Department for
Business, Energy
& Industrial Strategy

DOMESTIC HEAT DISTRIBUTION SYSTEMS EVIDENCE GATHERING

Executive summary

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Introduction

Meeting the UK's legally binding carbon emissions reduction goals will require deep decarbonisation of all sectors of energy use, including the energy used to heat our buildings. Many low carbon heating options including heat pumps and heat networks operate more efficiently at low temperatures and are most efficient at 45°C or less, versus the 60-70°C that fossil fuel boilers typically operate at[1]. To meet thermal comfort a reduction in the supply temperature within the home could require a change in the heat distribution system. There is significant uncertainty on the characteristics of heat distribution systems installed across the UK and the implications in terms of cost and disruption of a widespread transition to low temperature heating. This study aims to fill gaps in the current evidence base and focuses on two key areas: the state of heat distribution systems in the UK housing stock and the measures that could be taken to improve these systems.

Methodology

Three main sources of evidence gathering were used for this project a literature review, stakeholder engagement and primary data collection in dwellings. Relevant literature around heat distribution systems was gathered and analysed and a broad range of stakeholders were consulted, including from industry associations, accredited testing facilities, manufacturers, distributors, installers, and house builders.

Primary data collection took place in 515 domestic properties in the UK. An accredited Energy Performance Certificate assessor completed a survey of each property's heat distribution system while carrying out their Reduced data Standard Assessment Procedure (RdSAP) assessments for an EPC. This allows for a calculation of the "oversizing factor" of a dwelling's heat distribution system, defined by the rated thermal output of the radiators in a dwelling divided by the peak steady state heat demand (kW) for the same dwelling. From UK housing stock data[2], a full stock of dwellings in the UK with wet central heating systems has been created, and information gathered about heat distribution systems from the primary surveys is mapped across this.

Heat distribution systems in the UK housing stock

- 95% of dwellings in the UK have central heating, with 83% of homes' central heating powered by the gas grid[2].
- 90% of dwellings use wet heating systems with a boiler and radiators, although a small but increasing number of these dwellings use underfloor heating[2].

[1] Operating conventional gas condensing boilers at lower flow and return temperatures will increase their efficiency. So some results of this study are also relevant to improving the performance of existing systems.
[2] English Housing Survey 2016: Housing Stock Data, the Scottish Household Survey, 2015-17, the Welsh Housing Conditions Survey 2017-18, and the Northern Ireland House Condition Survey, 2016

1.4% of dwellings in the project sample surveyed had underfloor heating, whereas underfloor heating makes up 4% of the combined radiator and underfloor heating market, and its market share is growing[3].

Capacities of heat distribution systems

The capacity of a heat distribution system relates to the amount of useful heat that it can provide to a dwelling. In practice all dwellings require different amounts of heat, so the capacity of the heat distribution system in this study is characterised by an “oversizing factor”, defined as the ratio of the rated output of the radiators[4] in a dwelling to the peak steady state thermal demand (kW) of that dwelling. The oversizing describes the relative ability of the heat distribution system, to meet the steady state thermal demand (kW) of the property. The distribution of oversizing in the survey results is shown in Figure 1 below.

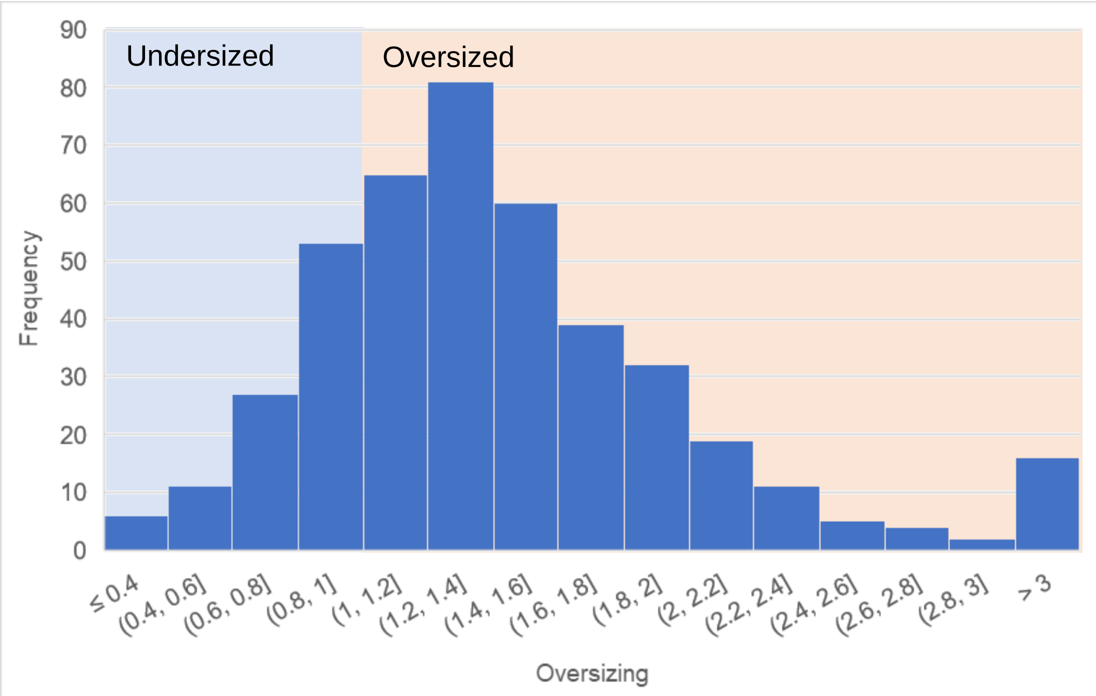

Figure 1 - The distribution of oversizing in the sample of UK dwellings.

There is some uncertainty in the calculation of the oversizing of each dwelling. Firstly, radiators are not expected to perform at the rated output suggested by their manufacturer; in this study a 10% decrease in radiator performance is assumed as a significant but not extreme decrease. Secondly, there is significant uncertainty in the calculation of the SAP heat loss coefficient, and studies have suggested that the heat loss coefficient of dwellings is 45% larger than that calculated by SAP when measured in a coheating test[5]. The impact of these uncertainties on the ability to provide thermal comfort at a range of flow temperatures is shown below.

[3] BSRIA World Radiators and Underfloor Heating – UK, BSRIA, 2018

[4] At standard conditions of 75°C flow 65°C return, 20°C room temperature.

[5] Magnitude and extent of building fabric thermal performance gap in UK low energy housing, 2018, Gupta and Kotopouleas, https://www.sciencedirect.com/science/article/pii/S0306261918304343

Conversion of heat distribution systems to low temperature sources

Many low carbon methods for providing space heating are designed to deliver heat at lower temperatures (for example in the range 35-60°C) than conventional fossil fuel boilers, which can provide heat in excess of 80°C[6]. This can be a barrier to uptake of low carbon heating technologies if the existing heat distribution system in a property is not capable of providing enough thermal output when operating at the lower temperature. Usual practice is that the heat emitters in a property are replaced with significantly larger ones when switching to operate at a lower flow temperature.

The UK stock model developed for this study gives the distribution of the oversizing of dwellings' radiators relative to their peak heat demand (kW) for the whole UK. It uses data from the sample of the UK stock surveyed for this project mapped to the full UK stock of wet heat distribution systems. The model results relating to the flow temperature that could be used in different proportions of the housing stock are shown in Figure 2. It shows that 10% of dwellings in the UK are already suitable, on a peak winter day, for heat pumps with a 55°C flow temperature with no changes to their heat distribution systems; only 1% are suitable for a heat pump with a flow temperature of 45°C. However, when considering reductions in radiator performance over time or additional heat demand above what is calculated by SAP these figures are significantly reduced.

Another consideration for the conversion to low temperature heating is operation during an average winter day rather than the peak day. Assuming the average temperature for the coldest winter month rather than that for the peak day, the proportion of dwellings able to provide comfort at lower flow temperatures increases, as shown in Figure 3. The results suggest that 53% of dwellings can be heated with a 55°C flow temperature with no changes in their heat emitters or flow rates for most of the heating season. Provided that the heat pump is able to meet the maximum required flow temperature for the peak heat demand (kW), the flow temperature could be reduced for much of the heating season, thereby increasing the overall efficiency; given that many modern heat pumps can operate with variable flow temperature[7],[8].

Further, these results suggest that there is an opportunity for hybrid heat pumps, or heat pumps with additional heat sources such as electric fan heaters[9], to be used with no changes to heat distribution systems, with the heat pump providing the vast majority of the annual heating demand (kWh), across a relatively large portion of the housing stock.

[6] Conventional condensing boilers are also more efficient when operating at lower temperatures, so a reduction in flow temperature also benefits dwellings with these installed.
[7] https://www.dimplex.co.uk/product/9kw-high-temperature-domestic-ground-source-heat-pump-sih9me
[8] https://library.mitsubishielectric.co.uk/pdf/download_full/751
[9] The use of lower efficiency electric fan heaters rather than heat pumps would create a larger load on the electricity network and the lower efficiency could result in more expensive heating for the resident.

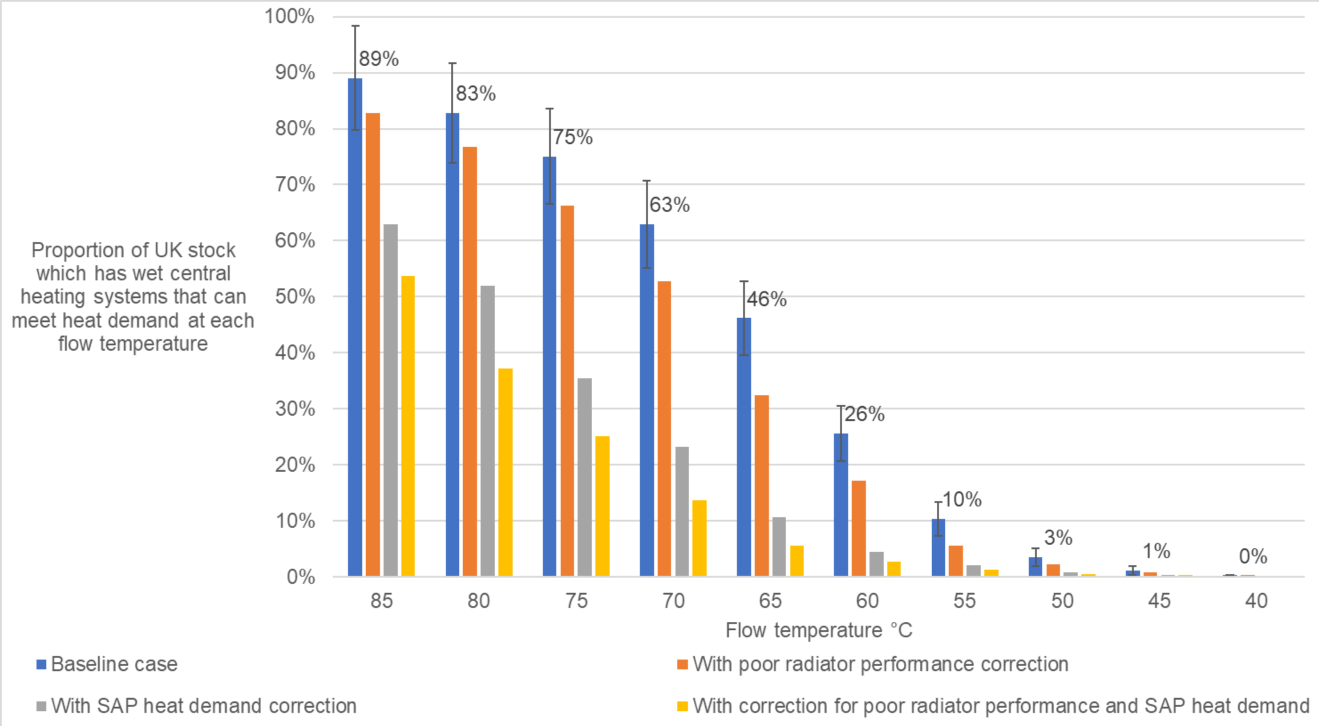

Figure 2- Proportion of UK dwellings, with wet central heating systems, that could meet peak heat demand (kW) at each flow temperature. (Average temperature across sample for the peak is -3.5°C. Error bars give 95% statistical confidence interval.

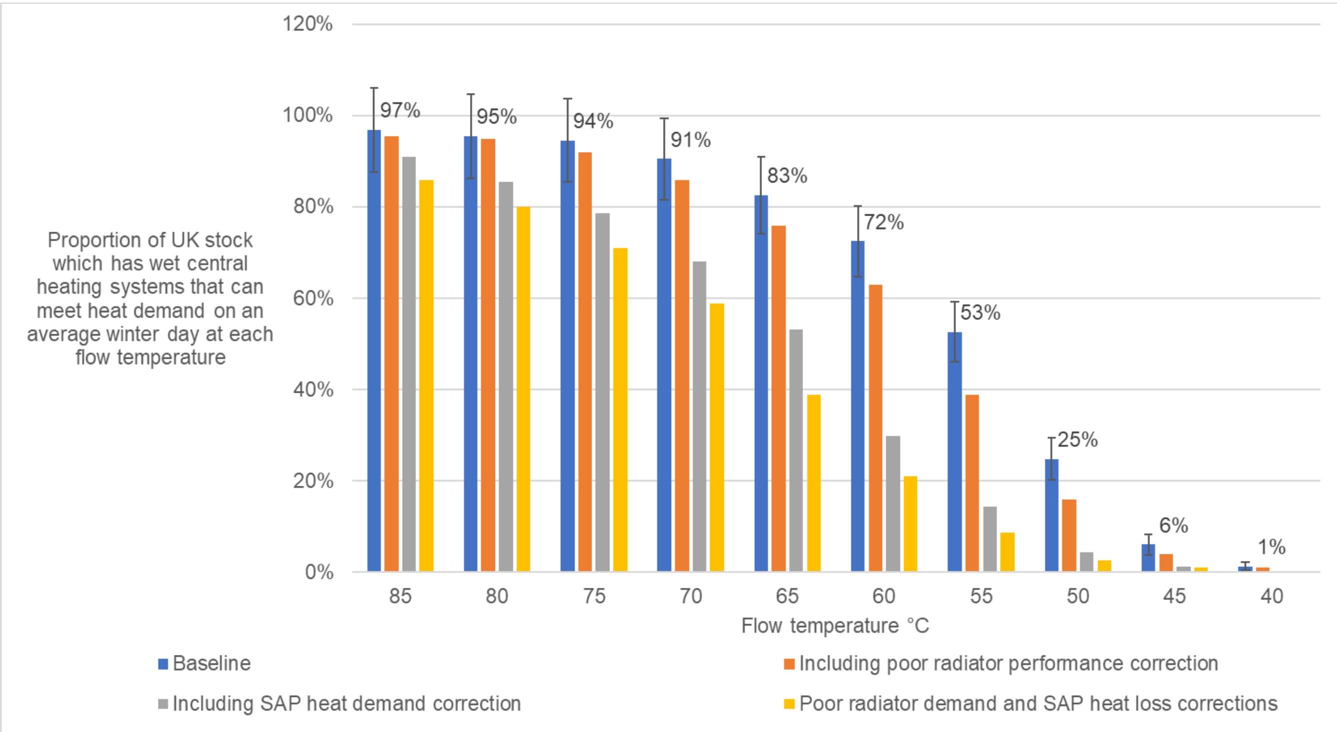

Figure 3 - The proportion of UK dwellings, with wet central heating systems, that could meet heat demand (kW) on a typical winter day at each flow temperature. (Average temperature across sample is 4.7°C, error bars give the 95% confidence interval)

Performance of heat distribution system technologies

The main inefficiencies of heat distribution systems are poor hydraulic balancing, which can reduce performance by 10%[10],[11]; the build-up of sludge which can reduce efficiency by 15%[12]; air which can reduce the system performance by 6%[13]; or limescale which can reduce the efficiency by 15%[14]. These reduce system performance significantly and can prevent the system from providing thermal comfort. Following best practice for the installation, commissioning, and maintenance of heat distribution systems will allow the heating system to perform to the specifications set out by the manufacturer. However little information is available to support how closely systems perform to their rated output.

In wet central heating systems, performance enhancing measures and maintenance can improve the lifetime of the system, increase the output of radiators relative to standard conditions, and/or reduce the heat wasted in the system.

Performance enhancing actions that can be taken to maintain the system include hydraulic balancing, power flushing of the system, manual flushing of radiators and radiator bleeding. Products available to reduce the build-up of air, sludge and limescale include corrosion inhibitors, water softeners and limescale reducers, magnetic filters and de-aerators. Products that can improve the output of radiators include radiator fans, heat transfer modifiers, high performance radiators. Products that can reduce the heat wasted by the system include thermostatic radiator valves, radiator reflectors, heat recovery systems and self-balancing radiators.

There is robust evidence around the benefits of some performance enhancing actions and products although for others this is lacking. The products designed to reduce air, sludge and limescale are thought to be useful for maintaining the system performance. In addition, there is robust evidence that thermostatic radiator valves can give energy savings of 3% in real dwellings and that radiator fans can increase the thermal output of radiators by 14%-19% in laboratory tests. There is still a significant gap in the evidence base around how these measures will impact performance in real systems in dwellings, and the evidence base for all measures could be increased by additional in situ testing.

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[10] BEIS, Heat in Buildings: Boiler Plus, October 2017
[11] *Sustainable energy association heating system plus*, August 2015
[12] https://www.eua.org.uk/uploads/5A8D4F9A4E161.pdf
[13] https://www.installeronline.co.uk/deaeration-maximise-heating-system-efficiency/
[14] https://www.viessmann.co.uk/heating-advice/how-to-prevent-limescale-in-boilers

Summary

History of Heat Distribution Systems

- 90% of dwellings in the UK have wet heating systems with radiators
- Steel panel radiators have always dominated the central heating market due to their low cost and reliability, and no major shift away from their use is expected.
- Underfloor heating only made up 4% of the combined radiator and underfloor heating market in 2018.
- The design and commissioning of heat distribution systems has changed relatively little over time.

Performance and Maintenance of Heat Distribution Systems

- Heat distribution systems are rarely hydraulically balanced and are often significantly oversized.
- An annual service of the heat distribution system should be standard practice, but only 20% of dwellings undertake this.
- The main inefficiencies of heat distribution systems are poor hydraulic balancing, which can reduce performance by 10%[15] [16]; the build-up of sludge which can reduce performance by 15%[17]; air which reduces the system performance by 6%[18]; or limescale which can reduce the performance by 15%.
- Proper maintenance and commissioning of the system can eliminate or significantly reduce these issues.
- The performance enhancing measures with the most robust evidence base around their use are thermostatic radiator valves, giving a 3% energy saving. There is some evidence that other measures improve performance, but further trials and testing of these are required to verify this.

Suitability of Existing Heat Distribution Systems for Low Temperature Heating

- Oversizing is a measure of the rated output of the radiators in the dwelling divided by the calculated heat loss of a dwelling. The heat distribution systems in the sample of properties surveyed have a mean oversizing of 1.46 with a median of 1.3, but there is a large spread with many properties significantly under or oversized.
- In the baseline case 10% of UK dwellings could meet heat demand (kW) with a 55°C flow temperature and 1% at 45°C on a peak heating day.
- On an average winter day, 53% of dwellings could use a 55°C flow temperature, and 6% could use a 45°C flow temperature, with no changes to their heat emitters or flow rates.

[15] BEIS, Heat in Buildings: Boiler Plus, October 2017
[16] *Sustainable energy association heating system plus*, August 2015
[17] https://www.eua.org.uk/uploads/5A8D4F9A4E161.pdf
[18] https://www.installeronline.co.uk/deaeration-maximise-heating-system-efficiency/

- When including a possible decrease in radiator performance over time and an increase in the heat demand (kW) relative to the calculated demand the proportions of dwellings which can be heated at low temperature is substantially reduced. Further work to better understand and quantify this uncertainty has been suggested to BEIS.
- These results are significant, since they help to quantify the number of dwellings for which changes are required to the heat distribution system when a low temperature heat source is installed. They suggest a significant opportunity for hybrid systems to be used to significantly reduce emissions without making any disruptive changes to heat emitters. Further work is needed to verify these results in relation to the 'real' output of systems compared to their rated output and the true heat demand (kW) of occupied properties.

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