Heat Pumps in the UK: How Hot Can They Get?

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The EST field trials published in September 2010 provided the first performance data for real heat pump installations in the UK. The range of results indicates that while heat pumps have definite potential to make a significant contribution to the Government's energy efficiency targets, there is work to be done in ensuring they perform to this full potential.

This paper contrasts the EST results against trial results from Switzerland and Germany[1], markets which are more mature than the UK. The results show that air-source heat pumps in the EST trials perform less well than those in Swiss and German trials, and ground-source performed significantly less well, but we believe that gap can be closed.

UK Heat Pumps don't perform as well as Swiss and German installations – but the gap can be closed

Heat pump installations in the EST trial did not perform as well as installations in the Swiss and German trials, as shown by Figure 1 below:

FIGURE 1: OVERVIEW OF THE SPFS[2] ACHIEVED BY RESIDENTIAL HEAT PUMPS IN THE UK, GERMAN AND SWISS HEAT PUMP TRIALS

Some of the **air source heat pumps** in the UK trial were comparable with those in Germany and Switzerland, but many did not perform as well. For **ground source heat pumps**, the difference was much starker, with a large gap between the UK, and German and Swiss installations. N.B. As we discuss in the following section, we cannot directly compare *all* results from the three trials due to different building types and system boundaries being used.

	UK	Germany	Switzerland
Air source	60% of installations: SPFs **1.7 – 2.2** 30% of installations: SPFs **2.3 - 3.2**	Range of SPFs **2.3 – 3.4** Cluster of SPFs around **2.5 - 2.6** (retrofit) and **2.9** (new build).	Range of SPFs **2.2 – 3.0** Half the units in the range **2.5 – 2.8**
Ground source	Range of SPFs **<2.0 – 3.2** 30% of installations: SPFs **2.3 - 3.2**	Range of SPFs **2.6 – 5.0** Nearly all of which above **3.0**	Range of SPFs **2.7 – 4.0** Average SPF **3.4**

Source: Energy Saving Trust; Fraunhofer Institute ISE, Swiss Federal Office of Energy

[1] Thank you for the views and input of Jaryn Bradford (Energy Saving Trust, UK), Fabrice Rognon (Planair SA, formerly Swiss Federal Office of Energy, Switzerland) and Marek Miara (Fraunhofer ISE, Germany)

[2] Throughout the paper we refer to Seasonal Performance Factor (SPF) – effectively the average COP (co-efficient of performance) measured throughout the trial period.

In Delta's view **the gaps between UK and Swiss & German heat pump performance can be closed if there is a concerted effort – led by the heat pump industry - focusing on setting guidelines/standards for training and skills, and putting in place the framework to build skills of installers**. A number of UK heat pump players are already making such efforts.

Comparing the three trials

The three trials were all led by independent organisations - the Fraunhofer Institute ISE in Germany, the Swiss Federal Office for Energy (the ministry for energy) in Switzerland, and the Energy Saving Trust in the UK. Table 1 compares some key features of the trials.

FIGURE 2: COMPARING KEY FEATURES OF THE UK, GERMAN AND SWISS TRIALS

Note that due to differences in methodology between trials, the results are not completely comparable – due to the wider system boundary used in the EST trial, the UK results are likely to be lower (possibly by a SPF of around 0.1) than the other trials.

Other important differences to note, which may contribute to lower SPFs in the UK, are:

1. The German and Swiss heating systems are typically of higher quality than those in the UK (in terms of the quality of components and control system).
2. UK and German installations were providing a higher proportion of DHW than in Switzerland.
3. UK buildings were (broadly) of lower quality in terms of insulation / rate of heat loss.

These issues may have reduced achievable SPF in the UK by a few percentage points, but these factors alone are not sufficient to explain the UK trial's poorer results.

	UK	Germany	Switzerland
Timeframe	2008 - 2010	2006-2010	1994 - 2003
Number of systems	83 units: ▸ 54 ground source ▸ 29 air- water	Retrofit: 72 units ▸ 35 ground source ▸ 35 air- water ▸ 2 water-water New build: 100 units ▸ 68 ground source ▸ 26 air- water ▸ 6 water- water	236 units since 2000: ▸ 95 ground source ▸ 105 air- water
Type of building	New build and older existing buildings	New build (58%) and older existing buildings (42%)	New build (60%) and older existing buildings (40%)
Heat distribution system	High temperature radiators and low temperature under-floor	High temperature radiators (97% of retrofit installations) and low temperature under-floor heating (90% of new low energy home installations)	Primarily low temperature under-floor, plus some radiator systems (48% of the retrofit installations)
System boundary	Wider heating system including heat pump	Heat pump and electrical back-up heater	Heat pump and buffer/ storage tank
DHW provision	HP provides DHW in all installations	HP provides DHW in all installations	HP provides some hot water in half the units (22% of used the HP solely for DHW)

Source: Energy Saving Trust; Fraunhofer Institute ISE, Swiss Federal Office of Energy

For the **UK new build market**; **German units in new 'low energy homes', and most of the Swiss systems offer the best comparison**. This is because they operate at low flow temperatures (compared with traditional boilers/wet heating systems) – in most cases 50°C and lower. New build homes in the UK can be designed with similar low temperature heating systems (such as under floor heating which could have a flow temperature of 35°C).

For the **UK retrofit market – which makes up the lion's share of the EST trial sites - the most relevant comparison is with the German trial in retrofit installations**. The German trial installed heat pumps in buildings that had previously had a boiler serving 'standard' sized radiators designed for high flow temperatures (similar to most of the UK housing stock).

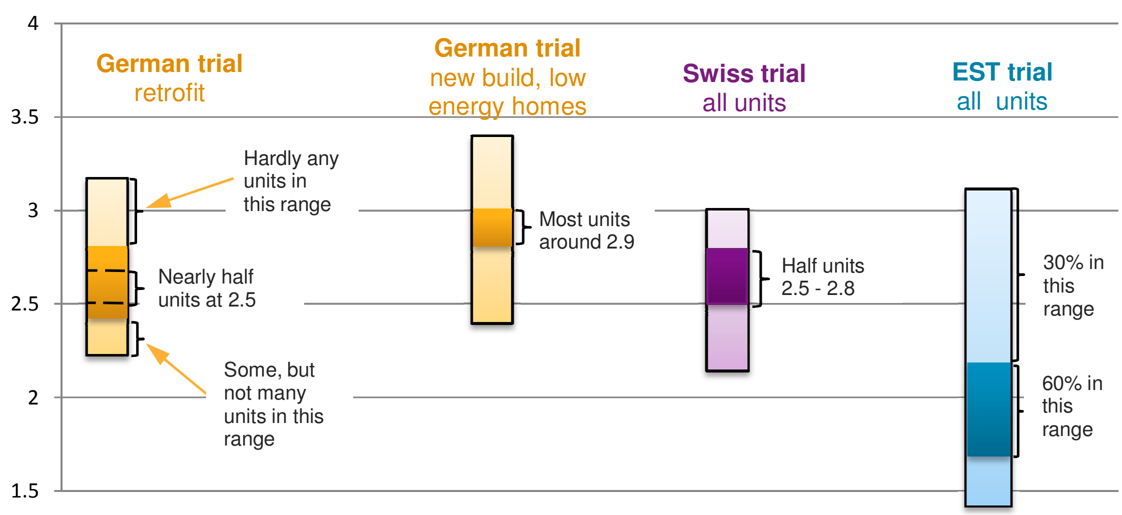
For the replacement market, the German trials show that better air source performance is possible

Existing buildings are the big prize for air source heat pumps. But replacing a gas or oil boiler with a heat pump has many challenges – in particular the mismatch between the heat pump's preference for low temperature water circulating around the heat distribution system, and the set up of the existing heating system for higher temperatures.

Figure 3 below shows that while there are some high performing UK units, on average German and Swiss units significantly outperform UK units.

FIGURE 3: COMPARING ASHP TRIAL RESULTS

We compare the Seasonal Performance Factors achieved in each trial.

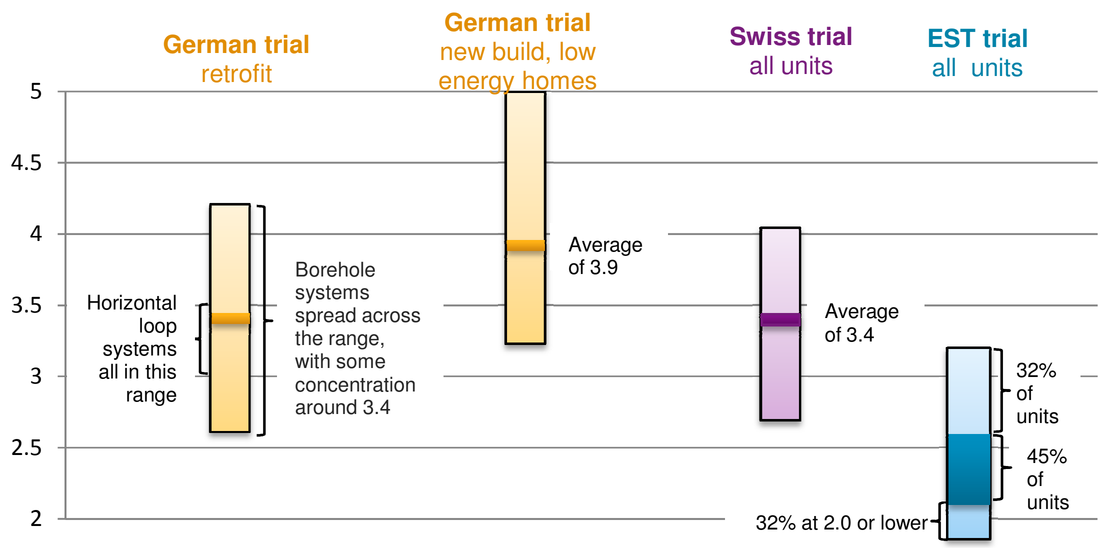


Source: Delta Energy & Environment – source data from Energy Saving Trust; Fraunhofer Institute ISE, Swiss Federal Office of Energy

UK ground source heat pumps fall way short

German and Swiss trial results show far better-performing ground source heat pumps than in the UK.

FIGURE 4: COMPARING GSHP TRIAL RESULTS



Source: Delta Energy & Environment – source data from Energy Saving Trust; Fraunhofer Institute ISE, Swiss Federal Office of Energy

How the UK can get its heat pumps performing closer to Swiss and German heat pumps

Get the basics right

- **Size the heat pump correctly:** Under-sizing the heat pump for the heat load is the most common problem - resulting in extensive use of direct electric heating and sub-optimal performance.
- **Correct set up of automatic controller settings:** Incorrect set-up can have a detrimental effect on the system efficiency – and thus SPF - if set to meet a higher than necessary heat demand.
- **Correct specification of the ground loop:** For ground source heat pumps, getting the specifications for the ground loop correct is critical. Getting this right for boreholes is more challenging than for horizontal 'trench-like' ground loops.
- **Correct set up of the system as a whole:** In addition to system components being efficient, the whole heat pump system – including back-up heaters, buffers, hot water tanks and heat distribution systems – must be laid out correctly to optimise efficiency.

A concerted effort to get heat pumps performing well in UK retrofits

Low flow temperature heat distribution systems

The best SPFs are achieved where the heat distribution systems have the lowest possible flow temperature requirements. Heat distribution is best via underfloor heating, which needs a flow temperature of around 35 degrees.

- Over-sized or fan coil radiators are a solution for retrofit properties – needing a flow temperature of around 45-50℃ or less.
- Traditional radiators, requiring a flow temperature of >65℃, will reduce SPF significantly.

In the EST trials, most of the trial sites had traditional radiators. With over-sized or fan coil radiators, heat pumps could have been run at lower flow temperatures, which may have enabled SPFs to be improved.

Maximise building insulation

A heat pump is at its most efficient running at low temperatures for long periods of time – a very different pattern of heating from the short bursts of high temperature heat from a boiler. To keep a poorly insulated building at a required temperature, a higher flow temperature is required than if it were well-insulated, meaning that the heat pump is working less efficiently.

In the EST trials, all of the buildings were retrofit properties, and thus most were poorly insulated – not ideal for heat pump efficiency.

In comparison, in the Swiss trials, just 40% of buildings were refurbishments, and of these, only 30% had had no additional insulation or efficiency measures – meaning only ~12% of the buildings in the Swiss trial had comparably poor insulation levels to the bulk of the EST trial sites. This is a further reason why the overall trial results showed higher SPFs being achieved in the Swiss trials.

Educate End Users

As discussed above, heat pumps are not at their most efficient running for short bursts at high temperatures – as one would use a traditional boiler. A significant problem in the EST trial was that end-users did operate their heat pumps in this way, resulting – of course - in poor performance. End-user education is essential – and typically, is not at the required level in the UK. This has been a major focus of work in Switzerland.

Outlook: Heat pumps can make a big contribution to de-carbonising UK heat

Delta believes that heat pump performance in the UK can improve significantly from the results found in the EST trials. Swiss and German trial results demonstrate this.

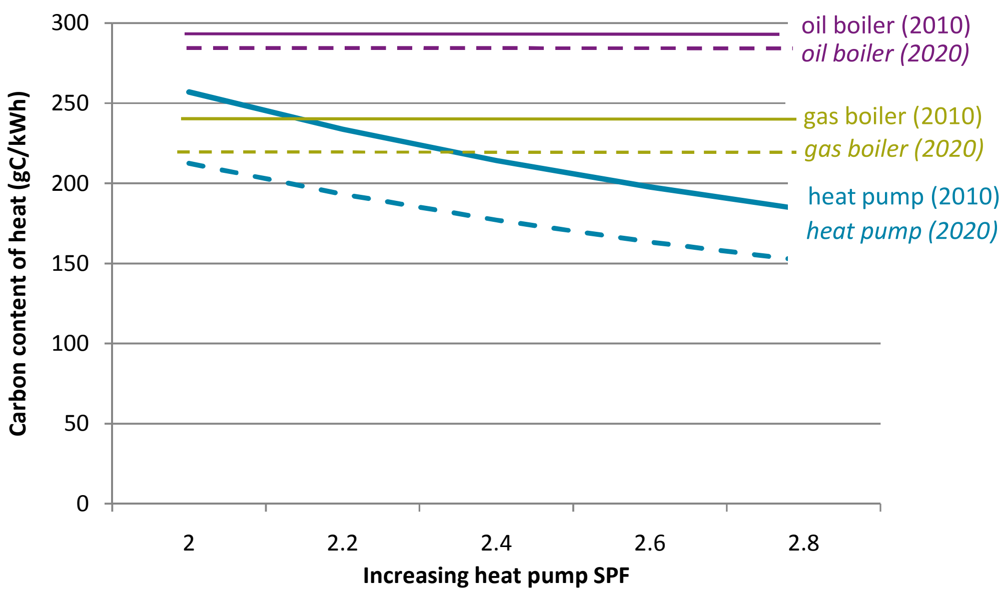
Heat pump's low carbon credentials are very sensitive to SPF. Figure 5 below shows that the SPFs for both air source and ground source heat pumps from the EST trials make heat pumps comparable or more carbon intensive than gas boilers. But if performance can be raised to closer to Swiss and German levels, heat pumps become a lower carbon option than gas boilers.

FIGURE 5: COMPARING THE CARBON INTENSITY OF A KILOWATT HOUR OF HEAT FROM HEAT PUMPS AND OIL AND NATURAL GAS BOILERS IN THE UK

Even with a 'poor' SPF of 2.0, heat pumps are a lower carbon option than an oil boiler. Against natural gas, heat pumps need to perform at the top of the EST trial range to be carbon competitive today. As the grid decarbonises, the carbon performance of heat pumps will further increase relative to gas and oil, as shown below (although injecting biogas into the gas network may also bring the carbon content down for gas boiler heating, as shown below).

Assumptions:

- Boiler of 86% HHV efficiency based on typical seasonal performance
- Carbon intensity figures (from DECC)
    - Electricity grid carbon intensity of 514g/kWh for 2010 (DECC) and 425 g/kWh for 2020 (based on the CCC 80% CO2 reduction scenario)
    - Gas carbon intensity of 198 g/kWh for 2010 and 178g/kWh for 2020 - assumes 0% biomethane on the gas grid in 2010 and 5% in 2020
    - Oil carbon intensity of 250 g/kWh for 2010 and 245 g/kWh for 2020 – assumes % biodiesel by 2020



Source: Delta Energy & Environment, 2010; Data from DECC

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