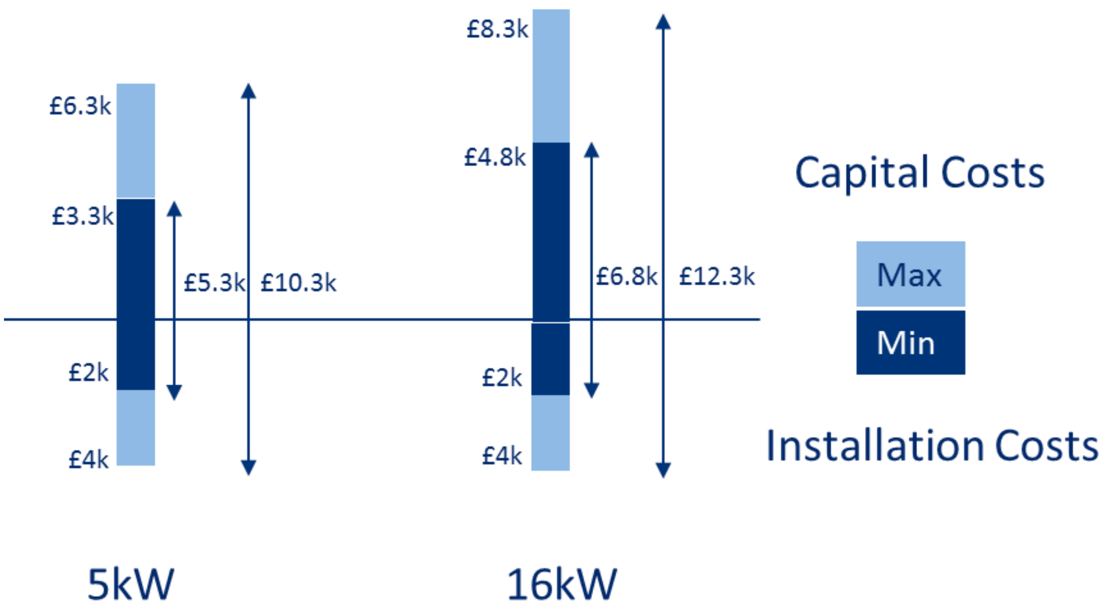
The typical costs found in this study are shown in Table 13 and described further in the following section. Within the table, packaged heat pumps are split between integrated products, and those where the boiler and heat pump are separate, but supplied together as a system.

Table 13 Typical costs of hybrid heat pumps

Product Type	Capacity (kW)	Heat pump product cost (£)	HP product cost (£/kW)	Install-ation cost (£)	Assumed boiler cost	Other capital costs (£)	Deduct costs for normal boiler	Total marginal cost (£)	Total marginal cost (£/kW)
Replace existing boiler with integrated product	5-11	3.5k-4.5k	400 - 700	3k - 4k	0	0 – 1k	2k	4.5k - 7k	500 – 1,200
Addition to existing boiler	5-16	1.6k – 6k	200 - 800	2k - 4k	0	0 – 1k	n/a	4k - 10k	350 – 1,600
Replace existing boiler with HP / boiler / controller package	5-16	1.6k – 6k	200 - 800	3k - 4k	1,3k	0 – 1k	2k	4k - 10k	350 – 1,600

The typical minimum and maximum end-user costs for a boiler replacement with a package hybrid heat pump for two different capacities are shown in Figure 15.

Figure 15 Illustration of typical minimum and maximum marginal costs for typical hybrid installations (not add-on)



Product costs

The capital cost of a hybrid compatible heat pump can be the same or a little more expensive than standard non hybrid heat pump; in many cases they are the same products. The main additional cost is the controller which can be £200-£500 – although some manufacturers are now building intelligent controllers into most or all of their range.

Three options are considered here:

- Option 1 is a single integrated heat pump/boiler
- Option 2 is an add-on heat pump to be fitted to an existing boiler
- Option 3 comprises a separate heat pump, boiler and intelligent controller (either supplied separately, or as a packaged solution)

Option 1 is only available currently from one manufacturer and end user prices for the heat pump itself are around £3,500 - £4,500 for units from 5kW to 11kW, with an integrated 33kW combi boiler. This equates to a wide product cost per kW range from £400-£700/kW.

For option 2, product costs range from £1,600-£4,000 for a 5kW heat pump to £3,000-£6,000 for a 16kW heat pump. This would normally include the outdoor and indoor split units, or monobloc units, and hydrobox. This equates to a wide product cost per kW ranging from £200-£800/kW.

Option 3 is effectively the same as option 2, except that a new boiler is also required, which may be supplied packaged with the heat pump, or purchased separately. Gas-fired condensing boiler prices range from around £500 to £2,500[23], but an average product cost of around £1,300 has been assumed. In theory a slightly smaller boiler is needed for a hybrid system. However stakeholder feedback, and a review of boiler prices has found that the price for a slightly smaller boiler may be just 10-20% lower, which would equate to just a few percent of the cost of a hybrid system.

Other capital costs

Additional equipment may be required such as a stand-alone controller (if needed), buffer tank (not usually needed), refrigerant pipework and metering. Altogether, this could add a further £0-£1000

Additional DHW equipment such as a new hot water cylinder is unlikely to be required as there will normally already be one in place which can be used or the boiler installed will be a combi model.

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[23] Typical prices from which.co.uk, November 2015 http://www.which.co.uk/reviews/boilers

Installation cost

Estimates for the installation cost provided by stakeholders varied widely, but generally fell in the range from £2,000 up to £4,000.

This can include the cost of upgrading some of the radiators. In some cases the heat pump is sized to supply all of the space heating load, which will be at lower temperatures than a boiler normally provides. In this case it is likely that at least some radiators will need to be replaced. More typically (especially for add-on installations) the heat pump is sized to provide the majority of the heating needs (e.g. 80%) and the boiler operates when higher temperatures are required. This reduces the need for radiator upgrades which could reduce installation costs by up to £1,000.

Alternatively, some of the more expensive hybrid add-on products operate at higher temperatures. These are more expensive to buy, but also reduce the need for new radiators.

Total installed cost

Here we consider the three scenarios above to give an indication of the potential total installed cost.

Option 1 - Replacement of existing boiler with integrated hybrid heat pump/boiler

Capital cost of £3,500 for a 5kW heat pump to £4,500 for an 11kW heat pump.

Up to £1,000 for additional equipment.

£3,000-£4,000 for installation.

However, in this case, if the customer was not purchasing a heat pump, they would pay to buy and install a gas fired condensing boiler. So if we just consider the additional cost of choosing a heat pump, then the cost of the gas boiler at £1,300 and its installation at £1,000[24] can be offset.

So the total installed cost could be £6,800 - £9,300 but the marginal total installed cost is around £4,500 - £7,000.

This equates to a marginal cost range of £500-£1,200/kW (based on the kW capacity of the heat pump only).

[24] Estimate of normal cost to replace a boiler based on values in Which.co.uk, accessed November 2015 http://www.which.co.uk/reviews/boilers/article/the-cost-of-installing-a-boiler, (assuming replacing boiler in same place plus moving some pipework)

Option 2 - Addition to the existing effective boiler and hot water system

In this scenario, the cost is simply for the heat pump and installation.

Capital cost of £1,600-£4,000 for a 5kW heat pump or £3,000-£6,000 for a 16kW heat pump.

Up to £1,000 for additional equipment.

£2,000-£4,000 for installation.

So the total installed cost varies between £4,000 - £10,000[25]. Marginal cost does not apply in this scenario as the effective boiler would not otherwise be replaced.

This equates to a very wide cost range of £350-1600/kW (based on the kW capacity of the heat pump and excluding the boiler capacity).

Option 3 - Replacement of existing boiler with package of hybrid heat pump, boiler, and controller

Capital cost of £1,600-£4,000 for a 5kW heat pump or £3,000-£6,000 for a 16kW heat pump.

Up to £ 1,000 for additional equipment.

£3,000-£4,000 for installation.

There is also a cost of £1,300 for a new boiler, but the customer would purchase this anyway for a boiler replacement, so this doesn't need to be included in the marginal cost. They would also normally pay up to £1,000 for installation and so this cost can be offset to calculate the marginal cost.

So the total installed costs could be in the range £6,300 - £11,300, but marginal total installed cost is £4,000 - £10,000[25].

This equates to a wide marginal cost range of £350-1600/kW (based on the kW capacity of the heat pump only).

Oil-fired boilers

This study focusses on hybrids with gas fired boilers. However, stakeholders installing heat pumps in larger, older, harder to heat properties off the gas grid often told us that they would often leave an oil boiler in place and install a heat pump with a hybrid controller (which allows a smaller heat pump to be used and fast response provision of hot water or is suitable where the maximum size of heat pump which can

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[25] assumes installation is £1,000 lower for most expensive heat pumps which operate at higher temperatures, with reduced need for radiator upgrade.

be installed using single phase electricity cannot meet the full load). In this case, the costs are similar to those above except that a larger heat pump may be used. These properties may also require a new hot water cylinder – although often the existing cylinder can be used.

Where an existing oil boiler is fitted with a hybrid heat pump this could also be ground source but this would substantially increase the installation costs.

Cost comparison with gas boilers and standard heat pumps

The cost of a fully installed hybrid heat pump system is from upwards of three times that of a typical gas boiler installation.

When comparing installation of a packaged hybrid heat pump with installation of a standard heat pump, hybrid systems have the additional cost of a boiler. However the heat pump may be significantly smaller and lower cost and the need for radiator upgrades is likely to be lower. Overall the hybrid heat pump is likely to be lower cost – we estimate by up to one fifth.

For add-on hybrids, where the system operates with an existing boiler, up-front costs will usually be lower than a standard heat pump. There is no boiler cost, the heat pump can be smaller, as the existing boiler can produce DHW and some high temperature space heating, and there can be reduced need for radiator upgrades. The cost could be one third lower according to our estimate.

Comparison with other studies

The cost of installing domestic heat pumps have been reported widely.

A wide range of costs were reported in the Sweett group report[26] for conventional air to water heat pumps, from £556/kw for 10-20kW products up to £1187/kW for 5-10kW.

The total costs of for installing an air source heat pump are given as £5,000-£15,000 in the CCC report[27].

The findings of this report of hybrid products range widely from £500 to £1,600 per kW, with total costs from £4,000 to £10,000 but these are based on marginal costs assuming a new boiler would otherwise be installed.

On a total installed cost basis the costs range from £6,500 to £11,500 or £500 - £1,900/kW.

We believe that the costs we have identified for installing hybrid heat pumps are comparable with the cost of installing standalone heat pumps found in other studies. At the high end the costs in this study appear lower, but that is probably because the

[26] Research on the costs and performance of heating and cooling technologies, *Sweett Group for BEIS, 2013*. Available on .gov.uk

[27] Fourth Carbon Budget Review -technical report, *Committee on Climate Change, 2013*

maximum size of heat pump considered was 16kW as hybrid products tend to be smaller.

It should be noted that the price premium of capital costs and installation costs for larger products is relatively low.

Variations in cost per kW relate more to the range of products sizes available than to the variations between product types. For this reason, cost per kW is a rather poor indicator for comparing performance across types. Care should be taken when comparing cost per kW for different product sizes – and indeed when comparing cost data from different sources.

Operating Costs

The ongoing operating costs comprise the electricity to drive the heat pump for space heating, the gas to fire the boiler for DHW and space heating top-up, and maintenance charges.

As these products include a gas boiler, they require a registered Gas Safe engineer to service them. The cost of maintenance is broadly similar to maintenance for a gas or oil boiler. Many companies offer an annual maintenance contract – and this is sometimes a requirement to validate the warranty.

- For a monobloc air source hybrid heat pump the maintenance requirement is similar to that for a gas boiler
- For a split air source heat pump however, the maintenance engineer will also need to be qualified to work with refrigerant gases
- Maintenance charges tend to be around £200 per year to £300 per year depending on level of cover, size of system etc. For this study we have assumed a typical annual maintenance charge of £250 per year

In terms of running costs, most stakeholders reported that hybrid heat pumps make little saving compared to a good quality, well-installed gas-fired condensing boiler, for example 0-5% cost savings. This accords with the scenario presented in section 7.

As installation of a hybrid heat pump is approximately three times the price of installing a replacement gas boiler, the cost savings are not likely to repay the extra investment over the product lifetime. Currently the economic case for installing the products is often founded on whether any financial incentive can be obtained to offset the marginal capital and installation cost of the equipment.

Whilst this study is focussed on gas boiler hybrids, it is worth noting that the economic case is strengthened when hybrid heat pumps are combined with oil or Liquefied petroleum gas (LPG) fired boilers. As the heat pump is supplying the heating, and displacing a higher cost fuel, running cost savings can be around 20%.

Opportunities for Cost Reduction

Hybrid products are generally very little, if at all, different to standard heat pumps. For add-on products, the only additional feature is the more intelligent controller. Therefore costs are not expected to reduce any faster for these than predictions for standard heat pumps.

There is scope for cost reduction in the controller, as the functionality becomes standardised, but the controller is only a small fraction of the overall cost.

There is also scope for cost reduction if more manufacturers design products in which the heat pump and boiler are integrated. The supply chain costs for delivering one product rather than two should be lower. As manufacturers strive to reduce the size of such products, material costs should reduce. Installation should also be simpler as installers become accustomed to such products. Stakeholders estimate that further cost reductions of up to 30% could be achieved against separate products, in a high take-up scenario (millions of products per year) under which more manufacturers offered integrated products.

This is in addition to any reductions in the cost of heat pumps generally. Stakeholders were divided over the opportunities for this.

Manufacturers in general felt that prices are currently similar across Europe where sales volumes are higher. Prices have remained fairly steady over ten years (and have therefore reduced a little in real terms). Under a low growth rate scenario this trend is expected to continue.

Under a high deployment scenario there was a consensus view amongst suppliers that prices would reduce, but generally in an incremental fashion rather than a significant or step-change reduction.

These findings support those of the CCC report[27] which state that stakeholders "generally consider the opportunity for reducing equipment costs limited, with no significant economies of scale expected to result from growth of the heat pump industry. Some learning is expected to bring down installation costs, equivalent to 10% of the installed cost by 2030". Price changes for hybrid products are likely to be in line with the overall trends for air to water heat pumps.

A similar finding is stated in the Delta-ee report[28] which predicted potential for a "10-15% reduction in equipment cost in a mass market scenario compared to 2014" for a 12kW domestic heat pump.

However it should be noted that several stakeholders believed that more significant cost reductions were possible given a high deployment scenario. They equated the potential heat pump market with the air conditioning market in which heat pumps technology with mass market take up has come down to a few hundred pounds.

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[28] Potential Cost Reductions for Air Source Heat Pumps, *Delta EE for BEIS, 2014*

9. Barriers and Drivers to Deployment

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.

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

Summary of key barriers

Standard heat pump barriers are summarised in Table 14, 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 14 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	* * *

Barrier	Description	Technology’s impact on standard heat pump barrier	Barrier strength
Aesthetics	Aesthetics are a major barrier for consumers	Similar to standard heat pumps	* * *
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.	* *

Barrier	Description	Technology's impact on standard heat pump barrier	Barrier strength
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 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

Consumer Barriers

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 that we spoke to 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.

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)'[29].

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 that we interviewed 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.

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[30]. Similar scales of awareness have been found in other studies[31].

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

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[29] Homeowners' willingness to take up more efficient heating systems, *Ipsos MORI and the Energy Saving Trust, 2013*

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

[31] Homeowners' willingness to take up more efficient heating systems, *Ipsos MORI and the Energy Saving Trust, 2013*

UK is not large enough. In Germany, for example, utilities have been very successful in driving awareness[32].

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.

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.

For hybrid heat pumps, the performance and subsequent energy bill savings are dependent on how the hybrid system is operated. If a choice of modes is offered, performance will vary, which means that performance and savings are more difficult to determine than for a standard heat pump. IEA Heat Pump Centre Annex 45 Hybrid Heat Pumps[33] is a collaborative research project which is expected to include an investigation on developing standard methods for assessing performance of hybrid heat pumps, so the impact of this barrier may be lower once this work is complete.

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

[33] IEA Heat Pump Centre Annex 45 Hybrid Heat Pumps, accessed December 2015, available here; http://www.heatpumpcentre.org/en/projects/ongoingprojects/annex45/Sidor/default.aspx

Technical Barriers

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.

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.

Shortage of necessary skills

There has been a lack of capacity of trained installers for electric heat pumps[34]. This is a **minor barrier** that could hold back supply once demand grows. Given the importance of installation quality on in-use performance[35], 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.

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

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

[35] Expert interviews

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.

Market Barriers

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[36]. 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.

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.

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[37]. 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.

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

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[36] IEA HPP Annex 42: Heat Pumps in Smart Grids – Market Overview, *Delta-EE, 2014*

[37] The Future of Heating: Meeting the Challenge, *BEIS, 2013*

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.

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[38]. 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**.

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.

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.

[38] English Housing Survey Headline Report 2010-11, *DCLG*, *2012*

10. Gap Analysis

Information has been collected across the full range of issues requested by BEIS. In general, confidence in the information is reasonable to good. However, in situ performance information is limited, and site specific.

- **Stakeholders have been willing to share information across the full range of topics considered.**
- **Stakeholder information has been cross checked against previous studies, and published information and data, and there is good consistency.**
- **As this technology is new to market, although there is good published performance information based on standard conditions, in situ verified results are limited. Furthermore, published information relates only to the heat pump performance, and not to the full system.**
- **Further trials and modelling would be helpful to more accurately determine the potential cost and carbon savings across the range of different property types in the UK.**

Gap analysis

At the outset of this study a wide range of questions were provided by BEIS and a key aspect of the research was to identify where gaps exist in the available information, or where information is available, but not to a good level of confidence. Recommendations for filling these gaps through further study were also requested.

We have therefore assessed below each of the key sections above to examine the data quality and gaps.

State of the art

As this is a relatively new application of heat pump technology, manufacturers are keen to explain how the technology works, and the various applications and configurations in which it can be used.

Therefore there is good information on the current status of technology, and in general suppliers have been open about product developments that are expected to reach the market in the next 1-2 years.

Product review

We have carried out a comprehensive review of products available in the market and included a description of the key features of each, along with a spreadsheet containing more comprehensive information on each product, including operating temperatures, 1 vs 3 phase, refrigerant type, COPs and SSHEEs. A few data points appear to be unexpected but confidence in the data generally is high.

We have highlighted the manufacturers specifically marketing their heat pumps as hybrid and provided product details for a sample of products from these manufacturers. In practice some manufacturers claim their whole ranges are hybrid compatible. It would be possible to record the COP and SSHEE data for entire product ranges but we took the view that this is not necessary.

A key element of hybrid heat pumps is the controller. We have collected details of the controller functionality but a more detailed study of the actual operating regimes for controllers from each manufacturer could be undertaken by interviews. Manufacturers are only likely to take part if the findings are confidential.

Market size review

Current market data is unreliable. Because of the limited number of players in the market, the absence of sales data from one or two (on confidentiality grounds) manufacturers makes it difficult to assess the actual number of products being sold. Therefore estimated values may be subject to a significant uncertainty.

The segmentation between the different product types has been difficult to determine due to manufacturer sensitivities. Some market reports are produced based on data collected from manufacturers but the granularity of the questions isn't sufficient to distinguish between packaged hybrid heat pumps, hybrid heat pumps supplied separately and heat pumps supplied to form simple bivalent systems.

Nevertheless, confidence is high that the figures presented in this report do show the correct order of magnitude for the current market.

BEIS could seek to approach suppliers directly, under NDA, to obtain a more detailed and granular view of current sales figures. BEIS could also consider discussions with bodies collecting market data regarding collecting more granular information within market reports. However, for policy purposes, it is likely that the order of magnitude numbers collected are sufficient to establish that current take up is low.

Standards review

The one standard that explicitly considers hybrid heat pumps only covers gas sorption products. The approach used in this standard could be applicable to electric heat pumps and was used to identify where work might be needed to incorporate hybrid heat pumps into some other standards. Tasks are proposed in IEA Heat

Pump Annex 45[39] which to look at developing standards hybrid heat pump for field trials.

System performance

Comprehensive data has been collected from manufacturers for COPs and SSHEEs for a wide range of heat pumps products. These data are quoted according to standard rating conditions. However, most manufacturers do not lab test all products at all conditions and so some of the data is calculated using manufacturer selection software. As provision of SSHEE information is compulsory under Ecodesign, and minimum performance standards exist, along with market surveillance, it is likely that manufactures are conservative in quoting SSHEE values. We have reasonable confidence in the lab performance values presented in the report.

However, because there is no test standard for hybrid systems, a significant gap for hybrid heat pumps, is that the published efficiency information refers only to the heat pumps element, and not the boiler. This is complicated by the fact that most heat pumps can be paired with different boilers, even from different manufacturers, and with existing in situ boilers.

Field trials have been carried out by a few organisations across a variety of manufacturer's products. However, the amount of performance data available is limited and there is a lack of consistency in the measurement of results within these trials. Several more in depth trials are currently underway. The format of the trials, and parameters measured depend on the organisations conducting them, as they have different drivers. For example, housing associations focus closely on the cost savings and occupier satisfaction whereas for utility companies and installers the accurate and repeatable measurement of in situ performance and comparison with lab performance is more critical. The monitoring results are currently not sufficient to evaluate the accuracy of the published COP/SSHEE data across the range of conditions.

Several of the trials are very small scale involving just one or two products. These can give a very detailed assessment of the operation and results in specific circumstances. They give good qualitative information on the factors (control etc.) which affect performance. But the results are specific to properties/users concerned and it may not be realistic to extrapolate the results to the wider market.

If BEIS wishes to obtain better data regarding the in situ performance of hybrid products then they should firstly seek to obtain direct access to the monitoring data for trials that have been / are being carried out, under NDA if appropriate. Secondly, in order to better quantify the difference between the published seasonal performance indicators and actual in use performance, further comprehensive trials

[39] IEA Heat Pump Centre Annex 45 Hybrid Heat Pumps, accessed November 2015, available; http://www.heatpumpcentre.org/en/projects/ongoingprojects/annex45/Sidor/default.aspx

based in the UK, with detailed monitoring, are likely to be needed across a wider range of property types and conditions.

Further research could be conducted into modelling the design of hybrid systems to optimise the system. There are a number of variables, the key ones being sizing of the system (in terms of the trade-off between the relative contribution of heat pump and gas boiler) and operation of the control system (in terms of the logic used for switching operation between heat pump and gas boiler). The control system has the bigger effect here, as the consumer, given the choice, would prefer to optimise the system to reduce cost rather than energy use or emissions. This could be a restricting factor on the contribution heat pumps could have on UK carbon savings especially with the large price differentials between gas and electricity.

IEA Annex 45 aims to quantify economic, environmental and energy performance of hybrid heat pumps in heating systems. This will be explored in a range of climates, countries and building types and standards with the hope of developing standards for field trials and filling in some knowledge gaps as described above.

Costs

Good data has been collected on the cost to the end user across the range of product sizes and types. In addition the cost of extras and accessories, including controls, has been identified along with typical installation costs for both air and ground source systems. Typical maintenance costs have also been identified. Confidence in capital and maintenance cost data is high. Confidence in the average cost of extras and accessories and installation is reasonable, however, in order to confirm the potential range of these costs a number of detailed scenarios could be created and installers could be asked to provide guidance and pricing for the best and most likely options against these scenarios.

Whilst an indication of the cost savings has been provided, this is clearly dependent on the individual property concerned. Therefore detailed analysis of the profile of potential cost savings for different product types has not been undertaken. This could be carried out either through modelling of housing stock, heat demands and scenario analysis to determine the potential of different solutions.

Or, perhaps more accurately, an exercise could be undertaken to identify a range of real properties (maybe with the help of manufacturers, installers and other stakeholders), document their characteristics (type, fabric, current heating system, current energy use/spend) and then model the impact of the technology options on this range of real properties.

Barriers to deployment

Good information has been collected and reported on the wide range of barriers to the increased uptake of heat pumps in general, and hybrid heat pumps in particular.

Annex A – list of standards

This section provides an extensive list of relevant technical standards.

Standard/Regulation	Comment
BS EN 14511:2013 Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers using electrically driven compressors.	Topic: Rated performance (steady state) Coverage: Electrically driven heat pumps for space heating and/or cooling, using air, water or ground heat sources. Four parts: 1.Terms and conditions 2. Test conditions 3. Test methods 4. Operating requirements, marking and instructions. Currently under revision - projected date for publication 2017
BS EN 14825: 2013 Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling. Testing and rating at part load conditions and calculation of seasonal performance.	Topic: Seasonal performance. Coverage: Electrically driven heat pumps for space heating and/or cooling, using air, water or ground heat sources. Currently being revised to align with ErP legislation and to include new calculations of seasonal performance and fossil fuel back-up. Publication imminent
BS EN 12309: 2014/2015 Gas-fired sorption appliances for heating and/or cooling with a net heat input not exceeding 70 kW.	Topic: Rated and seasonal performance and safety Coverage: Sorption heat pumps including use in hybrid appliances. Seven parts: 1 Terms and definitions 2. Safety 3. Test conditions 4.Test methods 5. Requirements 6. Calculation of seasonal performance; 7. Specific provisions for hybrid appliances.
prEN 16905: Gas-fired endothermic engine heat pumps	Topic: Rated and seasonal performance and safety Coverage: Gas-fired endothermic heat pumps Five parts: 1. Terms and definitions; 2. Safety; 3. Test conditions; 4. Test methods; 5. Calculation of seasonal performances in heating and cooling mode. Currently under development - projected

	date for publication 2017
BS EN 16147:2011 Heat pumps with electrically driven compressors. Testing and requirements for marking of domestic hot water units.	Topic: Performance for water heating Coverage: Electrically driven heat pump water heaters Currently being revised to align fully with ErP legislation. Projected date for publication 2017
BS EN 15450:2007 Heating systems in buildings. Design of heat pump heating systems.	Topic: Design of heat pump heating systems. Probably need updating. Coverage: Air, water and ground source.
BS EN 378:2008+A2:2012 Refrigerating systems and heat pumps. Safety and environmental requirements	Topic: Safety and environmental requirements mostly related to refrigerants Four parts: 1. Basic requirements, definitions, classification and selection criteria 2. Design, construction, testing, marking and documentation 3. Installation site and personal protection 4. Operation, maintenance repair and recovery. Currently being revised - close to publication
BS EN 12102:2013 Air conditioners, liquid chilling packages, heat pumps and dehumidifiers with electrically driven compressors for space heating and cooling. Measurement of airborne noise. Determination of the sound power level.	Topic: Noise measurement Coverage: electrically driven heat pumps
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.	Topic: System efficiency (SPF) Coverage: All heat pump types. Currently being revised to provide hourly and monthly calculation.
BS EN 13313:2010 Refrigerating systems and heat pumps. Competence of personnel.	Topic: Competence requirements
Commission regulation (EU) No 813/2013 Ecodesign requirements for space and combination heaters	Topic: Sets minimum seasonal space heating energy efficiency (SSHEE, η_s) requirements and requirements for product data Coverage: Products with an output ≤ 400

	kW. No minimum performance requirements are set for sorption heat pumps. Only covers products providing water based heating.
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	Topic: Requirements for energy labelling and product data Coverage: Heat pumps≤70 kW
Commission regulation (EU) No 814/2013 Ecodesign requirements for water heaters and hot water storage tanks	Topic: Sets minimum water heating energy efficiency requirements and requirements for product data. Coverage: Heat pumps with a rated output ≤ 400 kW and hot water storage tanks with a storage volume ≤ 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	Topic: Requirements for energy labelling and data fiche Coverage: Heat pumps ≤70 kW with an integral or separate storage volume ≤ 500 l
Number not available - Ecodesign requirements for air heating products, cooling products and high temperature process chillers energy related To be added latest details of Lot 21	Topic: sets minimum seasonal space cooling energy efficiency requirements Coverage: Heat pumps with a rated heating capacity up to 1 MW and a rated cooling capacity up to 2MW. Currently awaiting approval with implementation in January 2018
Microgeneration Certification Scheme (MCS) Guidance	MIS 3005 Installer standard for heat pumps MCS007 Product Heat pump standard MCS 026 - SCOP and SSHEE Calculator MCS 027 - SPER and SSHEE Calculator MCS 028 - DHW Calculator
Ground Source Heat Pump Association (GSHPA) Guidance documents	Shallow ground source standard Vertical borehole standard Thermal pile standard Thermal Transfer Fluid Standard (under development) Open Loop Standard (under development).

Annex B – Standard heat pump barriers

In this Annex we list the barriers identified for standard heat pumps (See section 9), which are also relevant for hybrid products, with a similar level of relevance and magnitude.

Consumer Barriers

Consumer confidence / trust

The reputation of standard heat pumps has suffered because of previous poor installed performance in the market. For example, one housing developer interviewed has an ‘absolute prohibition’ on using ASHP due to negative experiences from previous schemes, and will only consider them in exceptional circumstances. This is therefore a **major barrier**. Research suggested that poor performance was either due to poor installation[40] or incorrect operation, both of which can be overcome.

This barrier is common to all heat pump types, and acceptable performance would need to be demonstrated for this technology to earn consumer confidence. One housing association that was interviewed said that their sector typically had a technology time lag, and that if the take-up of hybrid heat pumps increased, it would be likely that they would follow suit. Overcoming this barrier therefore requires different techniques and strategies to demonstrate to consumers that the technology can be trusted.

Aesthetics

Aesthetics are a **major barrier**. Feedback from demand-side interviewees suggested that real-world buyers care more about aesthetics than marginal energy savings. This can be less of an issue in the countryside or for properties with more space, where units can potentially be concealed behind bushes or fences, or further away from buildings.

Hybrid heat pumps have no discernible difference to standard heat pumps in this regard.

[40] Expert interviews; Residential heat pump installations: the role of vocational education and training, *Colin Patrick Gleeson, 2015*

Technical Barriers

Noise

Heat pumps give out relatively significant noise levels during operation. This is **minor barrier**. This is less of a barrier for properties with more space (e.g. rural dwellings) where the heat pump could be located further from the building.

With hybrid heat pumps, a housing association reported that tenants were concerned that they could hear the heat pump running constantly in comparison to the boiler and made assumptions that they would be consuming more energy and costing more money. The noise therefore is a barrier in the absence of educating the tenants as to why it is constantly running but this is no different from standard heat pumps.

Installation and Maintenance Challenges

Poor installation of standard heat pumps had a very negative impact on their reputation in the market. To avoid a similar situation with hybrid heat pumps (if the market is even able to distinguish between them), it is important that similar poor installation is avoided as the market grows.

Speed of installation

When the boiler is a 'distress' purchase, speed of installation forms a significant part of the purchasing decision for a replacement. The gas boiler market is mature, with a number of experienced heating engineers in the market which would allow a boiler to be bought and installed in under a day[41]. Installation of a hybrid heat pump will typically take a similar amount of time to a standard product, however there is less likely to be a need to alter the heat distribution system or radiators, which can shorten overall system installation time. This is a **minor barrier.**

Installation of hybrids will typically take a similar amount of time to this, so hybrid heat pumps do not differ to standard heat pumps for this barrier.

Number of players in the supply chain

Feedback from interviews was that there are too many players in the supply chain, often resulting in poor specification or installation. A number of interviewees questioned why manufacturers are not involved in the design and installation of units. There was confusion as to why a manufacturer would not even perform a health check post-installation. This is a **minor barrier**.

Hybrid heat pumps do not differ to standard heat pumps for this barrier.

[41] The Future of Heating: Meeting the Challenge, *BEIS, 2013*

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