Department for
Business, Energy
& Industrial Strategy

Evidence Gathering – Low Carbon Heating Technologies

Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report

November 2016

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Prepared for BEIS by:

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

Acknowledgements

The Carbon Trust would also like to thank the following contributors for their valuable input:

Steve Addis, Lochinvar; Paul Aitchison, Panasonic; Richard Baines, Black Country Housing Group; John Barker-Brown, Kensa; Matthew Beard, Affinity Sutton; Rob Borruso, KCFC; Justin Broadbent, ISO Energy; Andy Buchan, TEEC; Guy Cashmore, Kensa; Stewart Clements, HHIC; Mitchell Cogger, Worcester Bosch; Bob Critoph, Warwick University; Zoe Davies, North West Leicestershire District Council; Craig Dolan, Vaillant; Tom Dollard, Pollard Thomas Edwards; Tony Evanson, Ocean Air; Andrew Faulkner, Samsung; John Felgate, Stiebel Eltron; Dan Fletcher, GHE Solar; Tom Garrigan, BSRIA (testing); Colin Goode, Fujitsu; Matthew Grieves, Sovereign Housing; Will Griffiths, BRE (SAP); Simon Groombridge, Calorex; Christian Hadley, Dimplex; Lara Hayim, Circle Housing Group; Mike Hefford, Remeha; Neil Hewitt, Ulster University; Karen Hilton, Fyne Homes; Rebecca Hogg, BSRIA (testing); John Holden, BRE; Andy Hooper, Hitachi; Graham Hutton, Linden Homes; Hugh Jones, Viessmann; Bevan Jones, Catalyst Housing; Louise Kew, E.ON; Edward Leddy-Owen, Rykneld Homes; Kevin Lowe, British Gas; Lee Mason, DHP UK; Mike Nankivell, Space Airconditioning/Heat Pump Association; Kevin Pacey, Environmental Site Supplies; Guy Ransom, Finn Geotherm; Dale Saunders, Taylor Wimpey; Christian Schober, Innasol; Nikhilkumar Shah, Ulster University; Michael Swainson, BRE (testing); Jon Terry, E.ON; Mark Thompson, InnovateUK; James Timbs-Harrison, Mitsubishi Electric; Thomas Vazakas, RPS Engineers; Nic Wincott, Neo Energy AB; Graham Wright, Daikin; Makoto Yasuda, Yanmar.

Acronyms

CCC	Committee on climate change
COP	Coefficient of performance
BEIS	Department for Business, Energy and Industrial Strategy
DHW	Domestic hot water
ErP	Energy related products (Ecodesign)
EVI	Enhanced vapour injection
GCV	Gross calorific value
GUE	Gas utilisation efficiency
GWP	Global warming potential
HARP	Home-heating appliance register of performance
LPG	Liquefied petroleum gas
MCS	Microgeneration certification scheme
NCV	Net calorific value
PER	Primary Energy Ratio
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
VHTHPs	Very high temperature heat pumps

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) have suggested that the overall cost-effective uptake of heat pumps in UK homes could reach 2.3 million by 2030[1].

Three studies were undertaken by the Carbon Trust for the Department for Business, Energy and Industrial Strategy (BEIS) to inform their evidence base on domestic high temperature heat pumps, domestic hybrid heat pumps, and gas driven heat pumps. The studies were designed to explore the role such technologies may play in the market and inform future UK policy intervention relating to low carbon heating technologies.

The studies were conducted from September 2015 to December 2015 using desk-based research, interviews with experts and stakeholders, and a stakeholder workshop. Experts from 53 organisations were interviewed across both the demand and supply side.

The purpose of this combined summary report is to provide a useful comparison between these related technologies.

The Technology

For the purpose of this report, high temperature heat pumps are considered to be products capable of producing an output temperature of at least 65°C[2]. These include products with optimised design for specific refrigerants, along with technology such as enhanced vapour injection (EVI), and cascade systems with two separate refrigeration cycles.

A hybrid heat pump system is considered 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

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

[2] In the heat pump performance standard, BS EN 14511:2013, an output temperature of 55°C would be defined as ‘high temperature’ and 65°C would be defined as 'very high temperature'. However, in the next revision it is expected that ‘high temperature’ will be re-defined as an output temperature of 65°C.

existing heat distribution system; and a dedicated control system to switch between the two sources. Both hybrid package heat pumps and hybrid 'add-on' heat pumps (for retrofitting to an existing gas boiler) are considered.

Gas heat pump technology can be split into sorption heat pumps and gas engine driven heat pumps. Sorption heat pumps can be split into two types – adsorption and absorption. Sorption units use a thermal compressor to heat the refrigerant, whereas gas engine driven heat pumps use a mechanical compressor (similar to electric heat pumps) but where the energy source is gas.

In each case, we have focussed on air and ground source heat pumps with a capacity of less than 45kW.

Current State of Market and Future Market Potential

The current UK market for heat pumps is small; around 18,700 units per year, of which around 17,700 are estimated to be domestic. The UK heating market is dominated by gas condensing boilers.

High temperature heat pumps are suitable for retrofit to existing properties as they can be used with existing, high temperature distribution systems (e.g. existing radiators) and are also capable of meeting hot water demand. Current sales are approximately 2% of total heat pump sales, numbering a few hundred units per year. They are typically specified to heat large, old, or listed properties, often off the gas grid.

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. Hybrid heat pumps currently have up to 18% of heat pump market share (but this includes bivalent heat pumps fitted to oil boilers).

There are no gas driven heat pumps available for the domestic market in the UK, but domestic scale absorption and adsorption heat pumps are now available in Europe. There is a wide range of potential applications. Absorption products can be operated at high temperatures and are therefore potentially suited to replace gas boilers in the retrofit market for use with existing high temperature distribution systems (e.g. existing radiators and hot water cylinders).

Gas sorption and hybrid heat pumps are also potentially suitable in the new build market. The estimated potential annual market for these technologies is estimated at 100,000 to 210,000 units – with a potential market of 29,000 to 66,000 for high temperature heat pumps.

Costs and Performance

A summary comparison of the costs and performance of the three heat pump technology categories is shown in Table 1 below.

The price of high temperature heat pumps ranges from 20% to 35% more than standard heat pumps, but the price premium based on fully installed costs is closer to 10-20%. The product price for high temperature heat pumps ranges from £3,000 -

£7,000 (air source), with the fully installed price ranging from £6,000 to £14,000.This compares with a typical gas fired boiler replacement cost of £2,500.

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.

An 18kW gas absorption heat pump product due to hit the market in 2016 (which is suitable for larger domestic properties) is expected to cost from £9,000 installed when launched, although costs could reduce by 20-30% or more with sufficient market growth. Adsorption products are now being made available in Europe and may be launched in the UK. The cost of these is likely to be £17,000 upwards for the product and ground source installation.

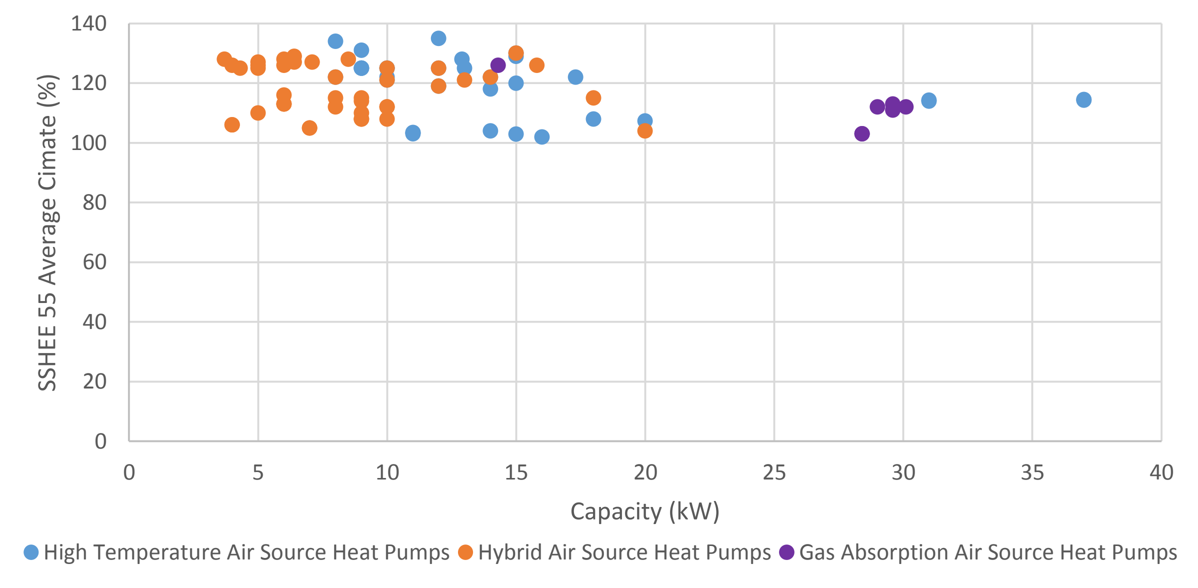
All of the technologies can deliver cost savings compared to a standard electric heat pump, particularly where expensive and disruptive upgrades to the heat distribution system would otherwise be required. However only gas driven products are likely to deliver a significant operational cost saving versus a new gas boiler. All of the technologies can deliver a carbon saving compared to a gas boiler however.

The seasonal space heating energy efficiency[3] (SSHEE) values, at 55°C output under average climatic conditions, for air source high temperature, hybrid and gas driven heat pumps (identified in this study) are plotted against capacity in Figure 1. There is a considerable spread in performance in the SSHEE of air source products but this does not appear to correlate with the capacity of the product. SSHEEs at 55°C vary from around 105% to 135% for all of the technologies, compared to around 93% for a typical new gas boiler.

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. Information gathered from a number of trials has shown that the technologies each perform satisfactorily in general, however particular care is needed with design and control strategies.

[3] The SSHEE is the performance averaged across a load profile representative of performance across the operating conditions during the whole heating season rather than performance at a single operating condition.

Figure 1 The SSHEE at 55°C under average climatic conditions vs capacity for a selection of high temperature, hybrid and gas driven heat pumps



Barriers to Deployment

A number of barriers exist to large scale uptake of heat pumps.

High temperature, hybrid and gas driven products can variously help to mitigate some of the traditional barriers. As most can provide the high temperature space heating outputs that customers are used to, and can also supply domestic hot water, they could help overcome the consumer inertia which favours conventional gas boilers.

Furthermore hybrid and gas driven products may help overcome barriers associated with moving away from gas fired heating systems.

However the technologies considered here still suffer from high upfront cost, the need for additional space, and low customer awareness and acceptance. They are new to the market and there is a lack of trial information, so the cost benefits and performance are unproven.

Conclusions

High temperature, hybrid and gas driven heat pumps all have potential to increase the uptake of low carbon heating solutions in the UK. High temperature heat pumps are particularly suited for off gas grid retrofit projects, and hybrids and gas driven products are suited to on gas grid properties. They may all be used with no or limited upgrades to existing heating systems.

Each offers some advantages (but also some disadvantages) compared to standard electric heat pumps, but it is not clear that these advantages are sufficient to stimulate widespread uptake of the technologies.

High temperature heat pumps may remain a niche market in the short term. Their target market tends to be large, old, or listed properties (i.e. with high heat loss), often off the gas grid and with high domestic hot water demand.

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.

Gas heat pumps may help to overcome consumer inertia (as consumers are familiar with gas fired heating), however they are still very new in the domestic market and high cost.

Summary

Error! Reference source not found. provides a high level summary comparison between the technology types considered within this report.

Table 1 High level comparison of high temperature, hybrid and gas driven heat pump technologies

	High temperature heat pump	Hybrid heat pump	Gas heat pump
Technology	Established HP technology with incremental improvements likely.	Established HP technology - may be more development of packaged products & controls.	Sorption tech new for domestic application – a few options being developed.
Application and market	Primarily off gas grid, retrofit. Static market. Some doubt over market for very high temperature.	Retrofit and new build – replacement and add-on. Static market, but growing engagement and positive market sentiment.	Both replacement and new build. Products due for launch. Some market optimism if costs reduce.
Performance – SSHEE 55°C	102 – 135% A/W* 104 -173% B/W**	104 – 130% A/W 114 – 146% B/W (limited products) (NB: heat pump only, excluding boiler)	103 – 126% absorption (A/W) 109 – 115% adsorption (B/W)
Capital cost (air source)	£3-7k (heat pump) £6-14k (total installed)	£1.6-7.5k (heat pump) £3.5 – 11.5k (total installed)	£6k / £10k (Absorption/Adsorption HP) £9-12k / £17-20k (Installed)
Price premium/saving	220%-440% premium over gas boiler 10-20% premium over standard ASHP	140% - 400% premium over gas boiler 20-35% **saving** compared to ASHP	290%-420% premium (absorption) vs gas boiler 0-10% premium (absorption) over ASHP
Annual energy cost[†] & carbon savings	Cost 0-40% vs oil[††] Carbon 50-60% vs gas	Cost 0-5% vs gas 0-20% vs oil/LPG[††] Carbon 20-30% vs gas	Cost ~20% vs gas ~40% vs LPG Carbon 20% vs gas
Drivers	Can be used for hard to heat, off grid homes. Can use with existing heating distribution system.	Consumer acceptance easier as gas boiler included. Can optimise operation based on energy prices. Demand management potential.	Consumer acceptance easier, as operates on gas. Cheaper fuel. No electricity grid capacity issues.
Barriers	High capital cost. Lack of performance data. Electricity more expensive than gas.	Additional capital cost to boiler. Hard to predict savings. Lack of performance data.	High capital cost. Lack of performance data.

* Air to water heat pump ** Brine to water heat pump [†] indicative annual energy cost savings (not lifetime savings)
[††] 20-40% according to stakeholders but oil prices have reduced since, and our modelling shows little or no cost saving compared to oil.

2. Introduction and Context

This summary report for the Department for Business, Energy and Industrial Strategy (BEIS) serves to inform their evidence base on 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. It focusses specifically on heat pumps that could potentially be implemented within the high temperature heating distribution systems typically found in the UK. It examines high temperature heat pumps[4], hybrid heat pumps[5] and gas driven heat pumps[6], each of which are the subject of more detailed reports.

Specifically, this report seeks to:

- Summarise the current state of the art
- Review the current UK market and future market potential
- List relevant technical standards
- Compare system performance (rated and in-use)
- Compare current costs and the potential for future cost reduction
- Discuss the barriers to deployment

The above topics form Chapters 4 to 0 of this report.

Scope

Geographical scope

The focus of this report is on products that are already available in the UK market. 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 categories addressed by this project are domestic high temperature heat pumps, domestic hybrid heat pumps and gas driven heat pumps.

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.

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[4] Evidence Gathering – Low Carbon Heating Technologies: Domestic High Temperature Heat Pumps, BEIS, 2016

[5] Evidence Gathering – Low Carbon Heating Technologies: Domestic Hybrid Heat Pumps, 2016

[6] Evidence Gathering – Low Carbon Heating Technologies: Gas Driven Heat Pumps, 2016

For the purposes of this study, we have focussed on air and ground source heat pumps aimed at the domestic market, with a capacity of less than 45kW capacity. We have reviewed:

Domestic high temperature heat pumps

Defined here as capable of producing output temperatures of 65°C[7].

Domestic hybrid 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.

Gas driven heat pumps

Heat pumps that use gas rather than electricity to drive a thermal compression cycle, including gas sorption (absorption and adsorption) heat pumps and gas engine driven heat pumps. For both technology groups, we looked at systems of less than 45kW capacity.

Applications

We have examined products which are aimed at domestic applications, and are potentially capable of being used with existing high temperature distribution systems (e.g. existing radiators) and therefore could provide a viable alternative to boilers in the retrofit market. These products can often produce domestic hot water (DHW) effectively, with reduced need for a specialised hot water cylinder compared to a standard heat pump.

Standard air to water and ground source brine to water heat pumps operate at much lower temperatures than gas or oil boilers, and therefore installation of heat pumps can require significant modifications to the heat distribution system (pipework, radiators etc.). High temperature, hybrid and some gas driven heat pumps, can negate some or all of the need for this, reducing disruption and installation costs.

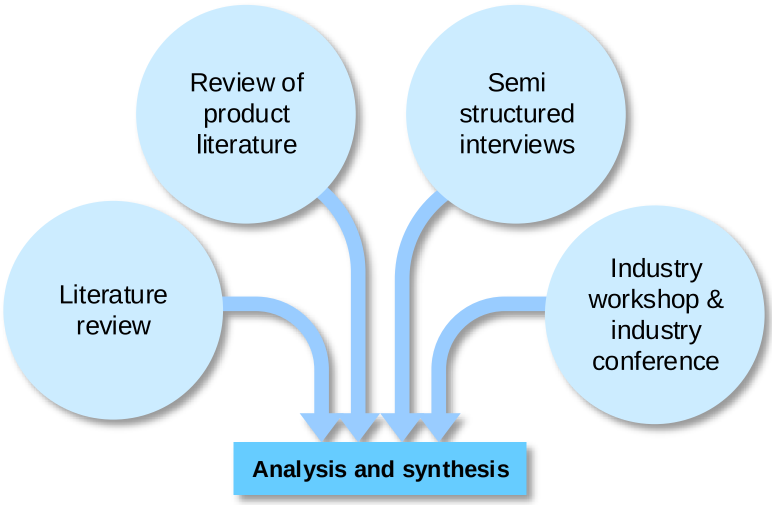
[7] In the heat pump performance standard, BS EN 14511:2013 an output temperature of 55°C would be defined as ‘high temperature’ and 65°C would be defined as 'very high temperature'. However, in the next revision it is expected that ‘high temperature’ will be re-defined as an output temperature of 65°C.

3. Methodology

Research and Analysis

The research for this project was primarily desk based, including a literature review, and study of supplier product information (sales material and technical data). We then spoke to key stakeholders in a series of semi structured interviews, followed up with an industry workshop. Figure 2 summarises the research process.

Figure 2 Summary of the research process



We reviewed over 150 documents relating to the three heat pump technologies selected for this study, as well as standard heat pump technology. We also collated product information and performance data from supplier sales brochures, technical and installation brochures, and technical data sheets.

During the course of the project the deadline for manufacturers to publish technical performance information under the Ecodesign (ErP) regulations passed, which allowed us to obtain standardised manufacturer SSHEE data (see section 7).

The Carbon Trust carried out 53 interviews across the three studies. We interviewed a wide range of stakeholders including: manufacturers, installers, trade associations, utilities companies and housing associations (see Figure 3). We also held a stakeholder workshop, attended by 14 key stakeholders.

Figure 3 Distribution of 53 interviews carried out

		Interviewees
Supply side	Installers Manufacturers Distributors	24
Other stakeholders	Test houses & standards bodies Utility companies Researchers/academics	13
Demand side	Local authorities Housing associations Housing developers	16
	Total	53

Stakeholders were 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.

4. Current State of the Art

There are a number of heat pump system designs that are capable of achieving high output temperatures, eliminating or reducing the cost and disruption of upgrading domestic heat distribution systems.

- **High temperature heat pump products with optimised design for specific refrigerants can reach temperatures above 65°C, and dual refrigeration cycle cascade products can operate up to 80°C. They can provide effective space heating with standard high temperature radiator systems and domestic hot water.**
- **Hybrid heat pumps can provide base load low temperature heating at high efficiency. The boiler is then 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.**
- **Gas heat pumps are at an early stage of deployment for domestic applications, with sorption units entering the UK market in 2016. Absorption heat pumps can reach higher temperatures than standard electric heat pumps, typically up to 65˚C. Innovation is underway for this technology to develop more domestic scale products, improve efficiencies and reduce unit size.**
- **However, the lower the output temperature, the more efficiently heat pumps operate, so the opportunity to upgrade emitters to allow operation at a lower temperature should generally be considered before specifying heat pumps capable of high temperatures.**

Available Technologies

Within this section we summarise the design and operation of the main types of high temperature, hybrid and gas driven heat pumps. The principle of heat pump operation is described first, using a standard electrically driven heat pump to illustrate.

Standard heat pumps

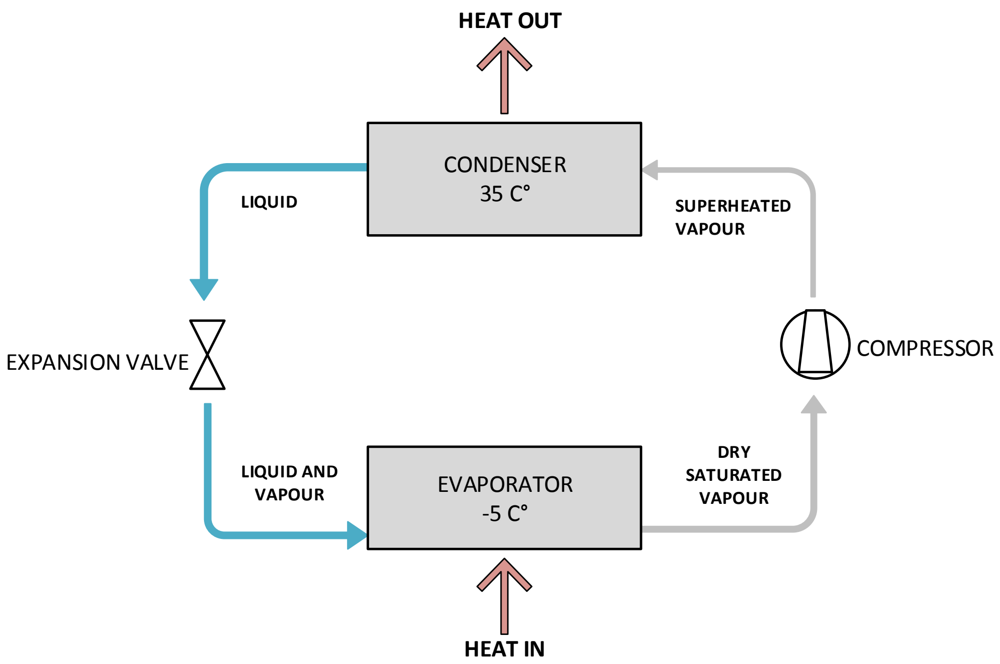
A heat pump transfers heat from a low temperature source such as ambient air, water, the ground or waste heat, and raises it to a higher useful temperature. Most heat pumps use a mechanical vapour compression cycle with the compressor driven by an electric motor. Standard vapour compression heat pumps work by alternately evaporating and condensing a refrigerant. The main components are shown in Figure 4 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 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.

For gas heat pumps, Primary Energy Ratio (PER) is used as a performance measure. This is the ratio of the effective heating capacity to the total primary energy input (before any conversion or delivery losses, for example electricity generation losses). Dividing the coefficient of performance (COP) of an electric heat pump by the average electricity generation efficiency (2.5 is used as a standard value) gives the PER, allowing the performance of the two technologies to be compared.

The seasonal space heating energy efficiency (SSHEE) is a measure of performance averaged across a defined load profile, which is designed to represent real life use[8]. SSHEE is also measured in primary energy terms allowing comparison of different technologies using different energy sources.

Figure 4 Standard vapour compression heat pump circuit



[8] 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

High temperature heat pumps

For the purposes of this study, we have focussed on air and ground source heat pumps with a capacity of less than 45kW that are capable of producing output temperatures of 65°C[9].

There are a number of heat pump system designs that are capable of achieving high output temperatures, which include:

- Products with optimised design for specific refrigerants
- Cascade systems with two separate refrigeration cycles
- Enhanced Vapour Injection (EVI)
- Sorption

Product design optimised for specific refrigerants

The most common refrigerants used in heat pumps today are R410A, R134a and R407C. Until recently the maximum output temperature for domestic heat pumps using these refrigerants was about 55°C, however now temperatures above 60°C can be achieved by altering the heat pumps design to use slightly different temperature and pressure characteristics.

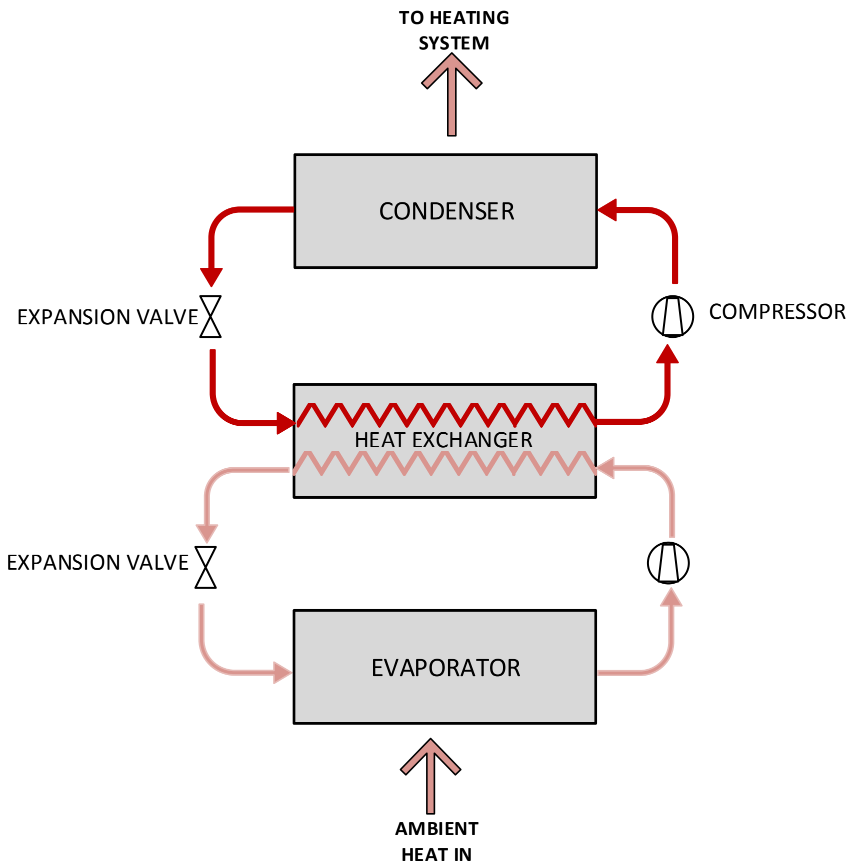
Carbon dioxide, propane and ammonia are natural refrigerants which can also be used to reach higher output temperatures up to 80°C. Alternatively, a sorption rather than a vapour compression cycle can be used.

Cascade systems

A cascade system consists of two single-stage cycles (a low temperature and a high temperature cycle using different refrigerants) which are thermally connected by an intermediate heat exchanger, as shown in Figure 5. Cascade systems are capable of reaching temperatures of up to 80°C.

[9] It should be noted that in the heat pump performance standard, BS EN 14511:2013, an output temperature of 65°C would currently be defined as 'very high temperature'. However in the next revision, and in Ecodesign regulations, it is expected that 'high temperature' will be re-defined as an output temperature of 65°C.

Figure 5 Cascade system diagram



Enhanced vapour injection (EVI)

The EVI technique requires an additional loop to be added to the standard heat pump cycle, with additional subcooling to increase the evaporator capacity. This technique provides a significant gain in heating capacity due to the increased refrigerant mass flowing through the condenser for the same size of compressor.

Sorption

Sorption products can reach high temperatures. They are covered below in the ‘Sorption’ section under gas driven heat pumps.

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, intelligent control system to switch between the two sources.

The maximum temperature provided by the heat pump component of a domestic hybrid heat pump system is up to 55˚C. However, it is much more common for the heat pump component to run at low temperatures to provide a constant baseload, whilst the boiler provides high temperature heating (when required) and domestic hot water. The heat pump typically meets about 80% of the property's heating demand.

Hybrid heat pumps have been divided into two categories: hybrid package heat pumps sold as a complete package (either integrated into one unit or sold together); and hybrid add-on heat pumps which can be added to an existing boiler. These two categories are described in Table 2.

Table 2 Comparison of packaged and add-on hybrid systems

Hybrid system	Components	Configuration	Application
Hybrid package heat pumps	• heat pump unit • gas boiler • intelligent controller	• integrated into a single product or • supplied as a set of matched products	• replace existing boiler system or • use for new build heating system
Hybrid add-on heat pumps	• heat pump unit • intelligent controller	• controller can be integrated or stand-alone	• can be retrofitted to an existing gas boiler

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. 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 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 the future for demand management (i.e. demand side response[10]: shifting the time of electricity demand).

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

Gas driven heat pumps

Three gas driven systems are currently available in the European market under two technology types: sorption (absorption and adsorption) heat pumps and gas engine driven heat pumps.

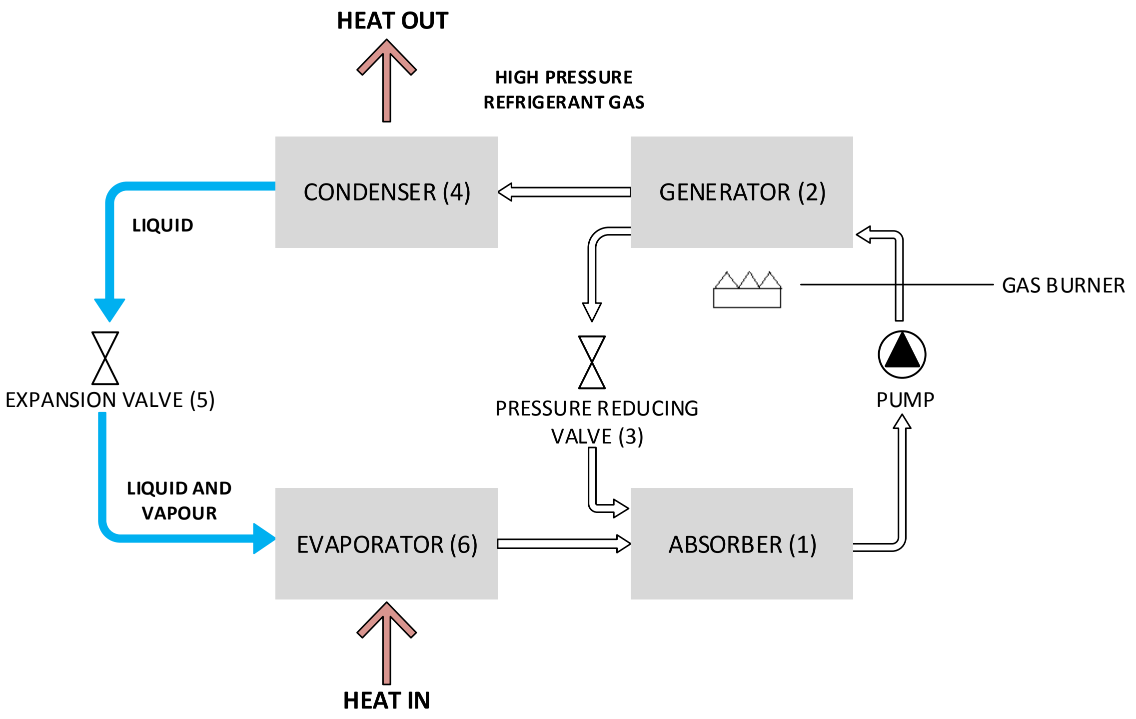
In a sorption cycle the mechanical compressor (as used in a standard electric heat pump) is replaced by a thermal compressor.

Absorption

In the UK, the only commercially available sorption systems are absorption units, and these are primarily focussed on the commercial market (larger than 30kW in size). They are used to produce hot water for space heating and/or DHW. A smaller model targeted at the domestic householder market is expected to be available in the UK in 2016.

As well as some of the key components of a standard electric heat pump (condenser, expansion valve and evaporator), an absorption system incorporates a type of thermal compressor (Figure 6). A gas/liquid working pair such as ammonia/water is used instead of the single refrigerant used in a standard heat pump. The refrigerant gas is absorbed into a liquid, sorbent and the pressure raised to the condenser pressure using a small liquid pump. This uses much less electricity than the electrical compressor of a standard heat pump. However a gas burner is then needed to boil the gas out of the solution.

Figure 6 Absorption cycle system diagram



Absorption heat pumps can reach higher temperatures than standard electric heat pumps, typically up to 65˚C.

Adsorption

Gas adsorption heat pumps are not currently available in the UK, but are being introduced in Europe.

An adsorption cycle again uses a thermal compressor, however the refrigerant vapour is adsorbed onto the surface of a solid instead of being absorbed into a liquid. The adsorbed refrigerant is then driven out by applying heat so this is a batch process. This requires a liquid/solid working pair, which tends to be water and zeolite. Zeolites are highly porous materials, which can adsorb relatively large quantities of water vapour. Adsorption heat pumps which use water as the refrigerant cannot be used with ambient air as the source in the UK because of the risk of freezing.

Whilst high temperatures of up to 75˚C can be attained with adsorption technology, it is recommended that the current models operate at a flow temperature of 40-45˚C. This is lower than other gas driven heat pump technologies and is comparable to a standard electric heat pump.

Gas engine driven

The gas engine driven heat pumps currently available in the UK are air to air variable refrigerant flow (VRF) products with capacities from 20 to 120 kW, used to provide heating, cooling and DHW in commercial buildings, particularly where there are limitations on electricity supply.

Gas engine driven heat pumps use standard components found in an electric heat pump: a compressor, condenser, expansion valve and evaporator. The primary difference is that the compressor is powered by a gas engine rather than by electricity, and heat is generated both through the refrigerant cycle and from the waste heat given off by the gas engine.

The majority of gas engine driven systems are air to air heat pumps, but they can also provide domestic hot water when installed with a hydrobox, which contains a heat exchanger to transfer heat from the refrigerant to the water circuit, to allow use with a water based heating system.

Potential Innovation

There is considerable scope for general heat pump efficiencies to increase - a new range of compressors, for example, show an improvement of over 12% in efficiency. The efficiency of heat exchangers is also steadily increasing.

High temperature heat pumps which use alternative low global warming potential refrigerants such as hydrofluoro olefins (HFOs) etc. may enter the market and are capable of reaching 65°C or over.

In addition, 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.

Recent technical developments have been seen in gas driven heat pump technology for the domestic market. A smaller, 18kW absorption cycle heat pump suitable for domestic application is expected to enter the UK market in 2016. Adsorption cycle heat pump design has also been optimised to suit UK heating demand patterns and single phase voltage requirements.

Several further areas of innovation may be realised within 18 months. The trend is not just to improve efficiencies but also to reduce the space requirements of products. More information on future gas driven heat pump innovations can be found in the Gas Driven Heat Pump report[11].

System Applications

Typical applications for each heat pump technology include:

- High temperature heat pumps – hard to heat, older or listed properties usually with high heat loss which need higher heating water temperatures (e.g.70˚C flow/45˚C return) or where upgrades to the existing heating system are difficult. These products are more likely to be cost effective for properties off the gas grid i.e. with electric, oil or solid fuel heating
- Hybrid systems – as an add-on to an existing gas boiler with a reasonable remaining lifetime; small, on gas grid properties to replace a standalone gas boiler (packaged hybrids); older properties with high heat loads and existing high temperature radiators where a heat pump alone cannot be used due to single phase electricity supply restrictions; and thermally efficient buildings (including new build) where a lower investment option is sought than a standard electric heat pump
- Gas absorption heat pumps - primarily commercial at present, due to the size of the currently available absorption products (generally >30kW). This may change in 2016 with the introduction to the UK of a product sized for the domestic market. Suitable for retrofit or new build domestic properties on the gas grid.
- Gas adsorption heat pumps – suited to domestic properties due to size constraints (<15kW). Suitable for new build properties with low temperature heat distribution systems, as best operated at lower output temperatures (e.g. 40-45˚C). Require space for a ground collector.
- Gas engine driven heat pumps - most commonly commercial buildings with a high demand for heating/cooling and long running hours, and to a lesser extent for industrial applications. Unlikely to be used for smaller domestic properties in the short term.

Domestic hot water

All heat pump technologies considered in this report can produce domestic hot water, though may at times require back up or the installation of additional equipment.

[11] Evidence Gathering – Low carbon Heating Technologies: Gas Driven Heat Pumps, BEIS, 2016

High temperature heat pumps are suited to producing domestic hot water and are appropriate in situations where there is a high, all year requirement for hot water, especially where they may be replacing use of an electric immersion heater.

Hybrid systems can also meet domestic hot water demand, commonly using the boiler component for this requirement, whilst using the heat pump for base load space heating.

Temperature specifications

Despite the availability of products which can operate at temperatures approaching those produced by a hot water boiler, most manufacturers and suppliers stressed that they typically recommend improving insulation, modifying the heat distribution system and upgrading heat emitters (radiators), where possible. Then the heat pump can be configured to run at lower temperatures most of the time, and will have a higher efficiency.

For hybrid systems, the boiler can usually provide high temperature heating and hot water using the existing high temperature heating distribution system. However this may not optimise the contribution from the heat pump. By upgrading some 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.

Gas absorption heat pumps can deliver relatively high temperatures and efficiency does not fall as quickly at high temperatures as electric heat pumps. It is expected that they can be retrofitted to most existing conventional heating distribution systems, without the need to replace all radiators. Gas adsorption heat pumps are recommended for operation at lower temperatures, thus generally require radiator upgrades where feasible.

System Comparisons

Table 3 shows some advantages and disadvantages of the variations within the three technology types.

Table 3 Advantages and disadvantages of heat pump system variations

System Variation	Advantage(s)	Disadvantage(s)
High temperature: Optimised design for refrigerant	• Little to no modification of standard heat pump required	• Improvements to heat pump components can improve efficiencies incrementally but there are fundamental limits on operating temperature range and temperature lift each refrigerant can provide • High price of electricity compared with other energy sources

System Variation	Advantage(s)	Disadvantage(s)
High temperature: Cascade	• Can reach temperatures up to 80˚C • The performance of each cycle can be optimised and the amount of lift for each cycle is reduced	• Two separate refrigerants required in two separate cycles so higher capital cost • More complex system • Larger space requirements • High price of electricity compared with other energy sources
High temperature: EVI	• Can reach high temperatures in one system with a single refrigerant (70-75˚C) • May also improve efficiency operating at lower temperatures	• More expensive than standard cycle • High price of electricity compared with other energy sources
Hybrid package	• Low price of gas relative to electricity • Consumers are used to gas boilers as a heating source • If case of distress purchase, the boiler could be connected straight away in advance of the full system commissioning • Heat pump and boiler operation can be controlled to maximise efficiency and/or minimise cost	• Potentially higher capital cost as package includes both heat pump and boiler • Uncertainty over the system performance as highly dependent on control settings
Hybrid add-on	• Can be retrofitted to most existing boilers. Consumers are used to gas boilers for heating • User doesn't have to wait until boiler needs replacing to add the heat pump • Heat pump and boiler operation can be controlled to maximise efficiency and/or minimise cost	• 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

System Variation	Advantage(s)	Disadvantage(s)
Gas absorption	• Can be used in large premises • Can reach high temperatures • Consumers are used to gas as a heating source • Use of ammonia which is a natural refrigerant with no global warming potential	• Difficult to reduce size to suit domestic properties • Use of ammonia as the refrigerant which is toxic, though it is a sealed unit and meets relevant safety regulations. Specialist training is required to handle ammonia
Gas adsorption	• Can have a smaller ground loop than other ground source heat pumps • Environmentally friendly, non-toxic and low cost refrigerant (commonly water) • Consumers are used to gas as a heating source	• Difficult to increase size to suit larger properties • Not a continuous process and may need thermal storage • Requires a ground loop which is expensive and needs space (cannot use ambient air as a heat source)
Gas engine driven	• Air to air systems can provide both heating and cooling • Can output at high temperatures • Retains efficiency well as outside temperature falls	• Designed for air distribution systems so requires a separate hydrobox to be able to function as air to water for wet heating systems • Current products sizes not suited to domestic applications

5. Market and Product Review

We have identified a wide range of manufacturers offering products designed and marketed as high temperature heat pumps and hybrid heat pumps. Absorption, and possibly adsorption products, may launch in the UK in 2016.

- **Product data has been collected for 83 high temperature products from 12 manufacturers. There are only three packaged hybrid product ranges but a large number of add-on hybrid heat pumps on the market.**
- **We have identified six manufacturers of gas driven heat pumps that currently operate in the UK, or may do so in the near future, however not all of these offer domestic scale products.**
- **Manufacturers offer a range of capacities, both split and monobloc products, fixed and variable compressor versions, and single and three phase units.**
- **High temperature applications are just a few percent of heat pump sales, numbering a few hundred units per year. Hybrid heat pumps currently have about 18% of the heat pump market share (if all bivalent systems are included).**
- **Significant market uptake of space heating heat pumps has been predicted over the next 15-35 years. High temperature, hybrid and gas sorption heat pumps could all provide an attractive option, as they can often operate with existing heat distribution systems and provide domestic hot water.**
- **The potential market could be 29,000-60,000 dwellings (off gas grid) per year for high temperature heat pumps, and 100,000 to 210,000 dwellings (on gas grid) for hybrid and gas driven heat pumps combined.**

Product Review

Product data was collected for 83 high temperatures products that are capable of reaching 65°C for the purpose of space heating[12]. Performance data collected

[12] Evidence Gathering – Low Carbon Heating Technologies: Domestic High Temperature Heat Pumps, BEIS, 2016

included the range of COPs (tested to EN14511) at A7/W65 (outdoor air temperature of 7°C and water output at 65°C) or B0/W65 (brine temperature and water output for ground source products) and the SSHEE at 55°C average climatic conditions (tested to EN14825) for each product range.

Data for 58 hybrid products has also been collected[13], although performance data relates only to the heat pump component, and not the heat pump-boiler system. A number of further products are marketed as hybrid-compatible or hybrid-ready.

Six manufacturers of gas driven heat pumps that currently operate in the UK, or may do so in the near future were also identified[14]. Absorption and adsorption products that are suitable for domestic use have been developed in Europe and are already being marketed there or trials are being undertaken.

Market Review

Market size and potential

In the UK the overall domestic heat pump market is small. The heating market is dominated by boilers (which make up 85% of the market[15]) 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[16]:

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

The estimated market size in the UK for domestic air source and ground source heat pumps in 2014 was around 17,700 a year, and is summarised in Table 4. This data was derived from BSRIA figures for total annual sales volume for air to water and ground to water heat pumps. The table also shows an estimate of the proportion operating at above 60°C, and the proportion that are hybrid[17]. The results are consistent with the sales data provided by stakeholders within the study.

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[13] Evidence Gathering – Low Carbon Heating Technologies: Domestic Hybrid Heat Pumps, BEIS, 2016

[14] Evidence Gathering – Low Carbon Heating Technologies: Gas Driven Heat Pumps, BEIS, 2016

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

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

[17] Market data for hybrid heat pumps is likely to include some 'bivalent' systems (a system without an intelligent controller). The figures for 'true' hybrid technology will be therefore lower, but there is a lack of reliable data to estimate by how much.

Currently there are no domestic scale gas driven heat pumps sold in the UK market, although some sales figures are available for commercial applications. Carbon Trust research in 2015 estimated sales of commercial absorption products at 100-200 per year. Gas engine driven products are currently available from two manufacturers in the UK, and sales figures are confidential.

Table 4 The estimated annual sales of domestic high temperature and hybrid heat pumps in the UK in 2014

Heat pump category	Annual heat pump sales volume (domestic & commercial)	Estimated annual domestic sales volume	Estimated proportion high temperature	Estimated annual sales volume high temperature	Estimated proportion hybrid	Estimated annual sales volume hybrid
Air to water	16,500	~ 15,900	2%	~320	18%	~2,860
Ground/ water to water	2,200	~ 1,800	2%	~40	18%	~325

Market potential

The overall air source and ground source heat pump markets in the UK have been flat for the last two years.

The future high temperature domestic heat pump market is difficult to predict. Manufacturers expressed that there are too many variables to make firm predictions of market potential, such as the future balance of incentive schemes and the relative prices of gas, oil and electricity which affect the competitiveness of heat pumps. They suggested that if current incentives and energy prices remain the same then the market is likely to remain stable.

The potential market in the UK for hybrid and gas driven heat pumps, as a replacement for gas boilers, is substantial because of the nature of the UK's housing infrastructure, where 85% of homes have a gas boiler[18]. The key to the growth of this market is for these technologies to become a cost effective consumer choice for gas boiler replacements. As discussed in section 8, the capital and installation costs for hybrid and gas driven heat pumps are several times higher than for gas condensing boilers. Significant cost reductions may be possible with higher deployment rates, but achieving wide uptake is also likely to require awareness raising and education of consumers to persuade them that gas driven heat pumps provide more efficient heat, and are a feasible alternative.

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

However during the research undertaken for this study, stakeholders were positive about the future for hybrid and gas driven heat pumps in particular.

The Committee on Climate Change (CCC) have suggested that the overall cost-effective uptake of heat pumps could be 2.3 million dwellings by 2030[19].

To estimate the proportion of the market which might be high temperature, hybrid or gas driven we have looked at their application, how they are marketed, the potential consumers and the market size.

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 of these, gas boilers are used to provide heating and/or hot water[20]. Heating and hot water for the remaining dwellings are supplied through off-gas-grid means such as solid fuel, oil or electricity. Industry sentiment suggests that high temperature heat pump technology will mainly be a cost effective replacement for the 15% of dwellings which are not on the gas grid.

Our estimate for the total potential addressable market for hybrid and gas driven heat pumps is around 15-30% of dwellings connected to the gas grid. Our estimate of the total potential addressable market for high temperature heat pumps is 25-50% of off gas grid dwellings.

The annual market for domestic heating replacements is approximately 1.67 million units[21] of which around 1.5 million are gas boilers[22]. Comparison of this 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[23] on drivers for homeowners' desire to purchase a new heating solution (e.g. distress purchases, replacement parts hard to find for existing solution, refurbishment) indicates that only 44% of the time would the heat pump supply chain be likely to meet the customer's needs.

Adding the annual replacement rate and the drivers for heating system purchases to the size of the potential addressable market gives an annual market potential for

[19] The Fifth Carbon Budget. The next step towards a low-carbon economy. Committee on Climate Change, 2015 - Middle scenario suggest heat pumps and heat networks from low-carbon sources provide heat for around 13% of homes

[20] Sub-national consumption statistics, BEIS, 2014

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

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

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

high temperature heat pumps of between 29,000 and 66,000 dwellings (all off gas grid opportunities), and an annual potential of between 100,000 and 210,000 dwellings for hybrid and gas driven heat pumps.

Market Segmentation and Competition

The three technologies addressed in this report are in direct competition with each other for some end users. If the property is on the gas grid, hybrid heat pumps may be a lower cost and more popular alternative with consumers than high temperature electric heat pumps at the current time. Hybrid heat pumps still face a number of barriers to shift the market away from gas-fired condensing boilers. They will also be in direct competition with domestic gas driven heat pumps when they are launched in the UK. In the short term, we believe hybrid products may grow market share more quickly due to their lower cost.

Hybrid heat pumps combined with oil or LPG boilers are also an alternative to high temperature heat pumps where the consumer is off the gas grid. According to installers interviewed, adding a small hybrid heat pump to an existing oil boiler is a more common alternative to installing a high temperature electric heat pump. If the existing boiler has a reasonable lifetime, this can allow the use of a heat pump for efficient space heating, whilst retaining the domestic hot water advantages of the boiler.

Hybrid heat pumps also face competition from other technologies including biomass boilers. Small or micro combined heat and power (CHP) units could also be a future competitor. These systems can be powered by gas and generate a small amount of electricity as they are used. They have the benefit of being similar in size, appearance and function of a standard gas boiler.

6. Standards Review

Standards for electric heat pumps are well established. Standards for sorption products are also available and for gas engine driven products are at an advanced stage of development. Performance measurement standards do not yet exist for hybrid systems based on electric heat pumps.

- **BS EN 14511 is a well-established standard for testing of steady state performance of electric heat pumps across a variety of rating conditions. BS EN 14825 is a related standard and defines the conditions for measuring seasonal performance. There are also BS EN standards governing the design and performance measurement of systems as a whole, as well as specific aspects such as safety and noise.**
- **BS EN 12309 defines the conditions for measuring performance of sorption products, and prEN16905 is being developed for measuring performance of gas engine driven heat pumps.**
- **The heat pump component of electric hybrid products can be assessed according to BS EN 14511 and BS EN 14825, but there is no agreed standard for measuring performance of the heat pump-boiler system as a whole. However a method for assessing hybrid performance has been determined for hybrid sorption heat pumps in BS EN 12309.**
- **Products must now meet the requirements of the Ecodesign Directive (2009/125/EC), notably the Ecodesign and Energy labelling requirements for space heaters and, where relevant, water heaters. This includes publishing information on seasonal space heating energy efficiency, and meeting a minimum energy performance standard.**
- **Both UK building regulations, and the Microgeneration Certification Scheme (MCS) require that high temperature heat pumps should only be considered after the feasibility of low temperature heat pumps has been considered.**

High temperature heat pumps are generally similar to standard heat pumps but operate over an extended temperature range and are well covered by existing British Standards most of which are also European standards. Both BS EN 14511 and BS EN 14825 are currently under revision to align them with the requirements of the Ecodesign and Ecolabelling regulations.

Gas driven heat pumps are covered by some existing British standards, most of which are also European Standards. A number of gaps and inconsistencies in the standards covering gas sorption heat pumps are currently being addressed and revised performance standards for gas sorption heat pumps have recently been published. Performance standards covering gas engine driven heat pumps have been drafted and are likely to be approved in the near future. There are still some gaps however as the sorption standard only covers products with hydronic heating systems and the standard for gas engine driven heat pumps covers space heating and cooling but not water heating.

There is currently no standard for defining the performance of electric hybrid heat pumps systems, and work is needed to develop this.

At present the performance standards developed for standard electrically driven heat pumps are sometimes being used for hybrid products. If the current BS EN14511 is used for electric 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 is used to calculate seasonal performance for electric hybrids it is likely to underestimate the performance of air, water and ground source products.

A methodology for determining the performance at standard rating conditions and the seasonal performance of hybrids has been developed within the sorption heat pump standard. There may be potential to adapt this approach for use with electric heat pumps.

Standards also exist to govern the design and performance measurement of systems as a whole as well as specific aspects such as safety and noise.

A comprehensive list and brief description of relevant technical standards can be found in Appendix A, Table 10

7. System Performance

A range of SSHEE and COP data has been analysed for high temperature, hybrid and gas driven heat pumps. There is a wide spread of performance for some categories and a lack of in-use performance data.

- **The standardised testing and reporting of performance information should make it easier to differentiate between high temperature, hybrid and gas driven products, and to compare them with standard heat pump products.**
- **Lab tested performance data was collected from product brochures, ErP data fiches and manufacturer interviews.**
- **The average SSHEE at 55°C (average climate conditions) ranges from 104-135% for air source high temperature products, 104–130% for air source hybrid products and 103–126% for gas sorption p. For comparison new condensing gas boiler SSHEEs are typically 92-93%.**
- **Information gathered from a number of trials showed high temperature, hybrid and gas driven heat pumps generally performed satisfactorily. Good system design, effective control and user training is critical to ensure good performance. There is insufficient in-use performance data to draw quantitative conclusions on the relationship between this and lab performance.**

Laboratory-Tested Performance

The rated performance of high temperature and hybrid heat pumps is tested according to BS EN14511. 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. The rated performance of gas sorption heat pumps is tested according to BS EN12309.

Figure 7 shows how the rated COP for a typical high temperature air to water heat pump varies with air temperature and output temperature. The data is taken from manufacturer capacity tables. It shows how COP improves when the water output temperature is lower, and the outside air temperature is higher.

Figure 8 shows the COP versus capacity for a selection of air source high temperature and hybrid heat pump products identified in this study, with an output water temperature of 55°C at an ambient air temperature of 7°C. The average COP for the high temperature products was 2.99 and ranged from 2.47 to 3.36. For the hybrids, the average was 2.68 and ranged from 2.17 to 3.23[24]. Within this limited sample the COPs of high temperature products appear to be slightly higher on average. As 55°C is a relatively high temperature for heat pump operation, it is perhaps no surprise that products optimised to operate at 65°C or more also perform well at 55°C. No notable variation in COP with increased capacity was found.

Figure 7 Rated COP versus air temperature for a typical air to water heat pump

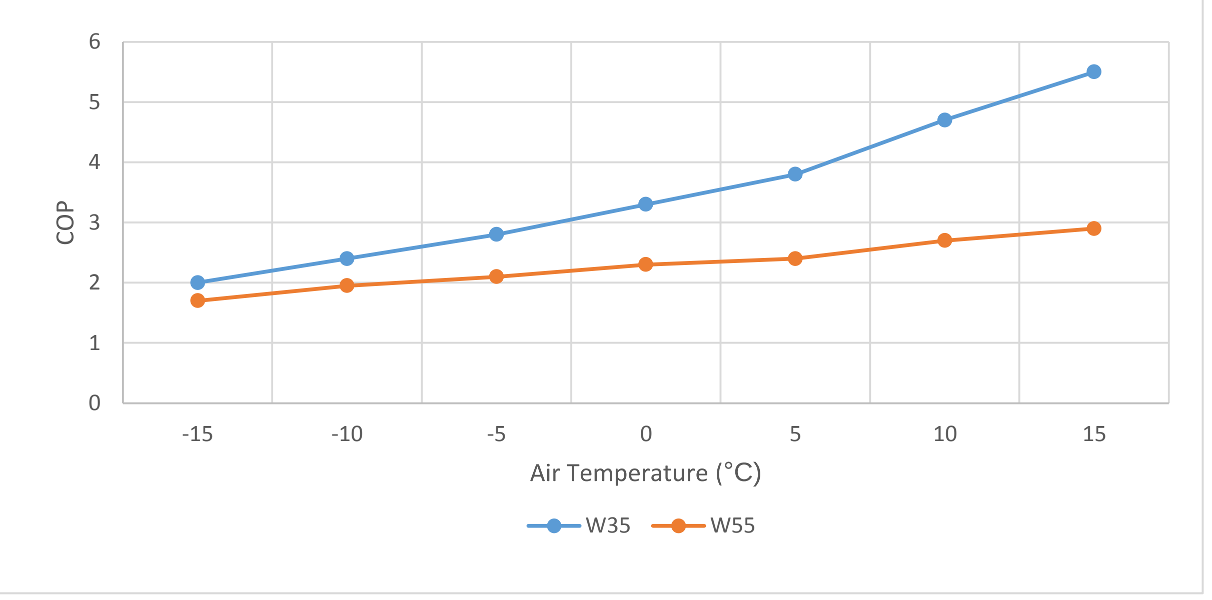
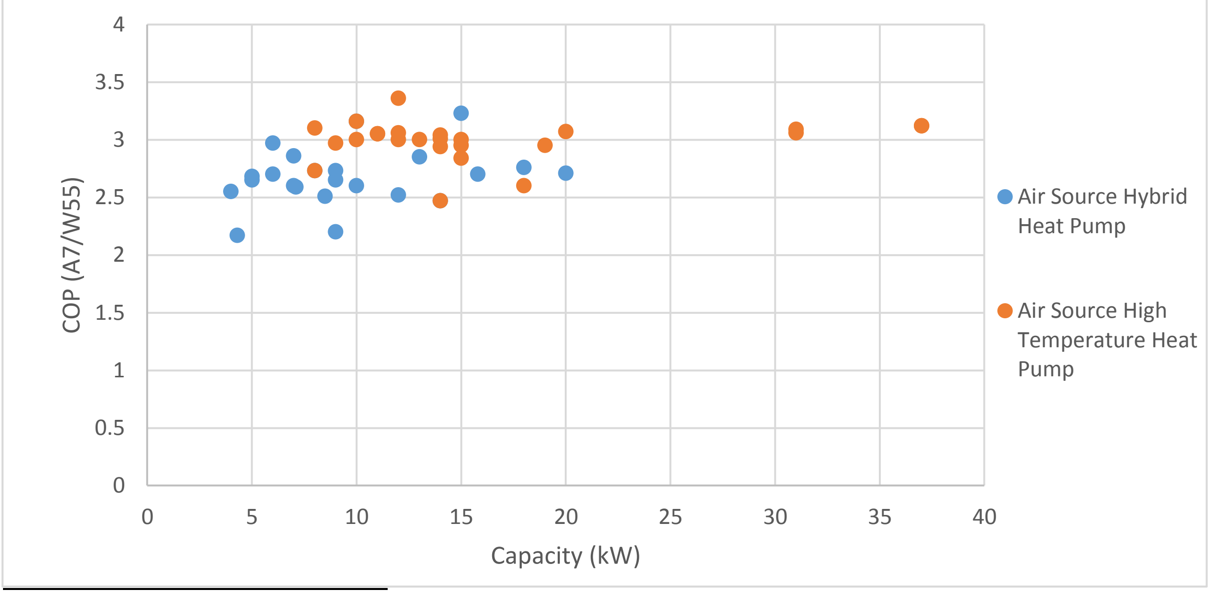


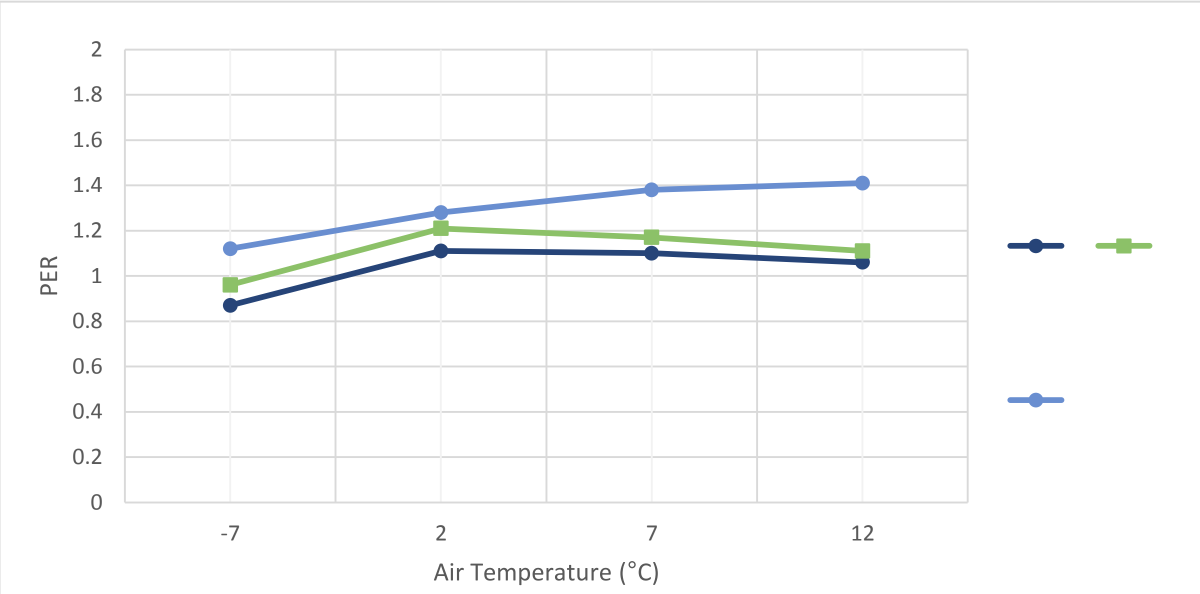
Figure 8 Rated COPs against capacity for a selection of hybrid and high temperature heat pumps at an air temperature of 7°C and an output water temperature 55°C



[24] Due to the lack of an accepted performance standard, COP and SSHEE values of electric hybrid heat pumps refer only to the heat pump component, not the whole heat pump-boiler system

The efficiency of gas sorption products is not reported as COP but PER. To recap, this is the ratio of the useful heating energy in relation to the primary energy input. Figure 9 shows the PER values of three gas absorption heat pumps at different ambient temperatures and a water output temperature of 55°C. The capacity and efficiency of gas driven heat pumps is not as adversely affected by falling ambient air temperatures as electrically driven air to water heat pumps. The 18kW product has a higher PER resulting from extensive testing and development as part of trials during its development as part of the Heat4U project trials[25].

Figure 9 Rated PER values at an output temperature of 55°C for different ambient temperatures for a range of air to water absorption heat pumps



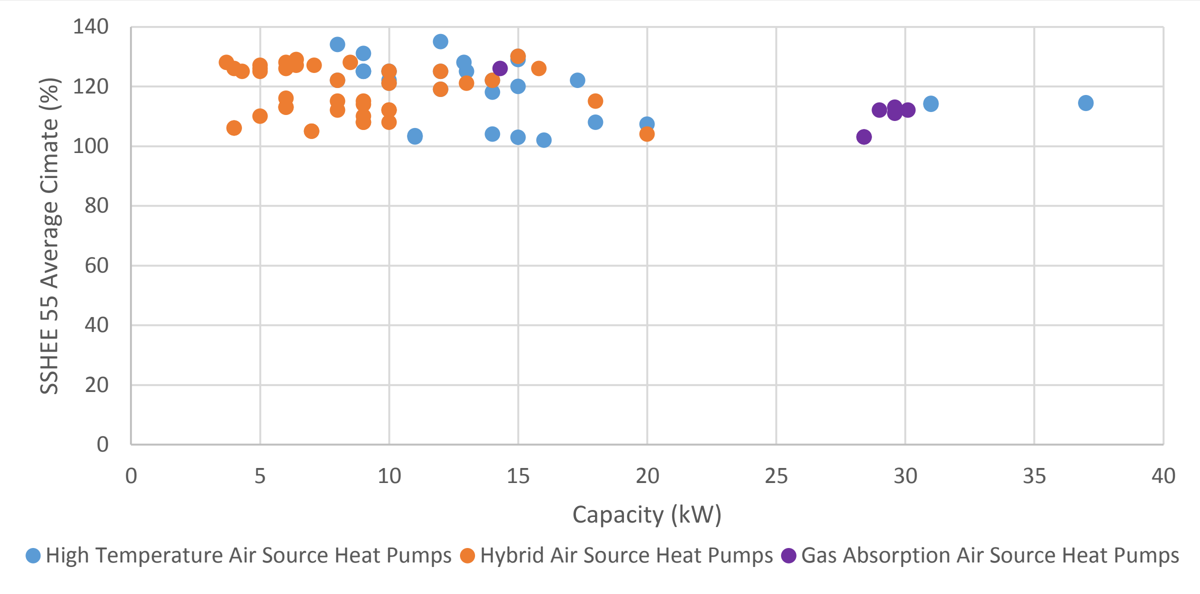
Ecodesign legislation setting minimum performance and labelling requirements came into force on the 26th September 2015. This requires manufacturers to provide data on the seasonal performance of products measured as the seasonal space heating energy efficiency (SSHEE) according to BS EN 14825.

The SSHEE values, at 55°C under average climatic conditions, for air source high temperature, hybrid and gas driven heat pumps (identified in this study) are plotted against capacity in Figure 10. There is a considerable spread in performance in the SSHEE values of air source products but this does not appear to correlate with the capacity of the product. The average SSHEE at 55°C under average climate conditions range from 102 -135% for air source high temperature products, 104–133 % for air source hybrid products and 103–126 % for gas driven. For comparison new condensing gas boiler SSHEEs are typically 92-93%. Unlike the relationship displayed in Figure 8, there does not appear to be a significant difference between

[25] Gas Absorption Heat Pump solution for existing residential buildings, HEAT4U, 2013

the high temperature and hybrid products. The SSHEE is the performance averaged across a load profile representative of performance across the operating conditions during the whole heating season rather than performance at a single operating condition.

Figure 10 The SSHEE at 55°C under average climatic conditions vs capacity for a selection of high temperature, hybrid and gas driven heat pumps



In-Use Performance

The heat pump technologies reviewed are relatively new and evidence of in-use performance is limited. A number of trials have been carried out, although these are mostly small scale, and the monitoring, although sometimes very detailed, is not always consistent across the trials. There is little in the way of published results as yet; most of the trial information discussed is based on interviews with stakeholders.

High temperature heat pumps

For high temperature heat pumps, we identified trials by a university, a utility company, a housing association and two manufacturers. Generally, users have been satisfied with the systems and the level of comfort received, however cost savings have been limited.

The housing association Affinity Sutton installed high temperature heat pumps in 15 off gas grid properties and reported very satisfied tenants. A trial of a high temperature heat pump in an occupied dwelling by the University of Ulster also resulted in satisfied tenants, except for some conditions when the air temperature dropped below 2°C. The heat pump struggled to maintain comfort levels as a result of defrosting of the system. The average daily COP of the system varied from 1.82 to 2.38 across the winter period; it is expected that the efficiency will improve in the summer. A trial of CO_2 heat pumps by E.ON found that overall system performance was lower than expected as a result of a problem with the overall control strategy.

The trial findings all stressed the importance of control strategy, and of informed occupants. From the small number of trials, it appears as though comfort levels can usually be achieved with flow temperatures of between 60˚C and 65°C with little modification to the existing high temperature radiator systems, however whether this can be achieved efficiently with a high COP is unclear.

Hybrid heat pumps

For hybrid heat pumps, there have been trials by manufacturers, utilities, universities, and housing associations. Generally tenants have been satisfied with the heating comfort provided. One manufacturer installed 9 hybrid heat pumps and analysis by Leeds Beckett University showed that the COPs varied from 3.1 – 4.0 during the heating season. Another trial of a 5kW system, providing space heating only, measured an SPF of 2.94 for the heat pump only.

As with high temperature 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. Ongoing trials are now examining how smart control of hybrids systems could be used to manage peak electricity demand. The Smart Community Demonstration Project Greater Manchester, set up by the Japanese New Energy Development Organisation (NEDO), is currently conducting research in this area and is due to report in 2017.

Gas driven heat pumps

Data for in-situ performance for domestic scale gas driven heat pumps is very limited. The best documented trial has been of the new 18 kW absorption heat pump. This was carried out as part of the Heat4U project which trialed units at five sites across Europe for one year. The gas utilisation efficiency (GUE) for space heating was 1.20 based on gross calorific value (or 1.32 based on net calorific value). The calculated energy savings compared to a gas condensing boiler were 30%.

Adsorption heat pumps are not available in the UK yet so there is no UK in-situ performance data available, however trials have been carried out in Europe. The Gas Heat Pump Initiative which ran from 2008 to 2012[26] aimed to develop sorption heat pump technology, through laboratory testing and field trials. Over 250 gas heat pumps were installed at locations throughout Germany. In these and other trials, adsorption heat pumps achieved GUEs of around 1.1 to 1.2 based on gross calorific value.

Expected technology lifetimes

The lifetime of high temperature and hybrid heat pumps should be similar to that of a standard heat pump at 15 to 20 years. No evidence was found that the lifetime varied with size but products are too new to be able to assess lifetime fully yet. With

[26] The Gas Heat Pump Initiative, http://www.IGHP.de

hybrid heat pumps, the consensus from stakeholders was that the boiler life would be longer than the life of the heat pump. Gas absorption heat pumps just include a small fluid pump, and adsorption products have no moving parts, therefore lifetimes of around 20 years are expected, but the technology is relatively new so there is limited experience available to verify this. Technology lifetimes for gas engine heat pumps are expected to be comparable with electric heat pumps at 15- 20 years.

Energy and Carbon Performance

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 boiler, and a standard 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 heat pump of 10kW or larger. The output water is assumed to be medium temperature (as defined by Ecodesign regulations), and we have used SSHEE at 55°C as the performance measure.

Carbon conversion factors and energy prices are shown in Table 5**Error! Reference source not found.**, taken from BEIS Green Book guidance.[27]

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

Table 5 Carbon conversions and energy prices from BEIS green book guidance

Carbon conversion factors (kgCO_{2e}/kWh) **:**	
Gas*	0.185
Burning oil	0.247
Electricity**	0.333
Energy prices (p/kWh):	
Gas*	4.11
Burning oil***	3.61
Electricity	14.83

* 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

We have assumed that the high temperature and gas absorption heat pumps will provide 100% of the space heating and DHW demand. We have assumed that the hybrid heat pump will provide 80% of the space heating demand 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, and that the standard electric heat pump provides 100% space heating but only 80% of the hot water, with the rest provided by direct electric back-up.

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 used by the gas heat pumps).

The SSHEE and also Water Heating Energy Efficiency (WHEE) data in Table 6 have been extracted from our review of heat pump products, and a brief survey of a sample of gas boilers.

Table 6 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			
High temp heat pump	102	135	118
Hybrid heat pump	104	133	119
Gas absorption heat Pump	103	113	109
Gas boiler			92.5
Standard electric heat pump			119
WHEE (%) / SPF			
High temp heat pump	65	115	85
Hybrid heat pump	96	116	100
Gas absorption heat Pump	103	113	109*
Gas boiler			82
Standard electric heat pump			101

* No data available – assume the water heating efficiency is the same as space heating

Energy use and savings

In Table 6 the energy use, cost and carbon emissions are calculated for high temperature, hybrid and absorption 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 are also shown. The savings for the high temperature, hybrid and gas driven heat pump relative to the counterfactual are then calculated. The ranges of savings relate solely to the range of product 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 7 Energy use, carbon emissions and savings for high temperature, hybrid and absoption heat pumps versus gas boilers

	High temperature heat pump	Hybrid heat pump	Gas absorption heat pump	Condensing gas boiler counterfactual	Standard electric heat pump counterfactual
Total space heating consumption kWh/yr	3,560 to 4,700	5,480 to 6,290	9,520 to 11650	12,970	4030
Total water heating consumption kWh/yr	700 to 1,230	2,440	1,590 to 1,940	2,440	1,030
Total energy consumption kWh/yr	4,250 to 5,940	7,920 to 8,730	11,110 to 13,590	15,410	5,070
Total carbon emissions kg/CO_2/yr	1,420 to 1,980	1,890 to 2,160	2,050 to 2,510	2,840	1,690
Total energy cost £/yr	630 to 880	640 to 760	460 to 560	630	750
	Savings compared to gas boiler counterfactual:				
Energy saving (%)	61% to 72%	43% to 49%	12% to 28%		
Carbon saving (%)	30% to 50%	24% to 34%	12% to 28%		
Cost saving (%)	-39% to 0%	-19% to 0%	12% to 28%		

N.b. indicative values only, subject to rounding errors

In the scenario modelled, only the most efficient high temperature and hybrid heat pumps break even in energy cost terms compared with a new condensing gas boiler, however energy and carbon savings of between one quarter and three quarters are achieved. The gas absorption heat pump results in savings of around 10-30%.

Compared with a standard electric heat pump, high temperature heat pump cost and carbon savings (around 15% on average) mainly come from avoiding the need for back up electrical heating.

Cost savings are up to 15% with a hybrid as a result of the price differential between gas and electricity. However carbon emissions are 10-30% higher for the hybrid heat pump in this case, as the gas boiler has a lower SSHEE than the heat pump.

The gas absorption heat pump uses over twice as much kWh delivered energy than an electric heat pump, but in terms of primary energy consumption, the energy demand is up to 30% lower. Carbon emissions are 20-50% higher in this scenario, but cost savings of 25-40% may be achieved, because of the price differential between gas and electricity.

The ranges of calculated savings for the technologies reviewed, relative to the counterfactuals, are shown graphically in Figure 11 and Figure 12. Negative values imply that the technologies are higher carbon or cost than the counterfactual.

It should be noted that the average carbon emissions factor for electricity is expected to fall in subsequent years, and so the carbon emissions associated with the high temperature, standard electric, and to some extent the hybrid, heat pumps are likely to come down over time.

Figure 11 Indicative relative carbon savings of high temperature, hybrid and gas driven heat pumps against gas boilers and standard heat pump for model scenario

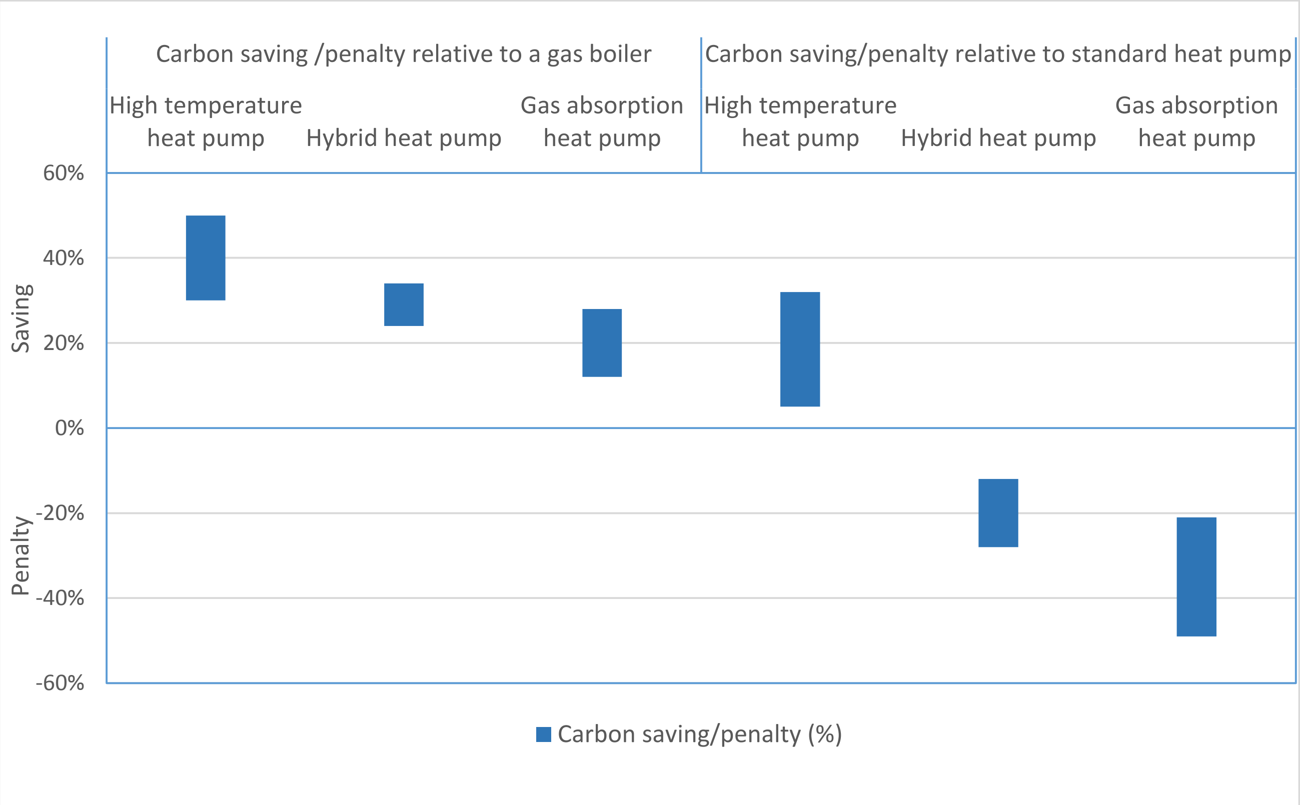
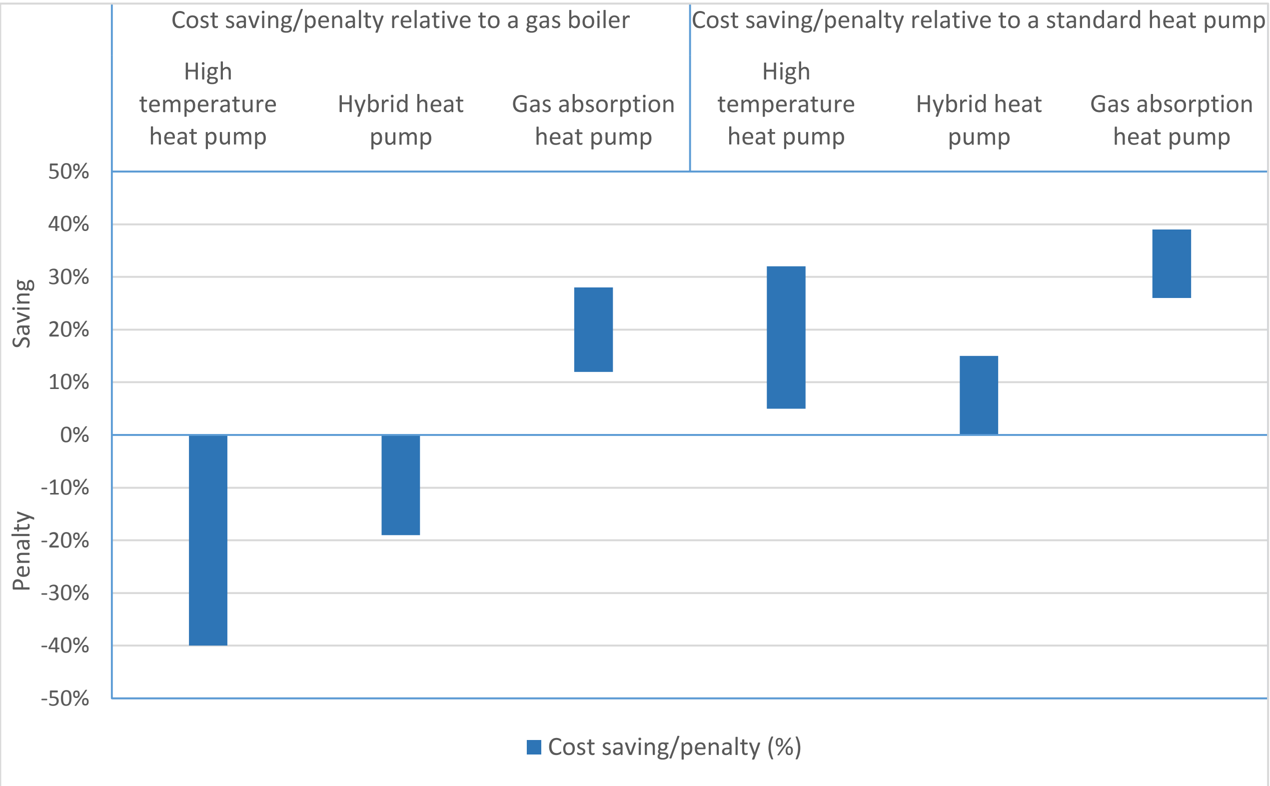


Figure 12 Indicative relative cost savings of high temperature, hybrid and gas driven heat pumps against gas boilers and standard heat pump for model scenario



8. Costs

High temperature and gas driven heat pumps are all, on average, more expensive to buy than standard electric heat pumps, although the installation cost can be reduced by a decreased need to upgrade radiators. Hybrid heat pumps can be cheaper than standard air source heat pumps.

- **The price of high temperature heat pumps ranges from £3,000 - £7,000 or £250 – £650/kW (air source), depending on product type. The 20% to 35% price premium for high temperature is reduced to 10-20% when taking full installation costs into account. Fully installed prices range from £6,000 to £14,000 for air source products. Installed costs for ground source versions can be anywhere between £10,000 - £40,000 depending on the type and size of ground collector used.**
- **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. Installed costs vary from £4,000 to £11,000 for air source hybrid products.**
- **Under a high deployment scenario, it is probable that high temperature and hybrid heat pump prices would reduce, but most likely incrementally rather than a significant or step-change reduction.**
- **An 18kW gas absorption heat pump, suitable for larger domestic properties, is expected to cost from £9,000 installed when launched, although costs could reduce by up to 30% according to stakeholders.**

Heat Pump Costs

High temperature, hybrid and gas heat pump systems mostly have the same cost elements as standard heat pumps as shown in

Table 8.

Table 8 Cost items for high temperature heat pumps

Capital cost	Installation cost	Running costs
• The heat pump itself • Boiler (package hybrids only) • For a split system, the refrigerant pipework between the units • A domestic hot water tank – if needed • A buffer tank – if needed • Controls and meters • Pipework, insulation, pumps etc. associated with any heating and hot water system • For ground source heat pumps, the ground collector • Upgrades to some heat emitters (radiators) – although this is not always required	• System design • Installation of the heat pump • Installation of refrigerant pipework • Installation/replacement of hot water tank and/or buffer tank – if needed • Installation of pipework • Electrical connection • For ground source heat pumps, the ground works (trenches etc.) • Installation of heat emitters if required	• Annual maintenance • Electricity cost and/or gas cost

The typical product and installation costs identified within the studies, are consistent with those from other studies, and are summarised in Table 9 and Figure 13 below. Figure 13 shows an indicative minimum and maximum for both the capital cost (top part of graph) and installation cost (bottom part of graph) of a 15-18kW heat pump for each of the technologies studied, based on the data collected from stakeholders in this study.

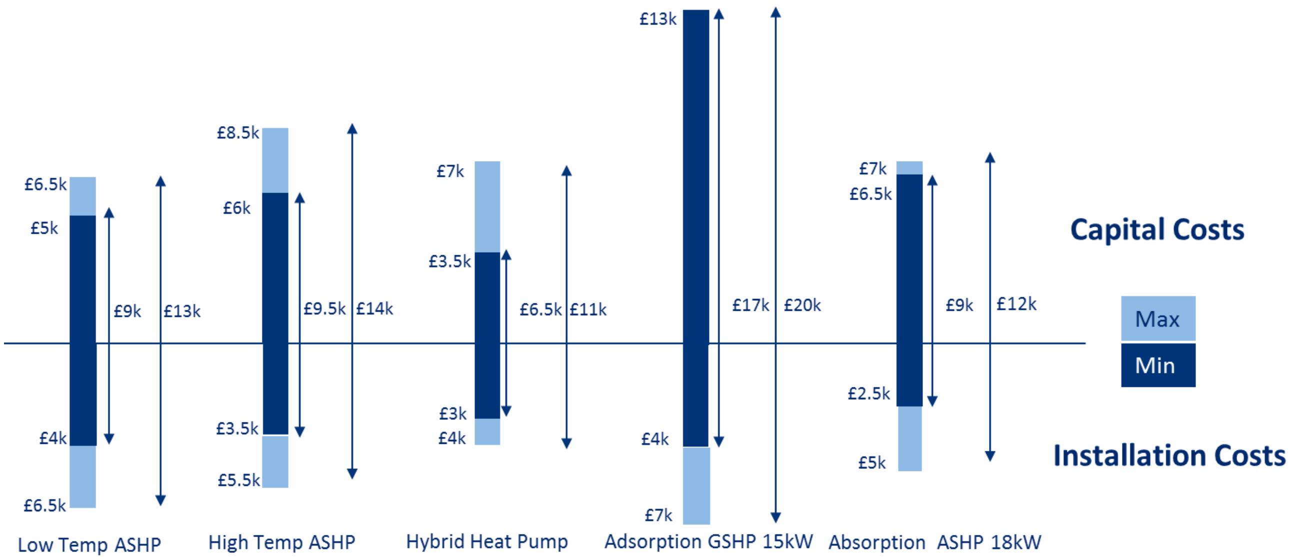
Table 9 Typical costs of high temperature, hybrid and gas driven heat pumps

Product type (°C)	Air or Ground	Capacity range reviewed (kW)	Capital cost (£)*	Installation cost (£)**	Total installed cost (£)	Total installed cost (£/kW)
High temperature heat pumps 80°C	Air	10-16	5k-9k	3k-5k	9k – 13k	650 – 1.1k
High temperature heat pumps >65°C	Air	6-15	3k-9k	2.5k-6.5k	6k – 14k	500 – 1.4k
High temperature heat pumps >65°C	Ground	6-30	4,5k–17k	5.5k-23k	10k – 40k	1k – 2.2k
Add-on hybrid - addition to existing boiler	Air	5-16	1.6k – 7k	2k - 4k	4k - 10k	350 – 1.6k
Package hybrid heat pump (boiler replacement)	Air	5-16	3k – 8.5k	3k - 4k	6k – 11.5k	500 – 1.8k
Domestics gas absorption (predicted)	Air	18	7k	2k-5k	9k-12k	500-650
Gas adsorption (predicted)	Ground or solar	10-15	13k	4k-7k	17k-20k	1.1k-1.3k

*Capital cost includes heat pump, accessories (and boiler for packaged hybrid)

**Installation cost includes some radiator upgrades where relevant

Figure 13 Comparison of capital and installed costs for different heat pump types (15-18kW capacity)



High Temperature Heat Pump Costs

The product cost of high temperature heat pumps has been found to be 20-35% higher than standard heat pumps. The price premium is a function of the technology used, and the temperatures reached. However, the percentage price premium for the fully installed cost is considerably lower at between 10-20%.

Stakeholders agreed that from a purely cost point of view, any avoided cost of upgrading heat emitters would rarely exceed, and may not offset the price premium for a high temperature heat pump.

Hybrid Heat Pump Costs

The total installed cost for a hybrid system could be between 20% and 33% lower than a standard heat pump, depending on whether an existing boiler is being replaced or retained.

However, the cost of a fully installed hybrid heat pump system is still upwards of three times that of a typical gas boiler installation.

Gas Driven Heat Pump Costs

An 18kW absorption unit is scheduled for launch in the UK within the next year. The estimated installed cost is around £9,000 upwards, broadly similar to a standard electric heat pump system.

There are no adsorption heat pumps on the market in the UK at present, however the likely future installed cost is expected to be around £17,000 upwards.

Price per kW

It should be noted that for both air source and ground source heat pumps, the cost of larger products is generally not significantly higher than for smaller products. For air source heat pumps the installation cost is also not reported to be significantly higher for larger products.

Therefore 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 – all products

The ongoing operating costs comprise the electricity or gas used to drive the heat pump, and maintenance charges.

The cost of maintenance has been found to be broadly similar to maintenance for a gas or oil boiler, for example £200/year. Many companies offer an annual maintenance contract – and this is sometimes a requirement to validate the warranty.

In terms of running costs, stakeholders indicated that little saving was likely to be achieved by high temperature heat pumps compared to a gas boiler, but 30-40%

energy cost savings have been realised compared to oil fired boilers (at 2014/15 prices) – although these have reduced with recent significant reductions in oil price.

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.

Trials of the planned 18kW absorption heat pump showed operating energy and cost savings of around 20%.

Opportunities for cost reduction

Stakeholders were divided over the opportunities to reduce costs of high temperature and hybrid heat pumps. Manufacturers in general felt that prices are currently similar across Europe where sales volumes are already 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, most stakeholders thought that prices would reduce, but in an incremental fashion rather than a significant or step-change reduction. However, a few stakeholders believed that much more significant cost reductions were possible given a high deployment scenario. They equated the market with the air conditioning market in which heat pump technology with mass market uptake has come down to a few hundred pounds.

For gas driven heat pumps considerable research is underway, and significant cost reductions are thought to be possible. In the short to medium term stakeholders estimated that the cost of absorption heat pumps could reduce by 20-33%, which could bring the products in line with hybrid gas heat pumps.

However, even at this price, the technology would still be at least twice the price of a typical gas condensing boiler installation.

Adsorption domestic heat pumps units are relatively new and are expected to be significantly more expensive than electrically powered heat pumps. There is scope to significantly reduce the product cost. However, in the foreseeable future, several stakeholders did not see adsorption technology being competitive in the UK market.

9. Barriers to deployment

While the heat pump technologies considered in this study help to mitigate some of the traditional barriers to the wider uptake of standard heat pumps, it is not clear that the benefits are sufficient to overcome the significant obstacles to their widespread uptake.

The findings on barriers are presented through highlighting some of the key barriers to standard heat pumps followed by whether each of the technologies exacerbates or alleviates this barrier.

We then explore other barriers to deployment that are faced quite uniquely by one of the technology types and look at the reasons for this.

Key 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. While prices have become more competitive, the cost of the three technologies examined in this report remains significantly higher than the total installed cost of a boiler, and in most cases more expensive than a standard heat pump.

Installed costs for high temperature heat pumps tend to be 10-20% more expensive than standard heat pumps.

Gas heat pumps are also expected to be significantly more expensive than standard electric heat pumps when first launched in the UK, although costs may come down significantly as scale increases.

Hybrid heat pump systems, especially add-ons to existing boilers, can be lower cost than standard heat pumps, due to smaller size of heat pump needed, and reduced need to upgrade radiators. For an add-on hybrid, the cost could be one third lower according to our estimate.

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)'[28].

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

High temperature heat pumps have an advantage over standard heat pumps in this regard because consumers in the UK are used to a heating system that delivers high water temperatures to the radiators when required (due to the prevalence of gas boilers), as well as providing hot water effectively.

Similarly, positioning hybrid heat pumps as an extra piece of equipment attached to the boiler, to make it cheaper and more efficient, could help to gain consumer acceptance.

Gas driven heat pumps also have an advantage in this area because consumers are comfortable with the concept of heating systems that use natural gas as the fuel.

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

In general fewer demand-side interviewees, such as housing associations and housing developers, were familiar with high temperature, hybrid or gas driven heat pumps than with standard heat pumps. This is an area where the new technologies have additional barriers to overcome.

Space constraints and planning permission

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 high temperature heat pumps, this barrier can be more significant as their larger size and higher noise levels mean that these restrictions must be considered more carefully to ensure compliance. Similarly this is a more significant barrier for gas heat pumps, as the space requirements for these units are generally higher.

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

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

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

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

Uncertainty over performance/savings

A barrier for standard heat pumps, which is exacerbated by high temperature, hybrid and gas driven heat pumps is the uncertainly of in use performance.

Laboratory performance metrics can never be fully reflective of in-use performance and it is difficult for consumers to calculate savings. For standard heat pumps this is a moderate barrier. Since 26th September 2015, the Ecodesign Directive has stipulated that seasonal performance data for heat pump units must be published and readily available to consumers. However, currently we have found this data is difficult to locate and the level of technical knowledge required to use this performance data is high.

For high temperature heat pumps, the impact of this barrier is greater, as the Ecodesign Directive stipulates that performance data must be recorded at an output temperature of 55˚C but for high temperature heat pumps the performance at 65˚C is more relevant.

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.

As domestic gas driven products are new to the market, it is also difficult to predict what in-situ performance is likely to be.

High electricity price / low gas price

The extensive gas network and relatively high cost of electricity per unit of energy compared to gas in the UK is a major barrier for standard heat pumps as it means that in-use cost savings from heat pumps are potentially lower compared to other countries[31]. Volatility around energy prices adds to uncertainty around savings.

This barrier remains for high temperature heat pumps but is partly overcome with hybrid heat pumps as the system can switch between the gas boiler and the electric heat pump to achieve the most cost effective means of generating heat.

Gas heat pumps should always generate some savings relative to a gas fired boiler.

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

Appendix A

A comprehensive list and brief description of relevant technical standards can be found in Table 10 below.

Table 10 List of relevant 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.

Standard/Regulation	Comment
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.

Standard/Regulation	Comment
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).

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