The Cost of Installing Heating Measures in Domestic Properties

A Delta-ee Report for the Department for Business, Energy and Industrial Strategy
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Final Report

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1. Introduction

Context & scope of work

BEIS currently uses assumptions on the installation cost per kW capacity for a range of heating measures to support internal modelling and to inform decisions making for policy development. These assumptions are based on a mixture of delivery data and externally commissioned research but have not been updated in some time.

Therefore, BEIS commissioned Delta-ee to carry out a study in order to provide BEIS with up to date robust data and insights on the **current costs** of installing different types of heating measures in domestic properties. BEIS also wanted an external challenge on its views and assumptions on the oversizing factors applied to different types of heating measures.

The scope of this study is to:

- Provide BEIS with up to date information on the installed cost (excluding VAT) of a range of domestic heating measures, including heating controls. This includes providing a detailed breakdown of equipment costs (e.g. heating system, hot water tank, ancillary equipment, radiators) for the different types of heating systems that can be categorised as a single heating measure.
- Provide deeper insight into installation (labour) costs versus equipment costs for various heating technologies, and for different types of installation (e.g. like for like replacement, new build installation, complete heating system retrofit, etc.).
- Present the fully installed cost of different heating systems as a function of the heating measure capacity.
- Present high, low and central estimates for the fully installed cost of each heating measure category.
- Try to provide more clarity on where costs are likely to be affected by delivery under a government policy.
- Determine the oversizing factor applied to the installation of boilers and heat pumps.

This data and insights gathered in this study will:

- Allow BEIS to update its assumptions on the cost of different heating technologies with current, robust and well evidenced data.
- Provide BEIS with a range of cost estimates for different heating measures, capturing differences in installations in different type of dwellings.
- Feed into analysis across several teams within BEIS – updating Department models and supporting cost analysis on heating measure interventions.
- Enable BEIS to more robustly analyse policy interventions in the residential sector.

2. Methodology

Overview

The main focuses for this study have been to:

1. Update BEIS's assumptions on the installed cost of heating measures, via primary and secondary research methods as well as utilising deep existing expertise.
2. Review and challenge BEIS's oversizing factor approach for boilers and heat pumps.

A range of heating technologies (of different size ranges) have been covered in this study, and a variety of research methods / sources of information were used. Below, we outline the core focus of this study, and the research methods applied.

Technology & capacity coverage

Technology coverage

Following discussions with BEIS, the technology focus for this study was agreed as follows:

- Gas boilers
- Oil boilers
- Biomass boilers (pellet)
- Air source heat pumps
- Ground source heat pumps
- Air-air heat pumps (air conditioners)
- Direct acting electric heaters (panel heaters)
- Storage heaters (high heat retention storage heaters, dynamic/fan-assisted storage heaters, and standard / slimline storage heaters)

The technologies covered as part of the oversizing analysis include: gas boilers, biomass boilers and heat pumps. The oversizing factor is discussed in detail in Section 4.

Technologies not considered in detail for this study include:

- LPG boilers
- Back boilers
- Chip and log biomass boilers
- Electric boilers
- Hybrid heat pumps
- Combined heat and power units (including fuel cells)

The excluded technologies make up less than 1% of the annual sales of residential heating systems in the UK. Brief notes on some of these technologies can be found in Annex A.

Capacities coverage

The capacity coverage (in most cases measured in kW) was limited to the most popular sizes for each technology type. For all technologies, the capacities considered in this study cover approximately 90% of the installed base & annual sales of systems in the residential sector.

Research methods used for updating BEIS's cost assumptions

Existing data / insights

Across a number of Delta-ee research services (some of which BEIS subscribes to) and various research projects on the UK heating market, Delta-ee has a wealth of data on the installed cost of heating measures in the UK.

The key sources of existing insights Delta-ee utilised for this study are:

- Heat Insight Service
- Electrification of Heat Service
- Delta-ee's Pathways Tool and Database

Primary research

Delta-ee applied various primary research methods to maximise the number of data points / quality of data it received during this study. These methods were:

- In-depth interviews with selected installers (that Delta-ee has good relationships with)
- In-depth interviews with selected manufacturers and industry associations
- Online surveys
- Cold calling

The core part of the data collection process involved detailed interviews with installers. In this study, Delta-ee had a total of 20 interviews with a range of installer types as detailed in Table 1.

Table 1: Number of interviews held with installers per technology type

Technology installer type	Number of interviews held with installers
Gas boilers	4
Biomass boilers	6
Heat pumps	7
Electric heating	3

Delta-ee also had conversations with four large product manufacturers covering electric heating, heat pumps and boilers.

To supplement the data gathered via these detailed interviews, Delta-ee also developed two online surveys: one for gas boilers; one for heat pumps. The boiler survey was recommended by the Heating and Hot Water Industry Council (HHIC) and was marketed by their installer engagement panel. A total of six responses were collected from the panel which have been analysed as part of the study. The heat pumps survey, covering air-water, ground-water and air-air heat pumps was recommended by a heat pump manufacturer (who agreed to distribute the survey to its brand accredited installer database – numbering in the thousands). The survey was sent to the manufacturer in mid-December and to date there have been no responses received.

Delta-ee also carried out a 'cold calling' exercise with 48 installation companies to increase the number of data points. This generate some useful base data (despite a low success rate) to use in the in-depth interviews with other installers.

Secondary research

Delta-ee also carried out an extensive review and examination of publically available sources of cost information. The core sources of information reviewed were:

- Cost comparison websites
- Websites and list price manuals of heating technology merchants
- Installer websites
- Existing data sets / reports from:
  - The Energy Savings Trust
  - BEIS existing cost data

Building up the cost database

In order to update the cost assumptions for BEIS, Delta-ee started by developing a framework to characterise the data required for each type of heating system, and developed an approach to arrive at a 'low', 'central' and 'high' estimate for the fully installed cost of the different systems.

The approaches used are summarised in more detail below.

Formulation of low, central and high cost estimates

The low, central and high estimates have been built up largely based on qualitative insights and views gathered via speaking to installers. These estimates are therefore based on a wide range of current in-situ heating system installations. In addition to robust secondary data sources, the real life experience of installers guided our judgements on what 'sensible' values are for the average / central fully installed cost of heating system, and what a 'lower cost' and 'higher cost' system looks like.

The cost database provides a degree of commentary as to the factors informing the range in each case. For the cost of the heating technology itself, the low and high estimate in most cases represents lower quality devices and higher quality devices (often with more advanced built-in controls and extended guarantees), respectively.

Framework for gathering data

In order to guide the collection of cost data, a high-level framework was developed. The purpose of the framework was as follows:

- Identify the **different sub-categories of each heating technology** (e.g. for a boiler there is a combi boiler and non-combi boiler, back boiler and regular). The aim was to identify the most common types of systems rather than being exhaustive.
- Identify the **most common installation types** (e.g. replacing like-for-like, replacing a non-combi with a combi, new-build installation, etc.). This helped to inform the discussions with installers / manufacturers, and helped focus on the most common types of installation.
- Identify the **typical capacity range of heating technologies** installed in domestic homes. The focus here was to cover the majority of the UK heating market (covering a range of small to large systems) by focusing on the 3 – 4 most common sizes of systems) rather than being exhaustive.
- Form a detailed breakdown of the **installation cost of heating systems**, to allow BEIS to gain further clarity as to how the installed cost for the customer builds up. The specific cost categories examined were:
  - Capital cost of heating device (no ancillary equipment)
  - Capital cost of ancillary equipment (e.g. pipework and valves)
  - Capital cost of heat distribution system (e.g. radiators, underfloor heating, etc.)

- Cost of labour to install the heating technology

Figure 1 below illustrates the framework developed, simplified to show an example framework for gas boilers.

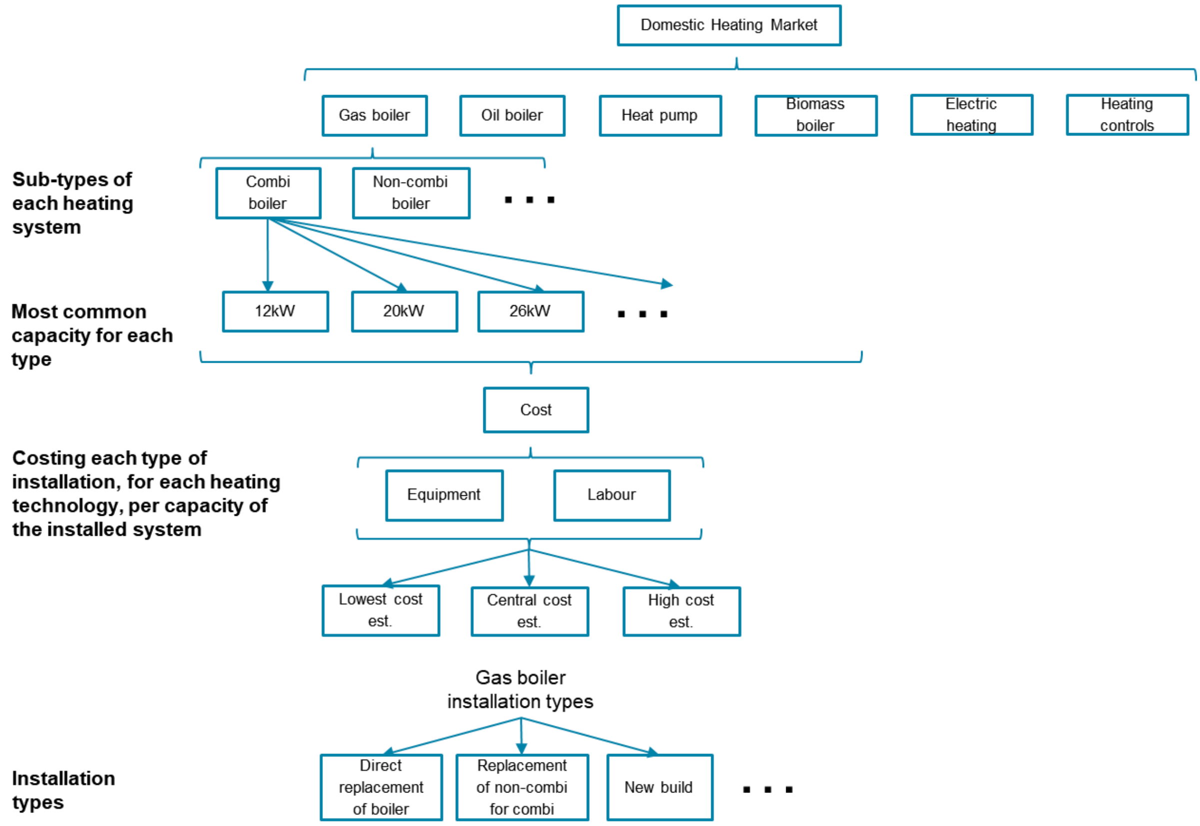


Figure 1: Illustration of the framework - simplified to show a single heating technology (gas boiler)

The detailed framework diagrams for each technology are given in Annex B.

Validation of the database

After the initial cost data was gathered and analysed for each technology type, Delta-ee shared the results with selected installers and industry contacts for challenge. This was to gather feedback and to ensure robustness in the final results presented to BEIS. Feedback received has been incorporated into the final costs presented in the Excel database.

3. Cost of heating technology results

Below, we extract the headline results on the fully installed costs for the different types of heating systems covered in this study. The tables that follow illustrate the fully installed prices for the most common / example types of installation for each technology as they appear in the cost database.

The detailed cost breakdowns for each type of technology (including variations by size of system) are contained in the accompanying Excel database.

Gas boilers

Table 2 illustrates the fully installed cost for a range of gas boiler installations. The two types of gas boiler examined were combi-boilers and non-combi boilers (which includes regular boilers).

Table 2: Example total installed price paid by a customer for common types of gas boiler installations

Installation description	**Cost in pounds (excluding VAT)**
24kW combi for combi direct swap by local installer/plumber (including labour and fittings but excluding controls and heat distribution system)	£ 2,250
24kW combi for combi direct swap by regional installer (including labour and fittings but excluding controls and heat distribution system)	£ 2,700
24kW combi for combi direct swap by national installer (including labour and fittings but excluding controls and heat distribution system)	£ 3,263
24kW non-combi for non-combi direct swap by regional installer (including labour and fittings but excluding controls and heat distribution system)	£ 2,568
Replacing an old 24kW non-combi with a 30kW combi by regional installer (including labour, fittings, removal of old equipment but excluding controls and heat distribution system)	£ 3,660
New build or full retrofit of first time central heating, 24kW combi by regional installer (including new radiators, putting in gas supply line and controls. High cost estimate of fittings used)	£ 5,400
New build or full retrofit of first time central heating, build 24kW non-combi by regional installer (including new radiators, putting in gas supply line and controls. High cost estimate of fittings used)	£ 6,228

Oil boilers

Table 2 illustrates the fully installed cost for a range of oil boiler installations. The cost of the oil boiler unit itself tends to be roughly twice the cost of a similar capacity gas boiler. The primary driver behind this is due to the more expensive components used in manufacturing of the boiler and the much lower volumes of boilers sold (as compared to gas boilers) driving margins up. Furthermore, oil boilers, unlike gas boilers, are not able to modulate their output. Oil boiler units are sold being able to produce a range of outputs (e.g. 15-21kW, 21-26kW etc.) and the output will be set by the installer during commissioning of the boiler. The two types of oil boiler examined were combi-boilers and non-combi boilers (which includes regular boilers).

Table 3: Example total installed price paid by a customer for common types of oil boiler installations

Installation description	Cost in pounds (excluding VAT)
21kW combi for combi direct swap (including labour and fittings but excluding controls and heat distribution system, assuming most of the existing fittings can be used)	£ 3,560
24kW non-combi for non-combi direct swap by regional installer (including labour and fittings but excluding controls and heat distribution system)	£ 2,770
24kW combi for an old 24kW non-combi swap by regional installer (including labour, fittings, removal of old equipment but excluding controls and heat distribution system)	£ 4,160
New build 21kW combi (including oil tank, new radiators and controls costs)	£ 7,440
New build 24kW non-combi by regional installer (including new radiators, cylinder, putting in gas supply line and controls costs)	£ 7,050

Biomass boilers

Table 4 illustrates the fully installed cost for a range of biomass boilers. Only pellet biomass boilers were examined in this study, with some commentary on log boilers and chip boilers being provided in the Annex A.

Table 4: Example total installed price paid by a customer for common types of biomass boiler installations

Installation description	Cost in pounds (excluding VAT)
25kW high-end boiler fully installed - excluding pellet store, no additional advanced boiler controls (assumed built in to boiler), and no heat distribution system costs	£ 18,900
25kW lower - quality / cheaper boiler fully installed - excluding pellet store, no additional control and excluding heat distribution system	£ 10,000
35kW high-end boiler fully installed - including additional controls, excluding pellet store and heat distribution system costs	£ 20,750
25kW high-end boiler fully installed - including medium size pellet store but excluding heat distribution system costs	£ 22,400
25kW high-end boiler fully installed - including pellet store and heat distribution system costs for a 3-4 bedroom house (radiators upstairs and downstairs)	£ 24,300

Heat pumps

Three type of heat pump were examined in this study – air-water, air-air and ground-water heat pumps.

Air-water heat pumps

Air-water heat pumps have become the most popular type of heat pump to be installed in the UK due to their lower cost compared to other types of heat pumps, and their suitability to a large portion of the UK housing stock. Table 5 illustrates the fully installed cost for a range of air-water heat pumps.

Table 5: Example total installed price paid by a customer for common types of air-water heat pump installations

Installation description	**Cost in pounds (excluding VAT)**
8kW air source heat pump (ASHP) fully installed including fittings, buffer tank, cylinder and controls, excluding the heat distribution system	£ 8,750
12.5kW ASHP fully installed including fittings, buffer tank, cylinder and heating controls, excluding the heat distribution system	£ 11,500
16 kW ASHP fully installed including all new fittings, large buffer tank and advanced cylinder and controls (complex system)	£ 14,050
8kW ASHP fully installed including fittings, small buffer tank and cylinder, controls and heat distribution system (new for a smaller house)	£ 14,750
16kW ASHP fully installed including fittings, large buffer tank and cylinder, advanced controls and heat distribution system (new in larger house)	£ 21,550
16kW ASHP fully installed including buffer tank and cylinder and heat distribution system (retrofit system with upgraded existing radiators)*	£ 14,900

* While upgrading existing radiators is much cheaper than installing a new heat distribution system, the issue with just upgrading the existing radiator network is that the time to heat a room will still take longer than if a new system of underfloor heating (downstairs) and radiators (upstairs) were used. In some cases this may translate into an installer recommended a home owner to install a larger capacity heat pump to compensate for this slower heat time.

Ground-water heat pumps

The fully installed cost of ground-water / ground source heat pumps is significantly more than that of air-water heat pumps – largely due to the requirement for the installation of a ground collector. However, ground source heat pumps are more efficient than air-source heat pumps, especially at lower outside temperatures. Table 6 illustrates the fully installed cost for a range of ground-water heat pumps.

Table 6: Example total installed price paid by a customer for common types of ground-water heat pump installations

Installation description	Cost in pounds (excluding VAT)
8kW ground source heat pump (GSHP) fully installed including small buffer tank and cylinder but excluding ground works and excluding controls, excluding the heat distribution system	£ 13,200
12kW GSHP fully installed including buffer tank and cylinder but excluding ground works and excluding controls, excluding the heat distribution system	£ 14,850
16kW GSHP fully installed including large buffer tank and cylinder, complex controls but excluding ground works and excluding the heat distribution system	£ 19,000
12kW GSHP fully installed including buffer tank and cylinder and ground works, excluding the heat distribution system	£ 20,850
12kW GSHP fully installed including buffer tank, cylinder, ground works, controls and the heat distribution (underfloor heating downstairs and radiators upstairs) system	£ 27,350

Air-air heat pumps

Air-air heat pumps are sometimes more commonly known as air conditioners. All new air-air heat pumps sold in the UK are reversible, this has been the case from around 2011, meaning that they have the ability to both cool and heat. Table 7 illustrates the fully installed cost for a range of air-air heat pump installations for different arrangements and capacity types[1].

Table 7: Example total installed prices paid by a customer for common types of air-air heat pump installations

Installation description	Cost in pounds (excluding VAT)
1 bedroom flat (1 x 2 kW for bedroom + 1 x 3.5 kW for lounge) - lower cost of fittings used due to smaller install	£ 2,400
2 bedroom flat (2 x 2kW for bedrooms + 1 x 3.5kW for lounge)	£ 4,000
3 bedroom flat (3 x 2 kW for bedroom + 1 x 3.5 kW for lounge) - large distance between indoor and outdoor units	£ 6,500
4 bedroom house (4 x 2 kW for bedroom + 1 x 5 kW for lounge) - large distance between indoor and outdoor units	£ 8,800

Hybrid heat pumps

Fully integrated hybrid heat pumps are still an embryonic technology in the UK. All heat pump and gas boiler installers we spoke to during this project have had no experience with installing fully integrated hybrid heat pumps. There are different control strategies / factors that influence when the heat pump operates versus the boiler. This will of course influence the sizing approach to heat pump and boiler,

[1] Air-air heat pumps are sold based on their cooling capacity. Therefore a heat pump listed as being a 2kW model can provide 2kW of cooling capacity. The heating capacity is in all cases higher than this value. The actual electrical consumption of the heat pump depends on its coefficient of performance (COP).

and will very likely change in the future. In this study, we focus on the component costs of each technology.

Installers very commonly consider hybrid heat pump installations to be the installation of two separate technologies – i.e. a gas boiler installation and a heat pump installation, rather than a single installation. Therefore, the installers interviewed for this study all consider the cost of a hybrid heat pump to be the sum of the cost of a gas boiler and a heat pump – that use the same hot water cylinder and heat distribution system. In most cases a lower capacity gas boiler and heat pump would be used (and certainly smaller than the size of a boiler / heat pump that would be installed if it was the sole heating technology for the property.

Electric storage and resistive heaters

The following type of electric heating are covered in the cost database:

- **High heat retention storage heaters**. High heat retention storage heaters are usually installed in the main bedroom(s) and the living room of a dwelling. Storage heaters store heat up during the night by charging up thermal mass media ('thermal bricks') using off-peak Economy 7 tariff electricity. This heat is then released during the course of the day. The heat output from modern high-heat retention storage heaters can be controlled and better stored to be used at a time when the heat is required - usually the following evening.
- **Dynamic / fan assisted storage heaters**. These are a more basic version of the high-heat retention storage heaters. They are used in the same situations as high-heat retention storage heaters. Modern units have more advanced controls that allow for more controlled release of the stored heat.
- **Static / slimline storage heaters**. These are an even more basic version of dynamic storage heaters. These costs have been included for comparison only - this type of storage heater was discontinued from the start of 2018. This type of storage heater's control system does not allow for the sensible release of heat when required by the occupants.
- **Panel heaters - also referred to as direct acting heaters.** Panel heaters traditionally do not contain a storage medium. They are often installed alongside storage heaters as part of a complete electric heating solution. They are most commonly used in smaller rooms and in bathrooms - spaces that are better suited to direct use of electricity for heating rather than having to rely on heat being stored up during the night.
- **Combination electric radiators**. These are considered a high-end version of direct acting / panel heaters. These type of heaters contain a small amount of storage medium that allows the heater to draw power for only a fraction (e.g. 1/3) of the time the unit is providing heating. High-end versions of these systems are installed alongside advanced controls as part of a completely integrated electric heating solution.

Homes that make use of electric heating often use multiple types of electric heating units. For example, it is common for storage heaters to be installed in the living room and main bedroom and for direct acting / panel heaters are often used in other parts of the home - smaller bedrooms and the bathroom. Table 8 illustrates the fully installed cost for a range of different types of electric heating systems.

Table 8: Example total installed price paid by a customer for common types of electric heating installations

Installation description	**Cost in pounds (excluding VAT)**
Cost to replace an old system in a 3 bedroom flat with combination of new high-retention storage heaters and panel heaters – including basic controls and disposal of old units	£ 3,290
Cost to replace an old system in a 3 bedroom flat with a new system of standard storage heaters and panel heaters - including basic controls and disposal of old units	£ 2,450
Cost to install a new system with high-end electric radiators (which have a small storage capacity), including standard controls, in a 3 bedroom flat	£ 5,115
Cost to replace an old system in a 1 bedroom flat with combination of new high-retention storage heaters and panel heaters – including controls and disposal of old units	£ 2,105
Cost to replace an old system in a 1 bedroom flat with a new system of standard storage heaters and panel heaters - including basic controls and disposal of old units	£ 1,585
Cost to install a new system with high-end electric radiators (which have a small storage capacity), including controls, in a 1 bedroom flat	£ 2,860

Controls

The cost of individual control components are listed in the cost database. The control components are listed including average installer margin but excluding VAT. It is uncommon for installers to be called out to install just a single component of a control system. Control equipment is in most cases installed as part of a complete heating system installation (and these costs are included in most of the fully installed cost data above). The main exception of this is the installation of internet connected controls, which are becoming increasingly popular.

4. Oversizing

Reviewing and challenging BEIS's oversizing factor approach was also a key part of the scope of this project. Below, we describe the oversizing approach for gas boilers, followed by higher level commentary on the oversizing approach for heat pumps and biomass boilers. The detailed methodology for each of the oversizing factors can be found in the Excel cost database.

Introduction to heating system oversizing

In order to define the oversizing factor (OSF), we refer to the typical sizing workflow, as presented in Figure 2. BEIS has communicated that its current central assumption is that the oversizing factor between A and F is approximately 3.1 for gas boilers, 1.15 for biomass boilers and for air-source heat pumps, and 1 for ground source heat pumps.

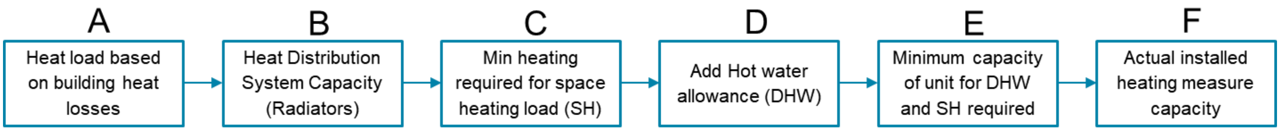


Figure 2: Heating measure typical sizing workflow

We have sought to understand the drivers behind over-sizing at each step in the typical sizing workflow, as displayed in Figure 2. Many installers consider "over-sizing" to refer to selecting models (step E to F above) – whilst common, especially as brands consolidate product ranges, the impact is limited. However, when considering the heating measure capacity in the context of building heat loss and hot water requirements (steps A to E in Figure 2) the OSF can vary much more significantly, especially as heating system sizing practises have evolved over time.

It is important to note that oversizing is a requirement of effective heating measure sizing (i.e. adding safety margins or heat-up allowances). Heating measure sizing is not driven solely driven by building heat losses, but instead by radiator output, pipe losses, DHW cylinder heating allowances, etc. In this section the OSF referred, unless otherwise stated, to is considered in the same manner as BEIS, i.e. installed capacity (F) vs heat demand (A).

Gas boiler oversizing

For gas boilers we expect a wide range of over-sizing, especially for low heat demand homes. The oversizing discussion to follow applies mainly to non-combi boilers as combi boilers are in most cases sized based on their hot water output / flow rate. The variation of historic radiator sizing versus heat load (which installers may not be fully aware of in many cases) leads to substantial variation that cannot be "managed out" by rigid boiler sizing practices – the installer must design according to the radiator capacity to avoid thermal inertia effects, which would increase the time for rooms to heat up. Table 9 indicates the likely impact of each deployment scenario, as summarised in Table 10.

Table 9: Drivers for boiler over-sizing from each pathway in the sizing chain as presented in Figure 2

OSF pathway	Impact by D/S	What drives the over-sizing factor?	Who drives the decision & why?
A to B	1-3: Medium -High 4 & 5: Low	Incorrect or out-dated heat loss calculations / radiator sizing. Efficiency measures reducing heat loss "Rounding" errors selecting closest radiator size. Customer pressure for aesthetics or comfort.	Boiler size dictated by radiator capacity – can't reduce boiler size if radiators were over-sized for building heat load, or are now over-sized due to efficiency measures. Design practices have evolved over time – heating systems remain in-situ without major changes.
B to C	1-3: Medium -High 4 & 5: Low	Changing guidance and judgement on heat-up allowance.	Installers/surveyors, following guidance received during training or some trade body, or perhaps company policies, which may not reflect current best practice .
C to E	2 & 3: Medium	Not adjusting boiler sizing. Incorrect sizing during standard to combi or combi to standard conversion.	Installers/surveyors, mainly by failing to re-calculate boiler sizes from heating & DHW system design.
E to F	All: Low - Medium	Available boiler capacities from preferred brand.	Installer/surveyor or customer brand selection (cost, preference). Installer attitude to OSF (to avoid undereating complaints). Customer pressure to upsize (comfort perceptions).

Table 10: Deployment scenarios for boilers

Deployment scenarios	
1	Boiler replacement like-for-like
2	Boiler swap standard to combi
3	Boiler swap combi to standard
4	New build / dry to wet conversion
5	New boiler and central heating upgrade

In order to derive a credible range of over-sizing factors for gas boilers, the distribution of the average Design Heat Load (kW), for each age of the dwelling stock in the English House Survey, was derived – presented in Figure 3. Design Heat Load (kW) was calculated from the average floor area (m^2) and Heat Loss Parameters (W/m^2K) of each age range, plus an assumption[2] on UK-wide design temperatures (K).

[2] Based on intermittent heating for a house in Manchester, and 21 degrees Celsius average internal design temperature

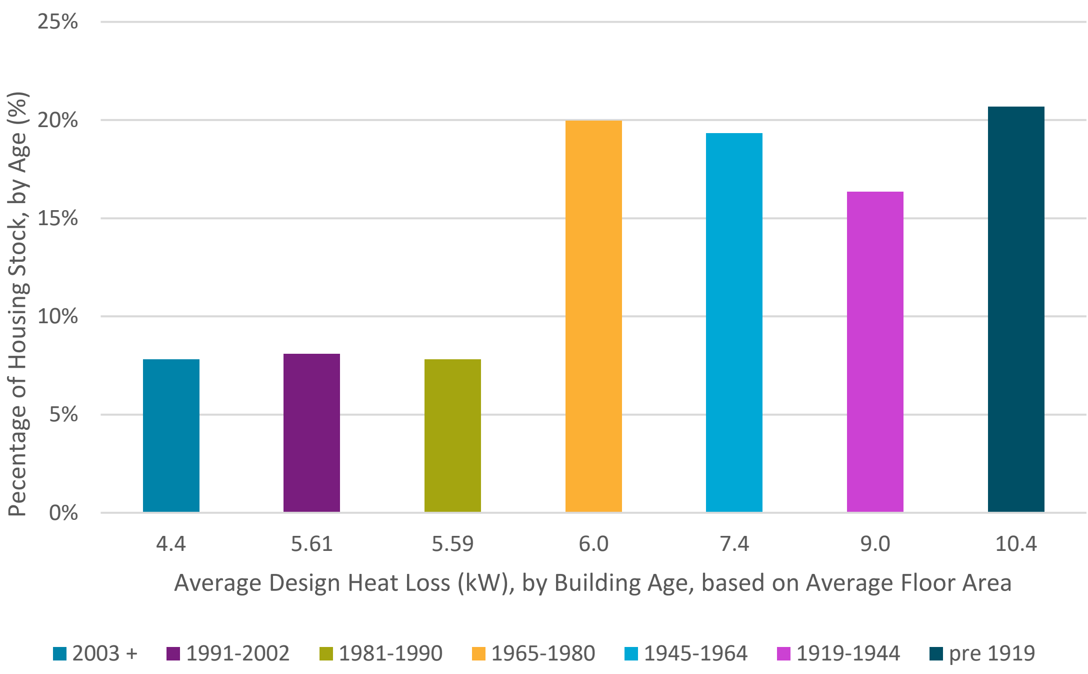


Figure 3: Average design heat load (kW) by dwelling age, from English Housing Survey 2015

In order to capture the potential variation in over-sizing factor for gas boilers, we tabulated the range of average (i.e. not representative of building stock variation) design heat load versus the most popular boiler output capacities – see Table 11. The boiler oversizing factors presented in Table 11 are the ratio of the boiler output to the average design heat load.

Table 11: Average space heating design heat load (kW) vs the most popular boiler output capacities (kW)

Average space heating design heat load (kW), based on 2015 EHS	**Boiler output (kW), based on majority of sales in 2017**				
	12	15	18	24	30
	Boiler oversize factors (boiler vs design heat loss)				
4.4	2.7	3.4	4.1	5.5	6.8
5.6	2.1	2.7	3.2	4.3	5.3
5.6	2.1	2.7	3.2	4.3	5.3
6.2	1.9	2.4	2.9	3.9	4.9
7.0	1.7	2.1	2.6	3.4	4.3
9.0	1.3	1.7	2.0	2.7	3.3
10.4	1.2	1.4	1.7	2.3	2.9

The unweighted average of all the values presented in Table 11 is 3.1. From this analysis, we believe that BEIS's assumption of a typical oversizing factor (between design heat loss and boiler output) of 3.1 is credible. We suspect that over-sizing will vary significantly, where the majority of boilers will be near or above this typical value.

We considered the distribution of Design Heat Load, as presented in Figure 3, versus the distribution of boiler sales by Boiler Output (kW) - as presented in Figure 4. In the example of combi gas boilers, despite the range in Design Heat Loss – which would be wider than the range of average design heat losses in Figure 3 - >60% of combi boilers have a heat output between 24-25kW. Clearly, this will introduce a wide variation in over-sizing factor. Further notes on boiler size distribution appears in Annex C.

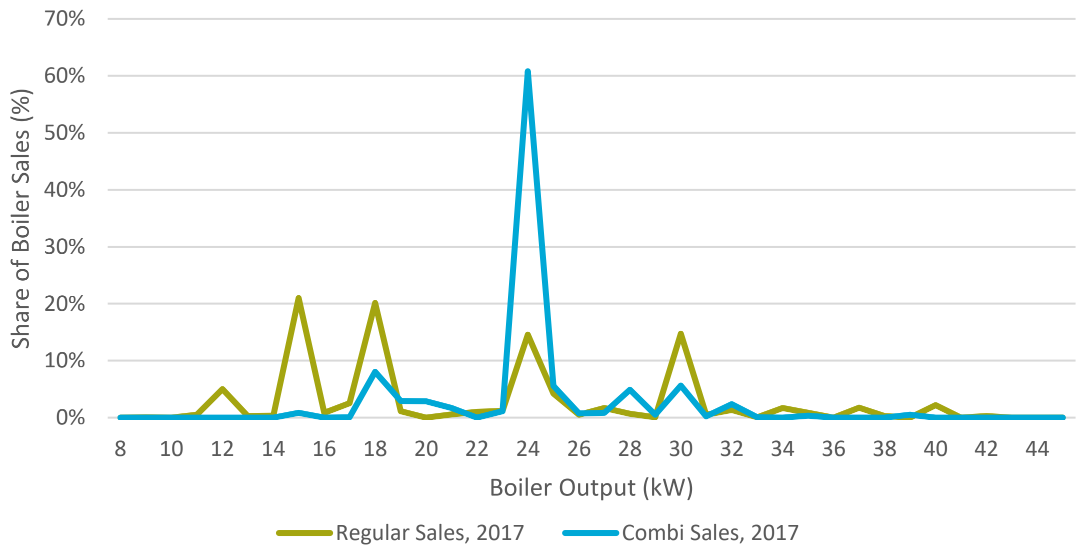


Figure 4: Share of boiler sales by boiler space heating output (kW) from 2017 industry sales data

By weighting the boiler oversizing factors presented in Table 11 by the average distribution of the boiler stock – as presented in Figure 4, the oversizing factor is then calculate to be 3.6. It is important to note that for each dwelling heat load the same distribution of boiler sizes is assumed – arguably an oversimplification. If the boiler oversizing factors presented in Table 11 are weighted according to the building stock breakdown, as presented on the y-axis in Figure 3, the average oversizing factor weighted according to the building stock is 2.9. If the boiler oversizing factors presented in Table 11 are cross-weighted according to both the building stock breakdown and the boiler size distribution then the oversizing factor is calculated to be 3.3.

It is important to note that the values presented above are purely theoretical oversizing values and are not supported by any in situ performance measurement. These values differ significantly from the oversizing factor values garnered from interviews with installers. As previously discussed, the majority of installers see the oversizing factor as just the oversizing that takes place steps E to F (Figure 2). The oversizing factors reported by boiler installers in the in-depth interviews and online surveys varied between 1.3 and 2.0.

Combi boiler oversizing

In most cases combi boiler are sized by installers according to the domestic hot water flow rate required. Therefore, for combi boilers most installers do not follow steps A to F (Figure 2) to size the boiler. It is assumed that if the boiler can meet the required hot water flow-rate requirement then the boiler will be able to comfortably meet the space-heating requirement. In cases where only a single bathroom is present in a dwelling the minimum combi boiler size installed is in most cases a 24kW combi boiler. A 24kW combi boiler is used since this is thought to be the minimum boiler capacity that can comfortably supply enough hot water to a shower / bath. For dwellings that require the simultaneous flow of hot water for two or more uses (e.g. two simultaneous showers) then in most cases a 30kW combi boiler will be installed. This in turn means that when considering combi boilers only the oversizing factors that appear in the last two columns of Table 11 apply. The unweighted average of the oversizing factors of 24kW and 30kW boilers (as they appear in Table 11) is 4.2.

Issues associated with boiler oversizing

Based on the calculations presented above, the average oversizing of gas boilers is between 280% and 360% (OSF 2.8 – 3.6) - boiler output versus building heat load. Our conversations with installers, boiler manufactures as well as the HHIC, indicated this large degree of oversizing is not detrimental to the homeowner. Modern boilers are capable of efficiently modulating their output to a fraction of the stated maximum boiler output. Most boilers can effectively modulate by a ratio of at least 5:1, with some boilers being able to modulate by a ratio of 10:1 or greater. For example, a modern 24kW boiler should be able to produce a minimum output of 4.8 kW (24kW / 5 = 4.8kW, using a modulation ratio of 5:1), or lower, while still maintaining its stated efficiency.

Oversizing of biomass boilers

A similar approach to the oversizing of gas boilers was used to determine the oversizing factor of biomass boilers. A key difference between biomass boilers and regular gas boilers is that biomass boilers tend to be installed in larger rural, off-gas grid, homes. Furthermore, rather than using a wide range of building heat loads, the analysis of the oversizing factor for biomass boilers was restricted to three typical dwelling types. This is because unlike gas boilers, biomass boilers are usually installed into a much more select number of dwellings types. These dwelling types were selected based on the in-depth interviews with the biomass boiler installers. Table 12 presents the typical oversizing values for biomass boilers.

Table 12: Oversizing factor calculated per dwelling type for most popular biomass boiler capacities

Dwelling type	Average space heating design heat load (kW)	Biomass boiler output (kW)					
		10	15	20	25	30	40
		Boiler oversize factors (boiler vs design heat loss)					
Rural new build (average detached)	7.0	1.4	2.1	2.8	3.6	4.3	5.7
Rural medium heat load (25% larger than average detached)	12.8	0.8	1.2	1.6	2.0	2.3	3.1
Large, old house (50% larger than average detached)	21.2	0.5	0.7	0.9	1.2	1.4	1.9

The average oversizing factor, based on the values in Table 12 above is 2.1. Based on the in-depth interviews with biomass boiler installers an assumed distribution of each biomass boiler capacity for each dwelling type was applied in order to weight the oversizing factor to better represent the true theoretical oversizing. These weighted oversizing factors are presented in Table 13.

Table 13: Oversizing factor for biomass boilers weighted according to assumed boiler capacity distributions per dwelling heat load

Dwelling type	**Biomass boiler output (kW)**						Average OSF (weighted by deployment rates)
	10	18	20	25	30	40	
	Estimated deployment rates						
Rural new build (average detached)	24%	60%	7%	7%	1%	0%	2.1
Rural medium heat load (25% larger than average detached)	0%	30%	35%	25%	8%	2%	1.6
Large, old house (50% larger than average detached)	0%	0%	1%	9%	45%	45%	1.6

The average weighted oversizing factors based on the assumed boiler distributions presented in Table 13 (giving equal weighting to each dwelling segment) is 1.8. It is important to note that the values presented above are purely theoretical oversizing values and are not supported by any in situ performance measurement. These values differ from the oversizing factor values garnered from interviews with installers. As previously discussed, the majority of installers see the oversizing factor as just the oversizing that takes place steps E to F (Figure 2). The oversizing factors reported by biomass boiler installers in the in-depth interviews varied between 1.0 and 1.3.

Oversizing of heat pumps

Due to the capital-intensive nature of heat pumps, they are mostly designed to meet the peak heat load of the dwelling with little 'headroom' / oversizing. In many cases, back-up immersion heaters are used to ensure the hot water cylinder can always supply hot water at the correct temperature.

A similar approach to the oversizing of gas boilers was used to determine the oversizing factor of heat pumps. However, rather than using a wide range of building heat loads, the analysis of the oversizing factor for heat pumps was restricted to three typical dwelling types in which heat pumps are commonly installed. These dwelling types were informed by the in-depth interviews with the heat pump installers. Table 14 presents the typical oversizing values for heat pumps.

Table 14: Oversizing factor calculated per dwelling type for most popular heat pump capacities

Dwelling type	**Average space heating design heat load (kW)**	**Heat pump output (kW)**				
		6	8	10	12.5	16
		HP Oversize Factors (HP vs Design Heat Loss)				
Old retrofit (average floor area of semi and detached)	8.0	0.8	1.0	1.3	1.6	2.0
New semi-detached	4.5	1.3	1.8	2.2	2.8	3.5
New-detached	7.0	0.9	1.1	1.4	1.8	2.3

The average oversizing factor, based on the values in Table 14 above is 1.7. Based on the in-depth interviews with heat pump installers an assumed distribution of each heat pump capacity for each dwelling type was applied in order to weight the oversizing factor to better represent the true theoretical oversizing. These weighted oversizing factors are presented in Table 15.

Table 15: Oversizing factor for heat pumps weighted according to assumed boiler capacity distributions per dwelling heat load

Dwelling type	**Heat pump output (kW)**					Average OSF (weighted by deployment rates)
	6	8	10	12.5	16	
	Estimated deployment rates					
Old retrofit	0%	25%	30%	25%	20%	1.4
New semi-detached	75%	20%	3%	3%	0%	1.5
New-detached	0%	75%	10%	10%	5%	1.3

The average weighted oversizing factors based on the assumed heat pump distributions presented in Table 15 (giving equal weighting to each dwelling segment) is 1.4. As reported for biomass boilers above, this is purely a theoretical approach to oversizing. The oversizing factors reported by heat pump installers in the in-depth interviews and online surveys varied between 1.0 and 1.15.

The efficiency of a heat pump, unlike any of the other heating technologies, is significantly affected by the outside temperature. Therefore, the peak heat output of the heat pumps decreases as the outside temperature decreases. This effect is greatest for air source heat pumps. Therefore, it is more challenging to calculate an exact OSF for heat pumps since their stated output is only for a certain temperature.

Oversizing of electric resistive heaters and electric storage heaters

Electric heaters are sized to cover just the space-heating requirement of a room. This means that per room or area of the house each electric heater will be marginally oversized. Based on conversations with installers and electric heating product manufactures, the rated peak capacity of an electric heater is usually less than 20% higher than the peak thermal load of the room. We estimate that the OSF for electric heaters is therefore likely to be in the region of 1.2.

5. Annex

A. Notes on other heating technologies not covered in the cost database

Back boilers

None of the installers contacted during this study still install back boilers. According to the 2016 English Housing Survey, as of 2015 there were 637,000 back boilers installed in the UK. This number has been declining by an average of 13% per year for the last 10 years (according to the 2015 English Housing Survey data). New installs are likely to number in the 100 per year. Back-boilers are very durable and long lasting and with regular maintenance can last much longer than combi or non-combi boilers. The cost of maintaining back boilers is also low. While we did not receive any concrete numbers from installers with much experience with back boilers, this cost is thought to be approximately £50 per year, on average. One of the most popular back boilers, the Baxi Bermuda, was discontinued in circa 2014. Our desk-based research indicates that the cost of a new 15kW back boiler is approximately £900, excluding VAT. This is the cost of boiler with margin (excluding controls, excluding the heat distribution system) - this is the theoretical cost of the boiler delivered to the home, with advice on sizing built in to the cost.

Due to the nature of back boiler systems, when a back boiler is replaced a large portion of the central heating system has to be replaced along with the boiler. This is largely due to most back boiler systems using a type of water distribution piping called micro bore. This type of piping requires replacing when newer types of boilers or heat pumps are installed. Therefore, the cost of replacing a back boiler is similar to the cost of a new build boiler installation.

LPG boilers

While LPG boilers were not a heating technology covered in detail, gas boiler installers (those interviewed and those responding to the online survey) were asked about how the cost of LPG boilers compares to that of gas boilers. Based on the response received, LPG boilers cost approximately 5% more than the cost of an equivalent capacity and model gas boiler. This is not surprising as LPG boilers operate in much the same manner as gas boilers. The cost of all ancillary and heat distribution equipment, including hot water cylinders (where appropriate) are the same for gas boilers and LPG boilers.

Wood chip biomass boilers

Wood chip boilers are rarely used in domestic installations. They are likely to make up less than 10% of the domestic biomass market. Due to the complex nature of operating and maintaining a wood chip boiler these types of boilers are usually limited to commercial and industrial applications.

Wood log biomass boiler

Log biomass boilers are rarely used in domestic biomass boiler installations. They are likely to make up less than 10% of all biomass boiler installations. Log boilers can only be fired when the user is present and therefore this limits their applications. Log boilers also require a more rigorous maintenance regime and more careful operation than pellet boilers. The most common case in which installing a log boiler is worthwhile for a homeowner is when the homeowner has access to a substantial source of local wood, usually in the form of a private woodland.

The cost of a log boiler of the same capacity as a pellet boiler is significantly less, up to 20% less. However, log boilers and pellet boilers of the same capacity cannot be directly compared since pellet boilers fire multiple times a day (automatically) and domestic log boiler usually are only fired twice a day (manually). This means that the capacity of log boiler required usually needs to be twice that of a pellet boiler to cover the heat load of a dwelling from only two firings a day. For example, if a 20kW pellet boiler were required to meet the heat demand of a household then in most cases a 40kW log boiler would be installed to cover the heat load of the dwelling.

Electric boilers

Electric boilers make up a very small proportion of the overall domestic heating market. There was a period approximately 10 to 5 years ago where electric boilers spiked in popularity. These boilers however were found to have numerous issues. Common issues include rapid scaling of the heating element, valve issues, expansion vessel issues, problems sourcing parts and difficult to repair units. There market niche is also significantly challenged by the electric shower.

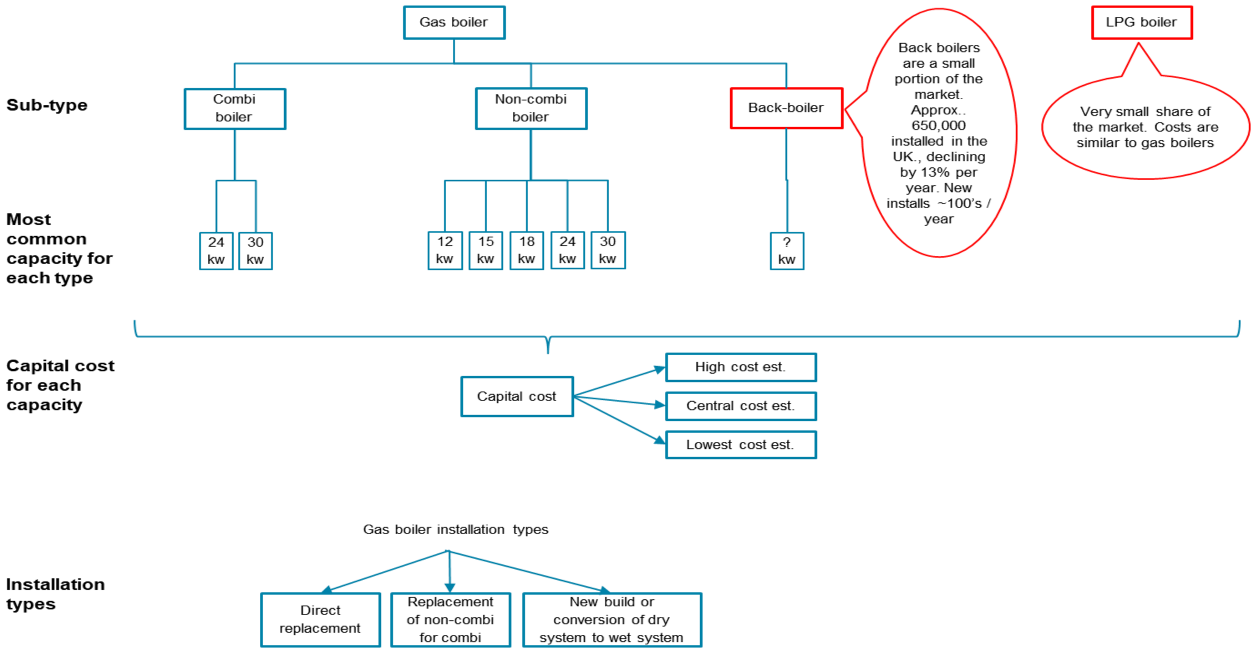
Combined heat and power (CHP)

Domestic combined heat and power units are very uncommon in the UK. The latest Proton-exchange membrane (PEM) fuel cell units cost on average £20,000 to £25,000 fully installed. A typical PEM fuel cells will have a thermal output of 1kW and an electrical output of 750W. Due to the low thermal output most domestic fuel cells are sold with integrated gas boiler units that raise the total thermal output to approximately 19kW.

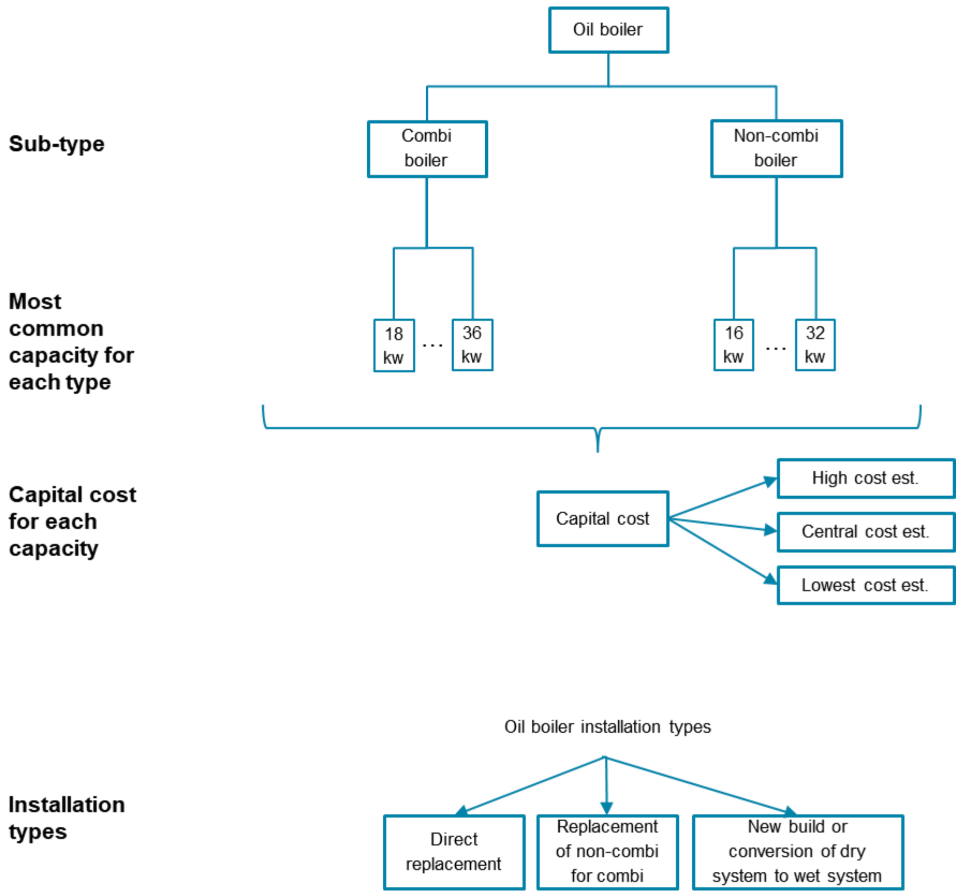
Stirling engines are another type of CHP unit. Sterling engines are not as popular as fuel cells. Sterling engines cost £8000 to £10,000 fully installed. A typical domestic Sterling engine has a thermal output of 6kW and is usually boosted by a gas boiler to approximately 25kW.

B. Detailed framework for each technology

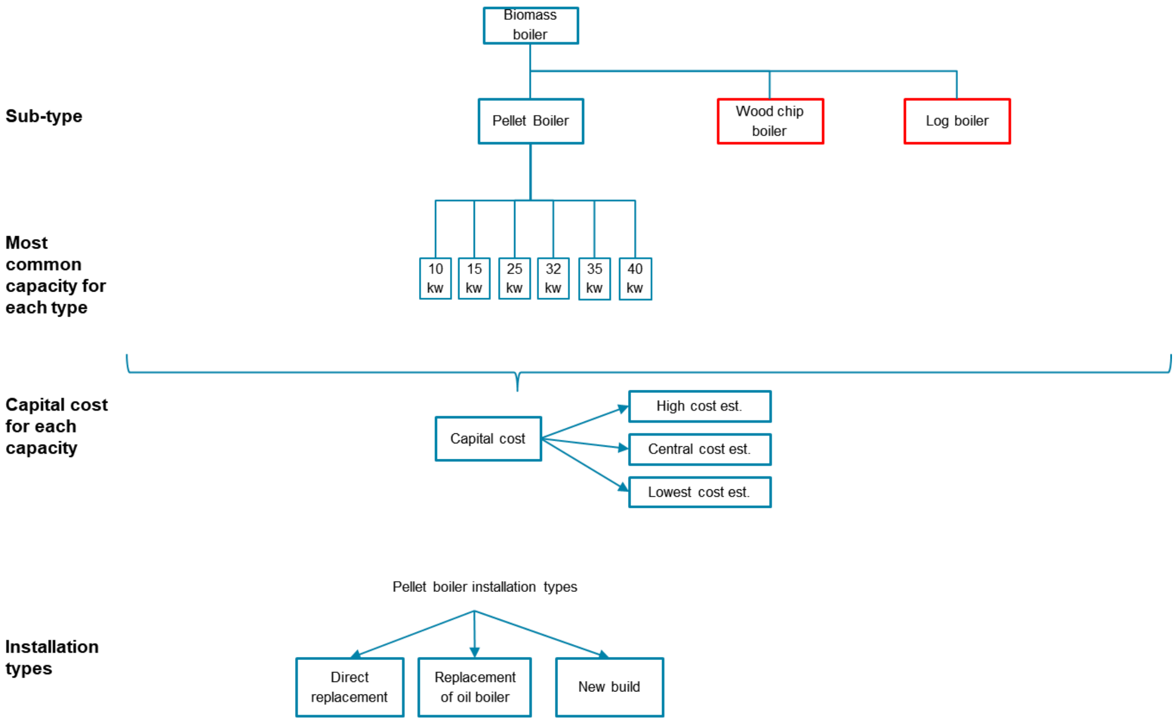
Gas boilers



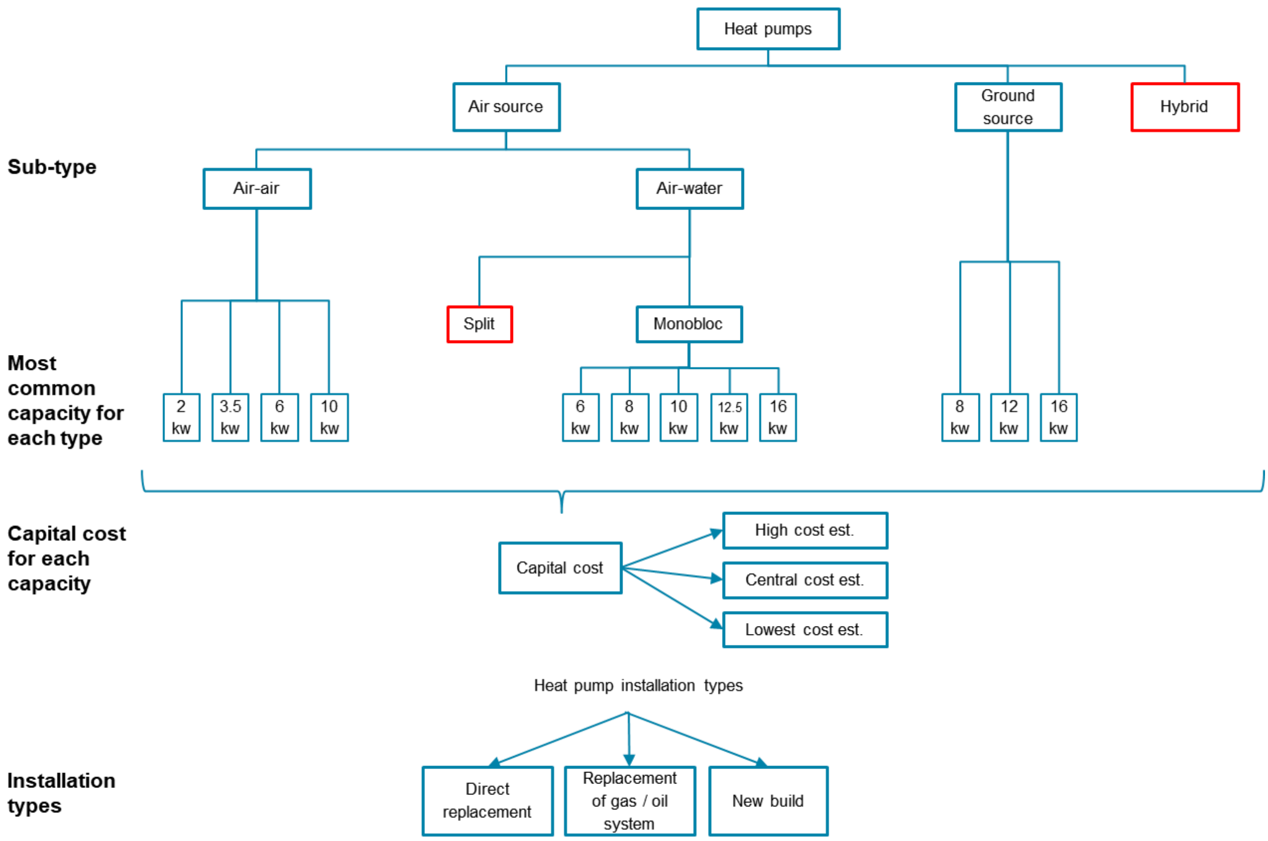
Oil boilers


Oil boiler
Sub-type
Combi boiler
Non-combi boiler
Most common capacity for each type
18 kw
36 kw
16 kw
32 kw
Capital cost for each capacity
Capital cost
High cost est.
Central cost est.
Lowest cost est.
Oil boiler installation types
Installation types
Direct replacement
Replacement of non-combi for combi
New build or conversion of dry system to wet system

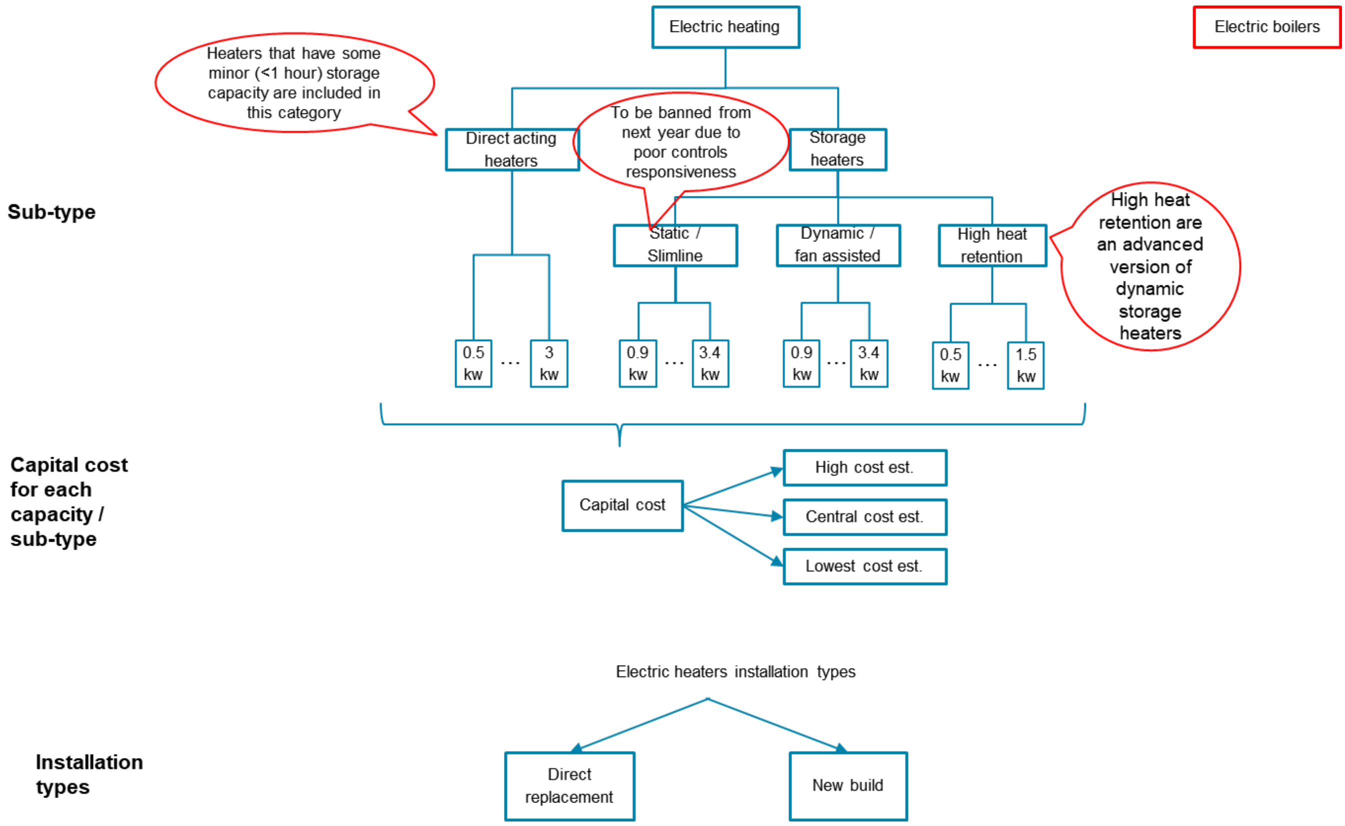
Biomass boilers



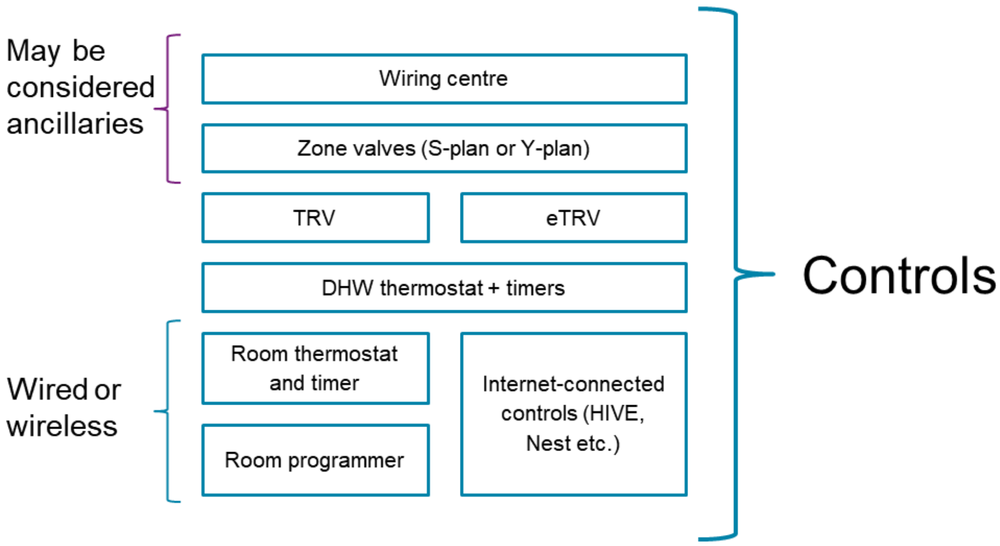
Heat pumps



Electric heating



Controls



C. Further notes on the oversizing of gas boilers

In order to support the ascertain that available boiler capacities could drive over-sizing, we analysed the SAP Product Characteristics database, to identify the distribution of boiler output (kW) for new boilers introduced to the UK market since 2012. The results are presented in Figure 5 (gas boilers), Figure 6 (LPG boilers) and Figure 7 (oil boilers). Clearly, there is evidence of grouping of boiler output around “popular” boiler sizes. This further supported by looking at boiler sales trends by boiler size, as presented in Figure 8 and Figure 9.

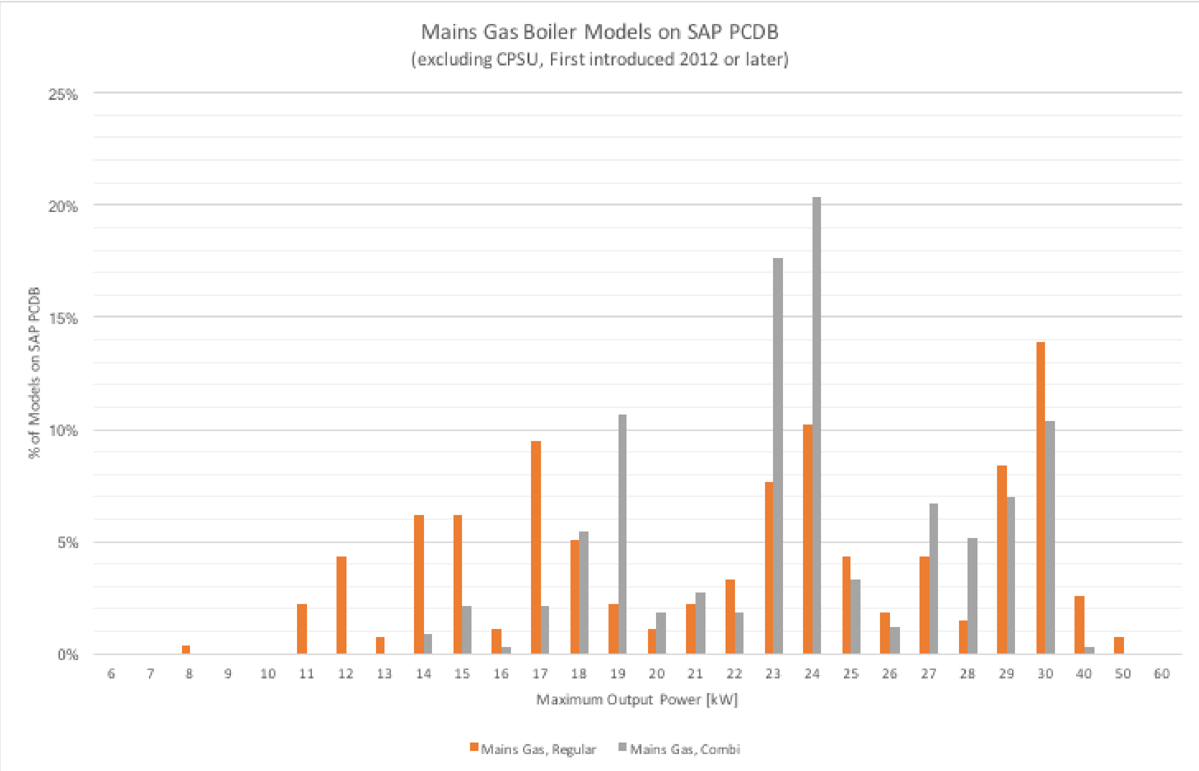


Figure 5: Distribution of gas boiler models (vs boiler rated output) on SAP Product Characteristics Database

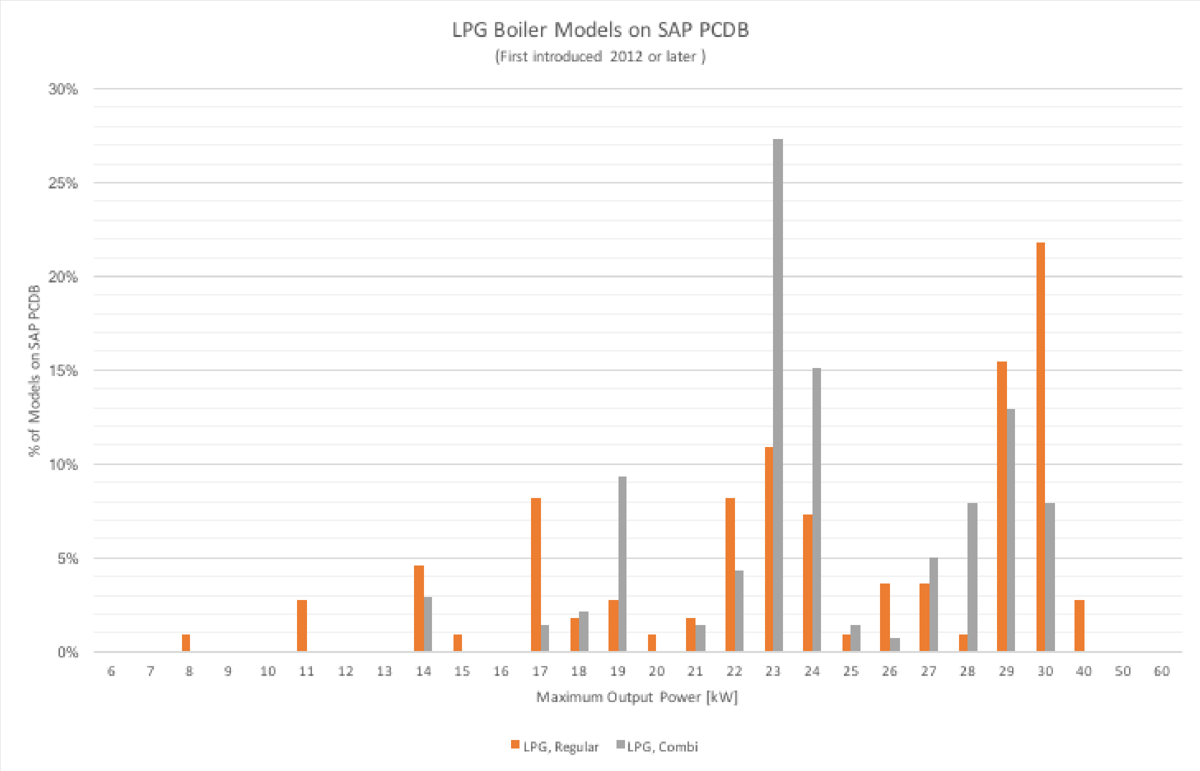


Figure 6: Distribution of LPG boiler models (vs boiler rated output) on SAP Product Characteristics Database

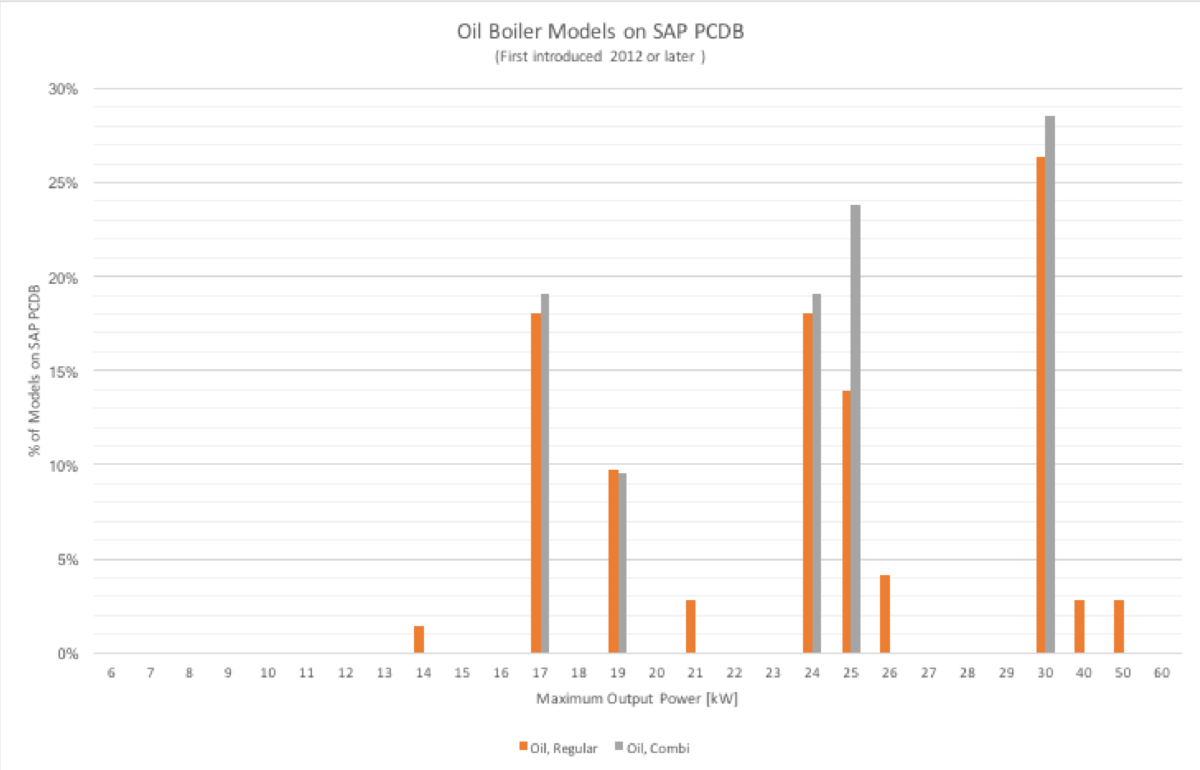


Figure 7: Distribution of LPG boiler models (vs boiler rated output) on SAP Product Characteristics Database

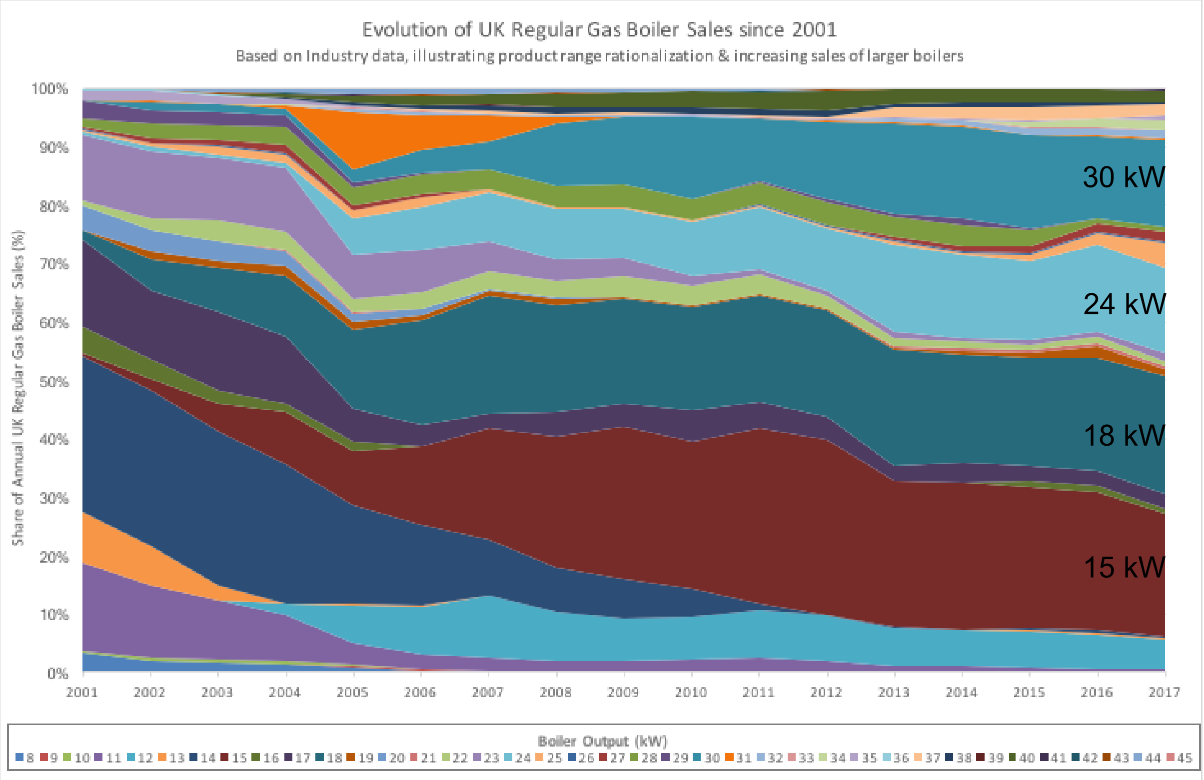


Figure 8: Distribution of gas regular boiler models (vs boiler rated output) from sales data

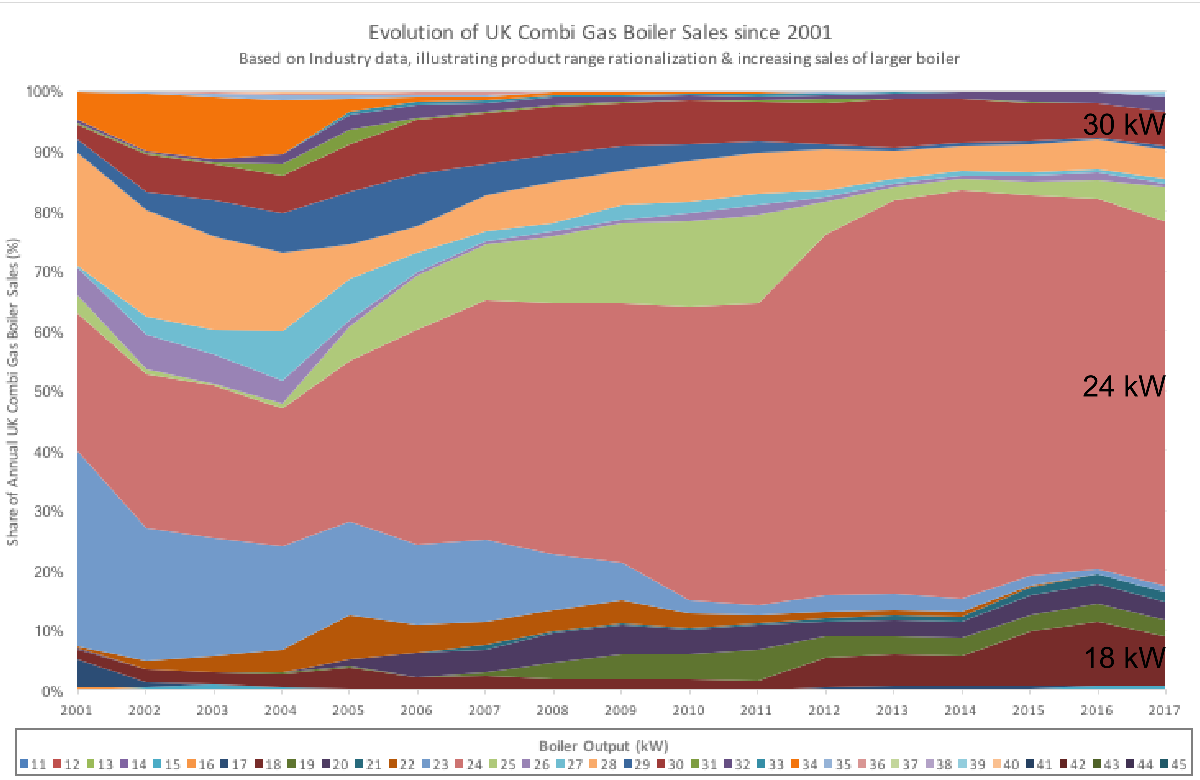


Figure 9: Distribution of gas combi boiler models (vs boiler rated output) from sales data

We have drawn several additional conclusions from our analysis of sales data (Figure 8 & Figure 9).

There appears to be general trend of size increase within regular boilers (Figure 8). Whilst this could be due to the segments of the building stock with boiler upgrades since 2001 to 2017, it is unlikely to account for all of the change. Instead, we presume that this is evidence of increasing boiler over-sizing.

If we consider the combi sales data (Figure 9), we find a general trend towards 24kW combi boilers, which has diminished both lower capacity boilers (i.e. evidence of increased over-sizing) and larger boiler capacities (which could be due to improved sizing behaviour and/or changing target building stock).

The common theme is that rationalised/standardised boiler sizes leads to a large variation in over-sizing factors (OSF), as boilers are matched with a wide range of buildings with design heat loads driven by continuous distributions of floor area and heat loss parameters.

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