GAS DRIVEN HEAT PUMPS: MARKET POTENTIAL, SUPPORT MEASURES AND BARRIERS TO DEVELOPMENT OF THE UK MARKET

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November 2013

Contents **Page**

SUMMARY

State of the art

There are currently two domestic or near domestic gas heat pumps available in the EU. One is a nominal 38 kW ammonia-water machine manufactured by Robur in Italy and badged by a number of manufacturers. The other is a 10 kW water-zeolite adsorption unit made by Vaillant in Germany. Viessmann has a similar adsorption machine about to go on the market and is working on a second generation absorption machine that is physically much smaller. Other companies are working on gas-fired domestic heat pumps but are at an earlier stage of development.

Short term market

The largest potential market for gas heat pumps is the UK. Gas heat pumps have the potential to take a share of the boiler replacement market which is around 1.4 million p.a. and of which 30% are system boilers rather than combi boilers. The route by which boilers pass from manufacturer to private householder is dominated (79%) by contractor/installers who buy from builders merchants and this must be the target route if there is to be a widespread uptake of gas heat pump technology. Important factors for the contractor/installer are:

- Familiarity with boiler (installed them before, received training from manufacturer, accredited installer)
- Easy and quick to install (weight/ fittings). Must be a 'one man fit'.
- Good back-up support from manufacturer should there be a problem e.g. spares available

The consumer's main concerns are capital cost and efficiency. The limit on payback time for the average consumer is about three years. The new build or major refurbishment market is smaller than the retrofit but still significant (175,000 p.a.). In this case the contractor/installer has much less influence and codes / regulations play a greater role.

Barriers

Specifier/Installer training is an important issue. MIS 3005 is being adapted for gas heat pumps and future products may not be so demanding in terms of installer competencies.

Consumer behaviour is an issue, the UK consumer being wary of new technology. Capital cost is also important and inclusion of gas heat pumps within the RHI could tackle both issues.

Safety and noise, whilst of obvious importance are not seen as the main challenges.

Support measures and standards

Inclusion in the RHI with a suitable tariff is the most appropriate and effective means of support available. EN standards (safety and performance) for gas heat pumps exist and are presently being improved. The MCS is defining a minimum acceptable level of performance, together with the methodology for calculation. Eco-Design for Energy Using Products (EuP) standards are still in the process of being drawn up.

Long term markets

Work on scenarios to 2050 suggest that gas may still have a place in the longer term and that (used in gas heat pumps) it might find most use in older and larger dwellings.

1. INTRODUCTION

1.1 Technologies

In the past there have been many approaches to the provision of gas driven heat pumps that have reached varying stages of development. Most, but not all, have not gone beyond RD&D to commercial launch. Systems can be categorised as engine-driven or sorption.

Engine driven systems can range from conventional gas fuelled engines driving conventional vapour compression heat pumps to novel engine types, sometimes combined with novel heat pump cycles. In the past, extensive research went into Stirling-Stirling, Rankine-Rankine and other concepts. Whilst some of the more adventurous ideas may still have some potential, the only ones to survive today as commercial systems are conventional engine types (spark ignition or diesel) driving conventional heat pump cycles via open compressors and recovering engine waste heat as useful output. The vast majority of these systems are sized for larger buildings (30kW +) where a strict maintenance schedule can be enforced and economies of scale work well. There are four major manufacturers, all Japanese, and European sales are estimated at around 10,000 in total [1]. Sales in Japan are an order of magnitude higher. The focus of this work is on domestic applications perhaps extending to light commercial, a size range less suited to the complexity and maintenance of engine driven systems, although in Japan there are domestic products championed by Osaka Gas. Within the EU there is consensus that the way forward for domestic units is through sorption systems.

1.1.1 Absorption, adsorption cycles

What all sorption systems have in common is that they use the ability of a liquid or solid sorbent to ab/adsorb large amounts of refrigerant to be used in a ‘thermal compressor’, analogous to the mechanical compressor in an electric heat pump. The refrigerant is ab/adsorbed at a low pressure and temperature, then the sorbent is heated (in our case by burning gas) and the refrigerant is then driven out (desorbed) at high pressure. The fundamental thermodynamics are the same whether the refrigerant gas is being absorbed into a liquid or adsorbed into a solid. There are engineering advantages and disadvantages in using solids or liquids but neither is inherently ‘better’ and the choice of one or the other in a particular application will depend on the way they are implemented and the resulting efficiency, cost, size, etc.

1.1.2 Refrigerants

The refrigerants used by either absorption or adsorption cycles need the same characteristics (high latent heat being the major one) and the three main refrigerants considered for both are the same: water, methanol and ammonia. Water has the highest latent heat by far and so for the same complexity and cost of machine gives higher COPs [COP is defined as heat output to load / Heat input from gas. This varies with both the ambient temperature and the delivery temperature but a seasonal average can be calculated for a specific climate and heat delivery system, e.g. underfloor heating, radiators]. Given enough clever design and extra heat exchangers etc the performance of the other refrigerants can be as good but this is at the disadvantage of higher capital cost. Water also has the benefits of low cost, being non-toxic, environmentally friendly etc but has one major disadvantage; its very low operating pressure. From a practical point of view it is not possible to boil water in the evaporator of a heat pump at less that about 5°C, when the pressure is less than one thousandth of atmospheric pressure. In the case of an air source heat pump this would restrict the ambient temperature at which any heat pumping could be carried out to more than 10°C which is clearly not sensible. Manufacturers currently working with water as a refrigerant [see below] either have to use the ground (which is warmer) as a heat source or even use solar energy. Both of these result in much higher capital costs and whilst they may have a niche market are not seen as having a large impact in the UK. Where water absorption comes into its own is gas fired air conditioning, where evaporating temperatures are higher and it is generally the system of choice.

Ammonia has much lower latent heat, but none of the other disadvantages of water. It is the refrigerant of choice in large industrial systems, is not a global warming or ozone depleting gas and can be used at ambient temperatures below -20°C. Its higher pressure allows smaller pipe sizes thereby reducing cost. Its disadvantages are that it is chemically incompatible with copper or brass and that it is toxic, however neither of these problems is insurmountable and existing regulations govern the design of refrigerators or heat pumps that use ammonia refrigerant.

Methanol is (in pressure terms) between ammonia and water and although methanol based systems are well below atmospheric pressure is should be possible to use it to extract heat from ambient air at around 0°C. It is environmentally friendly but has the disadvantage that it decomposes at temperatures beyond about 120°C which could be problematic. High efficiency systems tend to need heat input from the burning fuel at higher than 120°.

1.2 Existing and near market products

There are at present two products on the market with a third close to market and two others at an earlier stage of development. All are being developed or sold by European companies.

1.2.1 Vaillant [Information from Ref. 2]

The Vaillant system uses water as the refrigerant, together with a zeolite adsorbent and consists of the heat pump itself, a solar collector which acts as the low temperature heat source and a water storage tank. In summer the solar collectors can provide domestic hot water. It is only intended for use with underfloor heating systems with maximum output temperature of 40°C and under these conditions has a claimed reduction of annual energy use of 18% when compared with a condensing boiler. In principle it could also be used with fan convectors with a flow temperature of 40°C but perhaps requiring twice or more the wall area occupied by heat emitters compared with conventional radiators supplied by a gas boiler. The initial system sale price was around €16,000.

Heat pump

Water storage

Solar collector

Technical data of zeoTHERM VAS 106/4

Rated heat output range Heating 1,5-10 kW
Rated heat output range d.h.w. 4,2-12,5 kW
Adjustable flow temperature 20-75 °C
Recommended max. flow temperature HC < 40 °C
El. power consumption max. 100 W
Appliance width 772 mm
Appliance height incl. flue outlet 1.700 mm
Appliance depth 718 mm
Transport weight (without casing) 160 kg
Operating weight 175 kg
Integrated controller
zeolite module > no moving parts / no maintenance

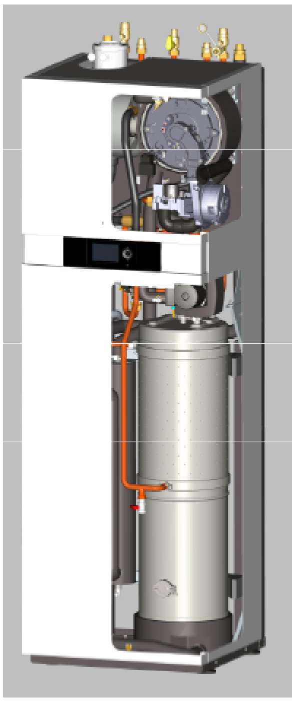
1.2.2 Robur [Technical data from Robur literature, Reference 3]

The Robur product is an ammonia water absorption heat pump (i.e. ammonia refrigerant, water absorbent) which offers air, water and ground source options. It is a development of technology previously used for air conditioning and thus is comparatively mature. The present air source machine can deliver domestic hot water at 65°C (gross COP 1.24) and will supply 38 kW to radiators (supply temperature 50°C) with a COP of 1.52 (gross), 1.38 (net). This represents a saving of about 40% in gas consumption compared to a condensing boiler. The unit is a single module intended to be positioned outside the heated building and 854(w) x 1256(d) x 1281(h). An 18kW unit, more suited to typical UK dwellings is under development. The product is ‘badged’ by a range of manufacturers including BDR Thermea and Bosch and the cost of the 40kW unit is c. £12,000.

1.2.3 Viessmann

a) Viessmann have a water-zeolite system intended for ground heat source and underfloor heating only and is very similar in concept to the Vaillant product. It is currently undergoing extensive field trials. The details below are from [4].

Viessmann Gas-Fired Zeolite Compact Heating Appliance
Features at a glance



- Hybrid Heating Appliance:
  Heating Power Modulation: 1,6 to 10 kW (1 to 7)
  Booster capacity for DHW: 15 kW
- SGUE Heating (VDI 4650-2): 135 % (Hi 35/28 °C)

  SGUE Heating (VDI 4650-2): 125 % (Hi 55/45 °C)
- Ambient Heat Source: 2013 GHS

  From 2014 also Solar
- Working pair completely environment friendly
- Installation, maintenance and service analog to condensing boiler compact units
- Gas-Fired Adsorption Heat Pump in the dimensions of Viessmann compact heating appliances
- Dimensions: BxHxT: 600x595x1875 mm
- Weight : <170 kg (separable in two parts)

Fuel savings are claimed to be 20-25% compared to a condensing boiler.

b) Viessmann also have an absorption heat pump (Vitosorp 300) at a much earlier stage of development but few details are available. It again uses a ground source but has improved performance and is physically much smaller. It probably uses methanol as the refrigerant and Viessmann hope to be able to produce an air source machine at a later data.

Viessmann Gas-Fired Absorption Heat Pump
Features at a glance

- Wall mounted hybrid appliance:

  Gas-fired absorption heat pump and a condensing boiler
- Seasonal heating GUE > 1.4 (55/45 °C)
- Seasonal heating GUE > 1.3 (65/50 °C)
- High modulation range (1.6 to 14 kW)
- Dimensions: BxHxT: 600x595x900 mm
- Weight : <90 kg
- Low noise
- Installation & Maintenance comparable to condensing boilers

1.2.4. Sorption Energy

The company (of which the author is a director) is a university spin-out developing an ammonia-active carbon adsorption heat pump. The concept is based on research carried out at the University of Warwick. The product envisaged would consist of an indoor unit of comparable size to a condensing boiler and an external air source evaporator. Emphasis is being placed on the need for low capital cost, low maintenance and installation by non-specialist personnel. Targets include 30% savings on gas consumption and a better than 3 year payback.

1.2.5. Other developments

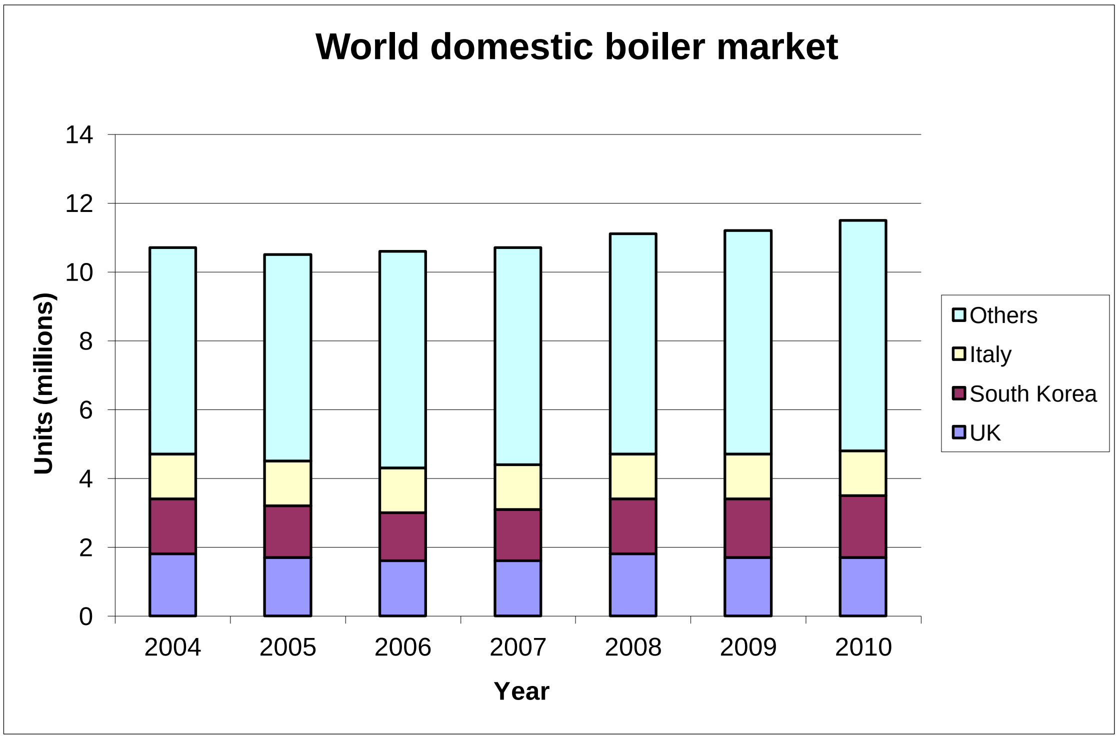
There are at least two other companies developing products in Germany and in the Netherlands.

2. MARKET POTENTIAL IN THE SHORT TERM

The information presented below is largely adapted from studies [5,6] carried out for Sorption Energy on the market for its heat pump concept, plus the report by Delta-ee [7]. The premise is that in the short term gas heat pumps must compete with condensing gas boilers rather than electric heat pumps and that any system that has the potential for major impact must be suitable for retrofit and be air source. Whilst ground source and new-build may be important niche markets, they are dwarfed by the market size of the retrofit market.

The world domestic boiler market is estimated at between 10 and 12 million units per annum. This includes all fuels: gas, oil and electricity. The UK is the biggest market in terms of volume and value, followed by South Korea and Italy. The UK is unusual within Europe in the extent of its gas infrastructure reaching 85% of households. In many other European countries, with less developed gas infrastructure, fuel oil and electricity tend to be used for space heating.

The size of the UK market is around 1.5 million domestic boilers units per annum and the figure below gives data to 2006 and projections thereafter. UK sales were 1.4M in 2012 [8]



Source: Ref. 6

The gas infrastructure is crucial to the market:

Country	Mains gas infrastructure	Attractiveness for gas heat pumps
UK	85% homes have mains gas. Virtually all homes on mains gas will have a gas boiler for central heating and hot water. Population 63m	High
Italy	50% of homes with mains gas. Italy is the biggest market for commercial gas powered heat pumps which are used widely in hotels/ hospitals etc. Robur S.p.A. is largest producer of these units and is Italian. Population 61m	High
Germany	50-55% of homes have a gas connection. 31% of homes are part of a collective (between 70-500kW) or District (500kW+) heating scheme. Some of these schemes will be gas powered (and may well be gas powered heat pumps. Germany feels very exposed with its reliance on Russian gas and is favouring other fuels. Germany does however tend to be far more open to new technologies than the UK. Population 82m	High
Netherlands	Similar market to UK with very high proportion of homes with mains gas. Population 17m.	High
South Korea	South Korea is large market for domestic boilers and also a market where underfloor heating is the norm. Gas infrastructure in place to majority of homes (pop. 50m)	Med/High
Poland	45%-50% of homes have mains gas which comes from gasification of coal. Population 39m	Med
France	Domestic heating is primarily electric powered. Population 63m	Low
Spain	Minimal domestic heating or gas. Population 47m	None
Scandinavia	Space heating is primarily electric heat pumps, mostly air to water. Population 25m	Low
US	Minimal domestic gas infrastructure. Space heating is primarily oil/ electric. Population 314m	None

The vast majority of UK homes have gas boilers installed.

UK housing stock Source: Housing and planning statistics, 2010 (latest issued statistics with cumulative totals to 2007)	**2007**	**%**	**UK boiler installations*** Source: Policy Brief: Improving the energy performance of domestic heating and hot water systems, July 2008, DEFRA	**# units installed**	**%**
Owner occupied	15,449	70%	Non-condensing gas boilers	17,645,000	**80%**
Privately rented	2,866	13%	Condensing gas boilers	3,205,000	**14.5%**
Rented from registered social landlord	1,886	8%	Non-condensing oil boilers	1,179,000	5.3%
Rented from local authority	1,967	9%	Condensing oil boilers	27,000	0.2%
Total	**22,189**	**100%**		**22,056,000**	**100%**

*note that these numbers date from 2008. Data from HHIC [9] indicates that in 2013 approximately half the UK's 26 million homes have condensing boilers.

Around 1.4m gas boilers are sold in the UK. The majority are unplanned, and a direct (i.e. similar form factor gas condensing boiler) replacement is required.

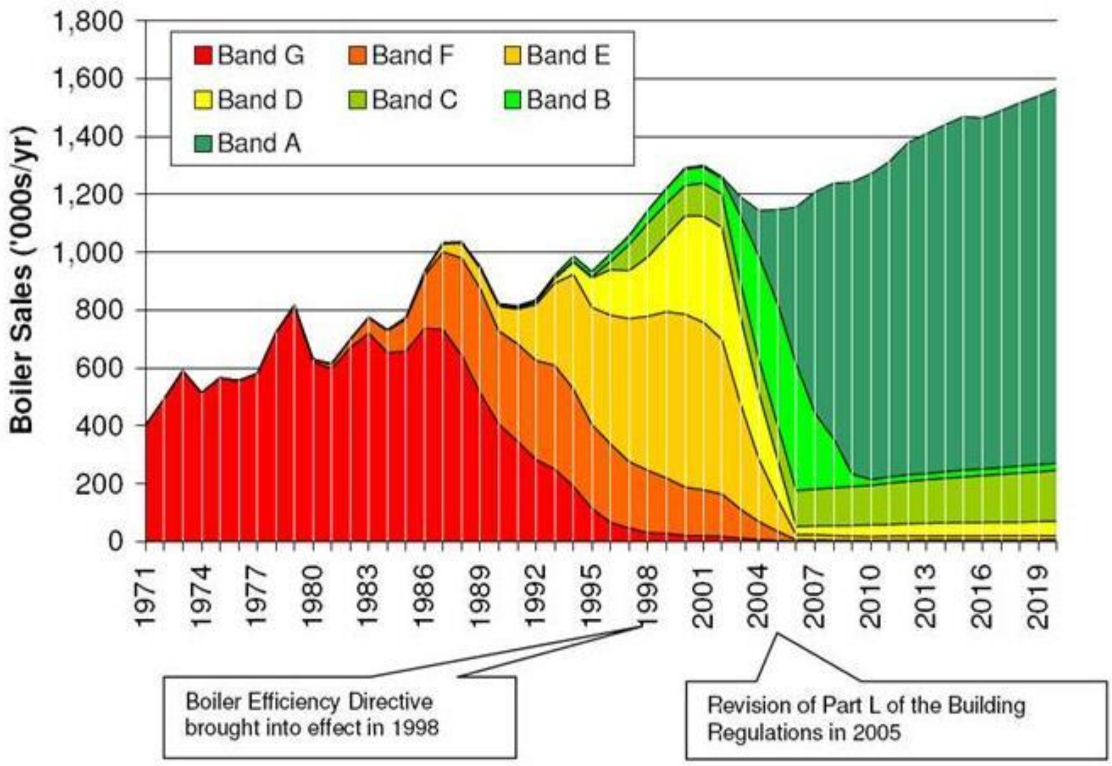
Segment	**Driver of purchase**	**Estimated annual sales, (000s)**
Private housing		
Boiler replacement	Most gas boilers are not replaced until they go wrong and not worth or possible (due to availability of spares) to fix them. Replacements are therefore	c.1,100

	often unplanned expenditures Gas boilers currently have a life expectancy of 10-15 years Boilers are simply replaced with a gas fired condensing boiler of similar form factor. Choices are vented/ unvented/ combi. System boilers represent about 30% of sales and this is this initial target market.	
New build	With new build there are more choices to consider for space heating including heat pumps, biomass, solar thermal. Necessary to meet Code for Sustainable homes which will influence decisions	c.150
Social housing		
Boiler replacement	Social housing tends to have asset management plans where boilers are automatically replaced after c.15 years. Deals will be in place with boiler OEMs for provision of boilers	c.225
New build	Need to meet code for sustainable homes. Wider choice of options than with replacement market	c.25
Total		**c.1,500**

Source: Ref. 6

It is clear that the largest opportunity is retrofit into private and social housing and so we need to identify the mechanisms that influence choice of technology.

Historically, regulation has driven technology uptake, witness the adoption of Band A condensing boilers influenced by building regulation:



Source: Ref. 10

The route by which boilers pass from manufacturer to private householder is dominated (79%) by contractor/installers who buy from builders merchants and this must be the target route if there is to be a widespread uptake of gas heat pump technology. In private replacements, the installer / contractor generally has most influence over the boiler selected as he advises the householder. The factors that influence the installer / contractor are:

- Familiarity with boiler (installed them before, received training from manufacturer, accredited installer)
- Easy and quick to install (weight/ fittings). Must be a ‘one man fit’.
- Good back-up support from manufacturer should there be a problem e.g. spares available
- Performance/ reliability (if the boiler breaks down it will be under warranty (2 years generally) from the manufacturer, but the installer will be called back).
- Incentives: manufacturers sometimes give vouchers to installers for each boiler installed.

A contractor would be unlikely to recommend a heat pump system unless he/she were able to install it.

The householder obviously has some influence over choice of system but tends to be less well informed. Factors influencing choice are:

- Capital cost (can be important if an unplanned / distressed purchase). [Note that RHI might mitigate additional capital cost]
- Performance efficiency is a factor for gas boilers, with all top boilers having 89-90% efficiency in lab tests. In the field, DECC estimates 85.3% for system boilers and 82.5% for combis [Energy Saving Trust, Final Report for DECC, Insitu monitoring of efficiencies of condensing boilers and use of secondary heating, Contract Number GaC3563, © GASTEC at CRE Ltd 2009]. Reliability information sits with the installer.
- If anything other than simple condensing boiler is suggested then payback likely to be important. Base point is a standard condensing gas boiler (£1800+VAT, incl installation).
  - Baxi rule of thumb is that any additional capital cost needs to pay back in three years for mass market product (note: households move on average every 6 years); payback up to 10 years for more niche product (e.g. targeted at larger households who tend to stay in their home for a long period)
- Availability of finance – to cover capital cost can help influence decision
- Physical size/ noise
- Advertising/ brand: There has been some but limited brand building
- Recommendation from friend

Social housing replacements will be determined by the provider's purchasing manager and decisions are based on 'best lifetime value'. Deals will be in place with OEMs. Large social housing groups generally have one or more boiler brands which they have selected as 'preferred' for installation. The small range of boilers means they are not completely reliant on one supplier, but also do not have a large variety of boilers installed which would be more expensive and complex to maintain. Decisions are made on 'best lifetime value' ie. minimising capital cost / installation cost plus lifetime maintenance costs. They look to achieve good performance in order to ensure 'Decent Homes' standard and not have reduction in SAP value. Since benefits of high efficiency do not accrue to housing association, investing in more expensive/ higher efficiency boilers would be difficult unless also 'best lifetime value' (which is most likely if RHI has a big impact)

The new build or major refurbishment market is smaller than the retrofit but still significant (175,000 p.a.). In this case the contractor/installer has much less influence and codes / regulations play a greater role.

	Decision/ recommendation criteria
Developer Householder (for major refurb)	• Best value investment criteria. • Sustainable credentials make a home more marketable • RHI will influence decisions
Architect/ heating specialist	• Meeting code for sustainable homes • Underfloor heating is often attractive to architects for new build/ major refurb which allows more efficient use of heat pumps

To summarise, private new build and retrofit homes are best target markets. Retrofit is by far the largest market and essential if gas heat pumps are to become mass market.

The payback times depend on the size of house and comfort standards since in the domestic range the capital cost of the heat pump is not strongly dependent on the nominal power output. Assuming economies of scale in production, payback times of 3 years seem feasible for larger houses and perhaps 5 years in smaller ones. RHI could improve the situation and make gas heat pumps a very attractive replacement for conventional gas boilers, depending on how it might operate. Initially it would be sensible to target larger owner occupied homes (4 bed+, 3m homes or 12% of the total) where residents tend to have longer investment horizon.

In private new-build (150,000 p.a) gas heat pumps will be most efficient with lower temperature water output. This requires a well insulated home with modern radiators or underfloor heating. This means it is well suited to a new build or major refurb.

Regarding the percentage of market penetration, one gas boiler industry estimate, given the assumption of a competitively priced product was 0.5% in year 1 rising to 4 % in year 3.

3. BARRIERS TO DEVELOPMENT

3.1 Specifier/Installer training

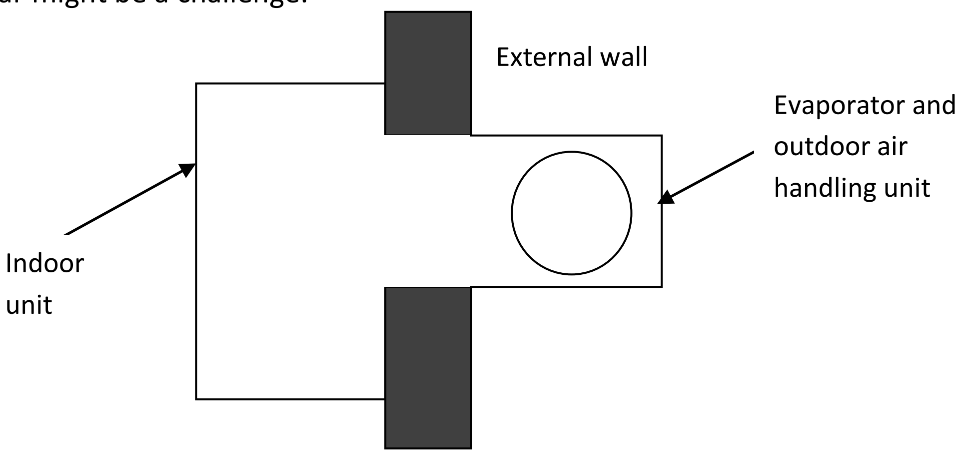
Given the difficulties that have been seen with specification and installation of electric heat pumps there are obvious pitfalls regarding poor choice of system, controls, etc. Discussions with boiler manufacturers and utilities have lead to the conclusion that it is technically feasible and also necessary that gas heat pumps should be 'black boxes' that can be fitted by a Gas Safe technician without specialist training beyond a one-day familiarisation course.

Where a product is unitary, consisting of an outdoor module that only needs water, gas electricity and control connections, this is straightforward. The Robur absorption heat pumps currently on the market are in this category and they do not need to be installed by a refrigeration engineer. The current situation is that Robur or the companies marketing their machines will provide their normal installers with training but that the refrigeration system is factory sealed and not to be tampered with. The refrigerant is ammonia and so for safety reasons the heat pumps are only manufactured as outdoor units. A smaller ammonia heat pump than the Robur unit might have a low enough refrigerant charge meet the regulations for use within a building, currently 2.5 kg for a sealed system [11].

The Vaillant and Viessmann heat pumps using water as a refrigerant must be hermetically sealed to prevent air leaking into the system and stopping it working. This also demands a single unit but for the German market they are designed as indoor units within cellars.

If the product is a split system with indoor gas-burning appliance and outdoor air source evaporator there are more challenges. 'Quick connect' refrigeration lines, pre-charged with refrigerant and using elastomeric O-ring seals were used in the past on split systems but are inherently a weak point liable to leakage. They are likely to be unreliable and making any refrigeration connection without use of specially trained fitters is not recommended. Possible technical solutions include:

1. 'Through the wall' unitary devices in which the outside evaporator has to be inserted through a sufficiently large hole in an outside wall (typically 450 mm square), as below. Designing a system to be installed by one person without lifting gear might be a challenge.



2. Ensuring that all refrigeration circuits are hermetically sealed and in the outside unit. The only connections through the wall would be tubes containing heat transfer fluid, water, exhaust flue and electrical wiring. The gas burner and heat exchanger would be within the building as in a conventional gas boiler. Manufacturers do not seem to regard this as a problem and do think that a split system is more marketable.

Controls need to be smart enough to look like normal gas boiler controls but to optimise operation in response to weather and demand automatically.

Standards for electric heat pump installations are in MIS 3005 [12], which covers all areas of supply, design, installation, etc. MCS is in the process of producing a similar standard, version 3.2 including gas heat pumps and indications are that they will include all competencies needed for electric heat pumps, plus skills needed for gas systems. If gas heat pump products are developed that do only require gas boiler competencies then a future relaxation might be appropriate.

3.2 Consumer Behaviour

UK consumers are well known to be conservative with respect to new technology and are therefore less likely to switch to new space and water heating systems unless there are clear incentives, such as grant support, to encourage investment in new systems or economic advantages that can be realised in the relative short term. Ref [5] even suggested that in the UK a sorption heat pump should be sold as a 'super-efficient boiler' rather than as a heat pump in order to avoid scaring customers with new technology. The situation in Germany would of course be reversed.

The table below show the results of a survey conducted in 1999 [13] into domestic heating and why consumer switched their heating systems.

Reason for new installation	Percentage
Fault or breakdown	49
Old installation probably going to break down	14
Reorganisation due to other building project	7
New requirements	7
New kitchen	6
No heating before	6
Efficiency concerns	4
Safety	2
Extension	2
Wasting money concerns	1
Comfort/Level of service concerns	1
Other	3
	100

Only approximately four to five percent of replacements are motivated by concerns over the efficiency of the old systems.

3.3 Safety

Safety issues, other than those already encountered in gas boilers, are mainly related to the refrigerant used. Water presents no hazard and methanol only the most insignificant concerns. However, ammonia is a toxic gas and all refrigeration systems using ammonia are tightly regulated. The existing Robur heat pumps are unitary with the heat pump placed outside the dwelling and they meet all regulations. In the worst case of the ammonia charge venting to the outside air there is inconvenience but no danger. In the case of a split system using ammonia containing components within a building there would need to be a failsafe system to ensure that in the case of overpressure (for example, due to a house fire) or corrosion and rupture of a component, the ammonia could only escape to the outside of the building and if necessary, be absorbed by a surrounding blanket of suitable material. In some respects the challenge is similar to the safety issues relating to gas escape and explosion in conventional boilers; the issues are soluble with suitable regulation and appropriate engineering design.

3.4 Capital cost

Ref [6] suggests that for a mass market consumer product, the payback should be 2-3 years and that for a more niche market 5 years is acceptable. The Delta-ee study [7] suggests that for a typical heat demand of 18,000 kWh per year the savings would be more than £300 / year even with conservative performance estimates. Assuming no difference in installation or maintenance costs and no Green Deal or other incentive it can be seen that the excess cost of a gas heat pump over a condensing boiler should ideally be no more than about £750 but that up to £1500 would still feed a niche market. The present 40kW Robur unit costs around £12,000. A scaled down version produced in larger numbers would presumably come closer to the target but only Robur could estimate how close. Sorption Energy (who are still several years from market) have studies by Capparo, Angle and Dynamiq suggesting the target is feasible but this has yet to be proven. For the UK market, capital cost is a more critical parameter than operating efficiency.

3.5 Noise

The major difficulty in eradicating source of noise in electric or gas air source heat pumps is the evaporator fan noise. Comparing an electric heat pump with COP 3 against a gas heat pump with COP 1.3 the gas heat pump has approximately one third as much heat to extract from the air. This could be achieved by having one third the volume flow rate with consequentially reduced noise.

Measurement of noise and existing standards and recommendations are discussed fully in the bpc report 'Acoustic noise measurements of air source heat pumps' [14].

The Robur 38 kW GAHP-A air to water heat pump [3], essentially a product for light commercial buildings, has noise data as follows:

GAHP-A noise levels		dB(A)
Sound power Lw measured according to EN ISO 9614	standard version	82.1
	low noise version - fan max/min speed	75.3/72.3
Sound pressure Lp at 5 metres, free field, at the front, direction factor 2.	standard version	60.1
	low noise version - fan max/min speed	53.5/50.3

3.6 Life/reliability

It is difficult to estimate the lifetime or reliability of new products such as these. Whether absorption or adsorption there are no components inherently subject to wear or corrosion if properly designed. As with all products there is a trade-off between capital cost and reliability and service life. Life should be at least ten years and there is no reason why it should not be twice that. Annual maintenance of gas burning components is recommended as it is with gas boilers but should be no more expensive, and would be combined with any necessary cleaning of the evaporator fins but all other components are hermetically sealed. Sorption systems using water as a refrigerant might prove to have a higher maintenance requirement. In principle it should be possible to prevent both ingress of air and to inhibit evolution of volatile gases into the refrigeration space that should only contain water in vapour or liquid form. However, in reality it might be necessary to purge any non-condensable gases on an annual basis. High pressure systems using ammonia or other refrigerant that is above atmospheric pressure can be sealed for life much more readily.

4. EXISTING SUPPORT MEASURES

4.1 RHI

Consultation for the domestic Renewable Heat Incentive is completed and tariffs have been proposed for heat pump technologies. The domestic RHI is due to launch in Spring 2014 and will therefore have an impact on heat pump deployment from that time onwards. As it stands gas-fired heat pumps are not included in either the domestic or non-domestic RHI, however their eligibility has not been ruled out for future revisions. [15, 16, 17]. The process in which new technologies, such as gas heat pumps, will be required to follow to become eligible for the RHI has also been laid out [18].

The RHI supersedes the Renewable Heat Premium Payment which provided up to £850 as a capital grant towards purchase and installation of an air to water electric heat pump.

The consultation for the domestic scheme includes air to water heat pumps. The tariff for domestic electric air source heat pumps is proposed to be 7.3 p/kWh. Eligibility depends on reaching a required level of energy efficiency and one acceptable criterion is accreditation of the product by MCS. MCS are currently looking at gas fired heat pumps and will shortly define a minimum GUE [Gas Utilisation Efficiency], and means of calculation, that should be met by products. Beneficiaries of the RHI will receive a quarterly payment lasting seven years to be paid to the owner of the renewable heating system [10].

4.2 Green Deal

The Green Deal provides finance for energy saving measures via the ECO (Energy Company Obligation). Electric air source heat pumps are eligible as part of the Affordable Warmth Obligation available only to low income and vulnerable households identified individually through benefits data. It is intended that measures are applied in a logical order so that feasible insulation would take priority over efficient heating systems so we could expect that gas heat pumps (if adopted) would tend to be in older, difficult to insulate, dwellings.

4.3 MCS

Electric air source heat pumps are covered by Microgeneration Certification Scheme: MCS 007 Product Certification Scheme Requirements: Heat Pumps Issue 2.0. This sets out minimum standards of performance such as minimum COP under standard conditions. These are referenced to EN 14511:2007 Parts 1 – 4 ‘Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling'. Without this, products are not eligible for Green Deal or RHI. MCS are in the process of issuing similar standards for gas heat pumps, based on a minimum GUE (based on higher calorific value and including electricity consumption) of around 1.15 and referencing to EN 12309. Parts 1-2 Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW.

4.4 Eco-Design for Energy Using Products (EuP) is the EU process for issuing regulations and energy labelling every device that uses energy as part of the drive to inform purchasers and users. The work on boilers and heat pumps was contracted to VHK (Van Holsteijn en Kemna). Their Task 4 Final report on Eco-design of CH Boilers (September 2007) gave a good technical analysis of electric and sorption heat pumps, system models, together with an extensive description of the different performance measures that can be used, their definitions, means of calculation etc. Recommendations for boilers (and heat pumps) were due to be completed in 2012.

5. MARKET POTENTIAL IN THE LONGER TERM

It is a commonly stated criticism of the concept of gas fired heat pumps that in the longer term there will be an all electric renewable energy system; electric heat pumps will be ubiquitous and there will be no place for burning fuel. Whether this is a likely outcome depends both on the ultimate technical potential of gas heat pumps and more difficult questions relating to the energy (electricity, gas, heat) supply grid and its development.

Seasonal COP's of present gas-fired systems range from 1.1 to 1.5, and the theoretical limit could exceed 3 but keeping within what might be possible in systems we can envisage now, a seasonal COP in the UK of 2.0 [Gross CV, air to water at 50°C] is certainly not unreasonable. Machines that can achieve these efficiencies will use thermodynamic cycles that are more complex, with cascaded temperature levels, improved heat regeneration, etc. and will probably be larger per unit of heat delivered. At the moment gas heat pumps must compete with gas boilers rather than electric heat pumps, but in the future we can imagine that they will have to compete more with advanced electric heat pumps and a COP of 2.0 might be necessary as well as desirable. The TINA Summary Report on Heat [19] suggested that 1.6 was a lower limit to be of interest in 2050.

DECC's document 'The Future of Heating: Meeting the challenge', published March 2013 [20] sees a future for gas heat pumps well beyond the 2030s. Points made include:

- Even condensing boilers have a major role in the 2030s.
- Based on the RESOM model, gas will still be used to provide heat in winter and, 'there will be no role for gas boilers in 2050. The ESME results suggest that gas absorption heat pumps (GAHPs) may be taken up as a more efficient solution.'
- 'The modelling is highly sensitive to the assumptions made on the costs and performance of technologies, including technologies which are yet to reach

commercial scale deployment such as hybrid systems and domestic GAHPs [gas (ab)sorption heat pumps]. However, the analysis does suggest that there is still no role for standalone gas boilers in 2050, with the least-cost path requiring us to begin to deploy more efficient gas technologies in the 2020s.

Figure 7, reproduced below, 'The updated strategic framework for low carbon heat in buildings over time' shows condensing boilers in use well into the 2030s, particularly in suburban areas and suggests that perhaps half will be replaced by 'more efficient systems such as gas absorption heat pumps', with the latter only diminishing in use in the 2040s.

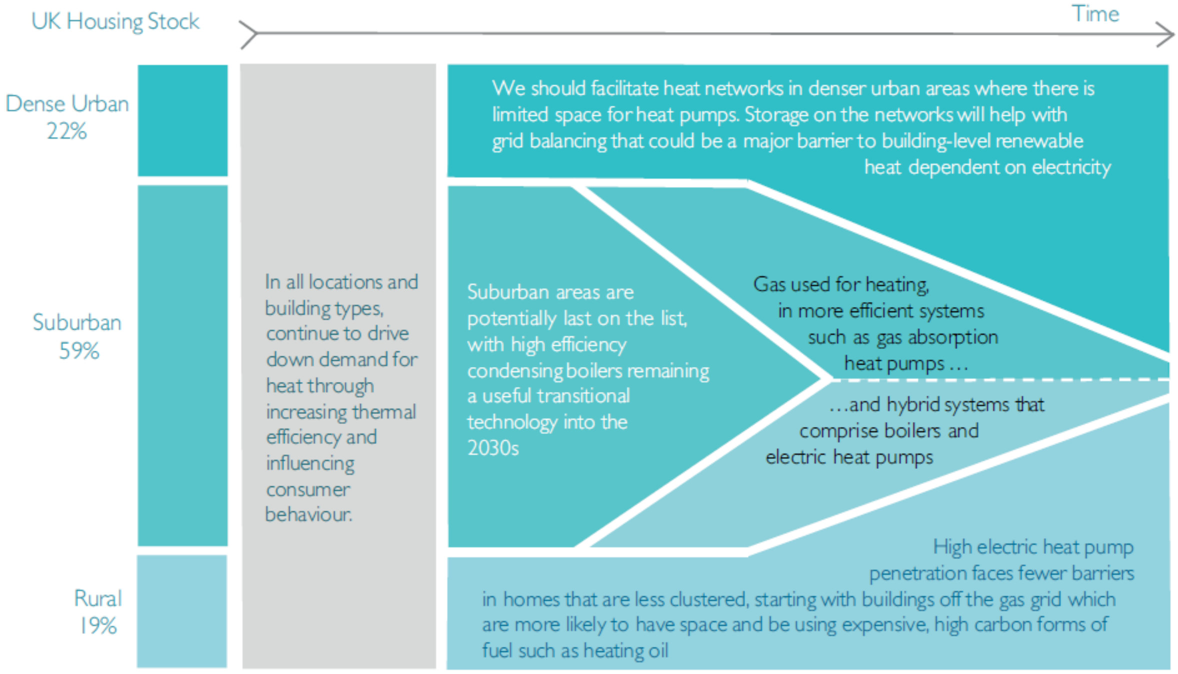


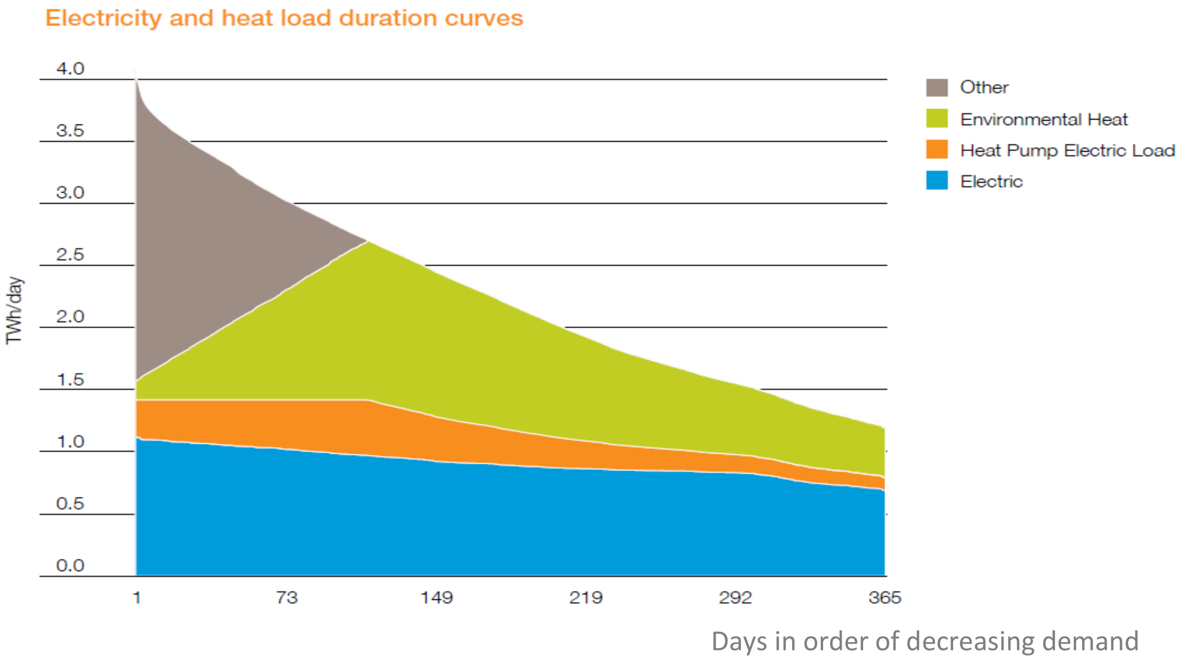
Figure 7: Updated strategic framework for low carbon heat in buildings over time [20]

Both the National Grid [21] and Delta-ee [22] have looked at scenarios for 2050 and beyond that encompass a role for both gas and electric heat pumps.

The National Grid GG (Gone Green) scenario with energy demand/duration mix as below shows that demand for heat is much 'peakier' than demand for electricity The bottom series shows demand for electricity excluding heating, which ranges from a maximum of 1,110 GWh/day to a minimum of 690 GWh/day (62% of peak daily heat demand). The remaining series represent heating load, which ranges from a maximum of 3,000 GWh/day to a minimum of 500GWh/day (17% of peak daily heat demand). The 'other' series includes gas, biomass and, for houses not connected to the gas network, oil. As a result of the large range in the heat demand it would be very difficult to electrify the entire heat load.

Electric heat pumps can be used to supply a significant fraction of the heat demand, represented by the orange and green sectors on the chart, with little requirement for extra electricity generation capacity, but in order to satisfy the entire load, filling the grey sector as well, it will be necessary to build between 100 GW and 150 GW of new capacity, most of which will run for half the year or less, with correspondingly unfavourable economics.

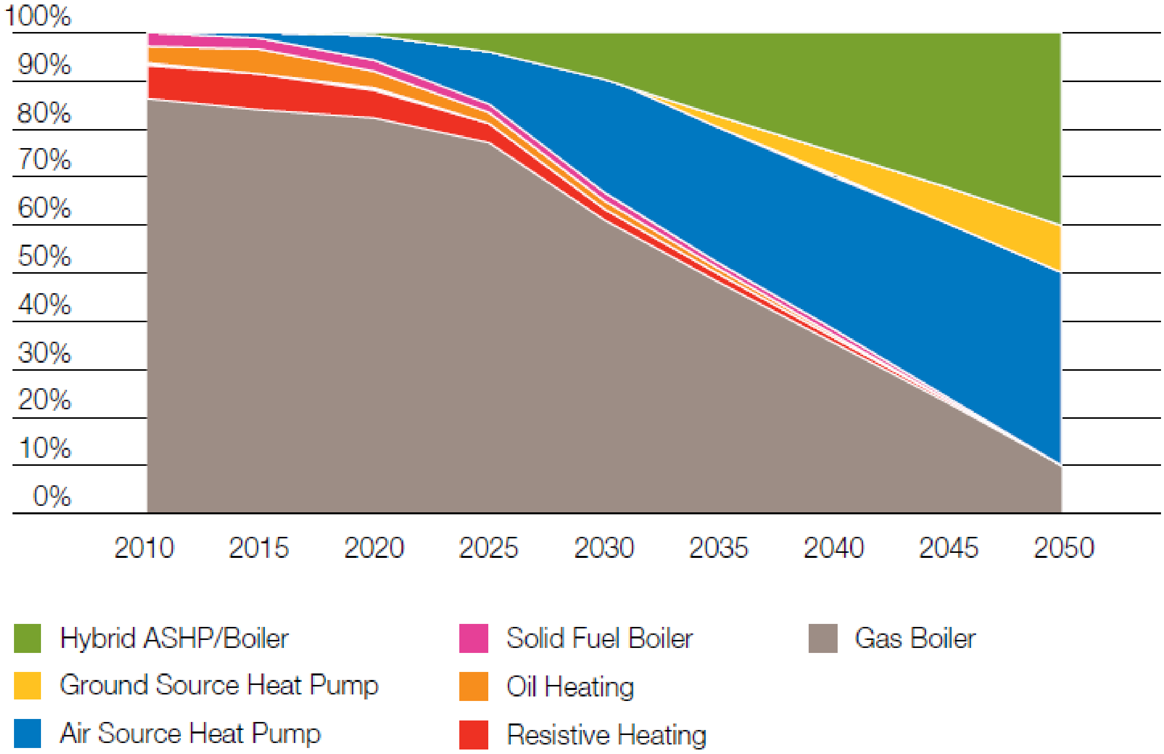
This assumes biomethane injection increases to 100TWh by 2050 as per Gone Green scenario. Electricity in heat pumps has higher carbon emissions than gas condensing boilers until 2015 and gas heat pumps can decarbonise heat quicker than electrification up to 2030. Dual fuel [Electric heat pump + gas or gas heat pump] can deliver similar carbon benefits to full electrification. The all electric solution needs a 100GWe capacity whereas a hybrid or gas heat pump mix needs only 13GWe. It is anticipated that gas heat pumps would be best used in older, larger, difficult to insulate properties with electric heat pumps in new build and smaller properties, apartments etc.



Source: Figure 9, National Grid, Future Energy Scenarios 2012 [21].

The breakdown of the evolving market is shown in Fig. 56 of the FES, below. In domestic and commercial premises there are marginal improvements in energy efficiency between 2030 and 2050 with most of the more cost-effective refurbishments of the UK's buildings being done by 2030. Between 2030 and 2050 most efficiency gains are made by the changing way heat is supplied in buildings with a shift to heat pumps for well insulated new properties with hybrid heat pump (gas or electric) and boiler systems being used in buildings in which the difference in seasonal heat requirements makes them less suited to be supplied by heat pumps alone. Note that gas boilers still make up some 10% of the mix in 2050, and that gas will also be used in the hybrid heat pump/boiler or gas heat pump systems.

Breakdown of the domestic heating market



Source: Figure 56, National Grid, Future Energy Scenarios 2012 [20]

Delta-ee's report, 2050 Pathways for Domestic Heat [22], carried out detailed modelling to 'provide a desk top study on the optimal appliance technology pathways, by property type, based on known and emerging heating technology, required to meet carbon and renewables targets, highlighting the impact on consumers (cost to change and behavioural) and the potential load changes on the gas and electricity distribution networks out to 2050'.
It developed a residential heat model that used a very detailed housing stock model, segmenting the UK housing stock into 35 segments. For each segment the thermal demand, and how this changes decade by decade to 2050 was defined.
It also used a technology performance model, forecasting future cost and performance of many appliances: gas boiler; gas heat pump; low electrical efficiency micro-CHP; high electrical efficiency micro-CHP; gas boiler + solar thermal; air source heat pump; ground source heat pump; hybrid gas boiler + air source heat pump; biomass boiler; district heating; direct electric (storage) heating.
Finally it combined these with a customer choice model that incorporated physical fit of different technologies with different parts of the housing stock; customer uptake based on payback and upfront cost; and customer attitudes to different technologies.

This residential heat model was used to determine the future appliance mix under three scenarios

1. Customer Choice – allowing the customer to chose based on physical fit, customer economics and attitudes

   Carbon reduction targets for the residential sector will not be met by a combination of reducing thermal demand allowing customers to chose their heating appliance (without government intervention). Even when strong progress is made on low carbon heating appliance cost and performance, and with 75 TWh of biomethane, carbon reductions (2040-50 compared to 2010-20) of only 46% are achieved. Gas boilers continue to be used in 19 million homes, based on their low capital & running costs & excellent fit with UK homes.

   Unsurprisingly, the Customer Choice scenario fails to meet the 2050 carbon reduction targets.

2. Electrification and Heat Networks – Delta-ee defining a pathway where these solutions dominate in 2050

   It assumes virtually all homes use either electric heating (heat pumps & direct electric) or heat networks, fed-by zero carbon heat. There is no role for gas. 96% reduction in carbon emissions (from 2010-20 levels).

3. Balanced Transition – Delta-ee developing a pathway where electric heating, heat networks and gas all play a role in 2050

   BT has an approximately even split across three heating types: (1) heat networks (dense urban areas & new build), (2) low carbon gas appliances (suburbia), (3) electric heating (some suburbia, rural and new build). This includes 75TWh of biomethane. There is a 90% reduction in carbon emissions.

The conclusion was that Balanced Transition can be achieved with less government intervention (and at less cost) than Electrification & Heat Networks, while achieving 90% (rather than 96%) carbon reduction from today to 2050.

High efficiency gas appliances, have lower running costs (and in some cases upfront costs) for certain parts of the housing stock than electric alternatives, in addition to easier retrofit into existing homes with gas boilers. This gives them stronger customer appeal, and potential for a lower level incentive.

In addition, a greater mix of technologies, has lower impact on the energy system – the addition of hybrid heat pumps and gas appliances to the mix, results in a additional peak electricity generation demand 50% lower than under E&HN, and district heat is focused solely on high density housing (rather than stretching into suburbia) limiting costs.

In summary the report suggests keeping a variety of options open. The scale of the challenge to decarbonise heat gives lower risks, and potentially a lower cost path than pursuing a narrower end point. Although BT achieves a 90% (rather than 96%) carbon reduction from today to 2050 it has two key benefits:

- It avoids moving an additional 12 million homes completely away from gas – where the highest customer costs are imposed.

- Lower impacts on the energy system -, additional peak generation demand grows to 24GW, rather than 48GW, as under E&HN. Costs (discounted, opex and capex) to re-enforce the electricity distribution network are €8bn lower. Part of the €4bn cost to shut down the entire gas network is avoided.

The message from all three sources (DECC, National Grid, Delta-ee) is similar; there should be a place for gas heat pumps in the longer term to 2050 in a balanced and sustainable yet affordable energy supply and utilisation system.

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