Chapter 7
Combined heat and power

Key Points

- The Good Quality CHP capacity decreased by 13 MWe between 2018 and 2019 from 6,063 MWe to 6,050 MWe. (Table 7A)
- The amount of good quality electricity produced in 2019 was 23.5 TWh (Table 7.4), which is 2.2 per cent higher than in 2018. The good quality electricity generated by CHP in 2019 corresponds to 7.1 per cent of all electricity supplied in the UK.
- Sixty-nine percent of the fuel used in CHP schemes in 2019 was natural gas. This is essentially unchanged from 2018. In 2019, the share of total fuel that was renewable was 18.8 per cent, a 1.0 percentage point increase between 2018 and 2019.
- The Oil and Gas sector has the largest Good Quality CHP capacity (36 per cent), followed by the Chemicals sector (19 per cent), Other sector (13 per cent) and then the Transport Commerce and Administration sector (9.4 per cent).
- Both the absolute and relative CO_2 savings delivered by CHP fell have fallen each year between 2017-2019 for all fuels however savings delivered by CHP relative to the fossil fuel basket are more steady over time.

Introduction

7.1 This chapter sets out the contribution made by Combined Heat and Power (CHP) to the United Kingdom's energy requirements. The data presented in this chapter have been derived from information submitted to the CHP Quality Assurance programme (CHPQA) or by following the CHPQA methodology in respect of data obtained from other sources. The CHPQA programme was introduced by the Government to provide the methods and procedures to assess and certify the quality of the full range of CHP schemes. It is a rigorous system for the Government to ensure that the incentives on offer are targeted fairly and benefit schemes in relation to their environmental performance.

7.2 CHP is the simultaneous generation of usable heat and power (usually electricity) in a single process. The term CHP is synonymous with cogeneration, which is commonly used in other Member States of the European Community and the United States. CHP uses a variety of fuels and technologies across a wide range of sizes and applications. The basic elements of a CHP plant comprise one or more prime movers (a reciprocating engine, gas turbine, Rankine cycle turbine using steam or organic fluids and, more recently, steam screw expanders) driving electrical generators, with the heat generated in the process captured and put to further productive use, such as for industrial processes, hot water and space heating or cooling (via absorption chillers). In cases where the outputs of the CHP scheme are power, heat and cooling, this is referred to as tri-generation.

7.3 CHP is typically sized to make use of the available heat[1], and connected to the lower voltage distribution system (i.e. embedded). This means that, unlike conventional power stations, CHP can provide efficiency gains by avoiding significant transmission and distribution losses, which currently represent about 7.6 per cent of electricity demand in the UK. These gains are reflected in the calculation of CO_2 savings delivered by CHP (see paragraphs 7.29-7.30). CHP can also provide important network services such as black start[2], improvements to power quality, and some have the ability to operate in island mode if the grid goes down. There are six principal types of CHP system:

[1] But not always, see paragraph 7.6. In such cases there is an impact upon the electrical capacity and electrical output classified as CHP.

[2] Black start is the capability to operate in island mode if the grid goes down.

steam turbine, gas turbine, combined cycle systems, reciprocating engines, Organic Rankine Cycle (ORC) and steam expander systems. Each of these is defined in paragraph 7.37 later in this chapter.

UK energy markets, and their effect on CHP

7.4 Two major factors affecting the economics of CHP are the relative cost of fuel (principally natural gas) and the value that can be realised for electricity both for own use and export. This is known as the spark spread (i.e. the difference between the price of electricity and the price of the gas required to generate that electricity). The larger the spark spread the more favourable are the economics of CHP operation. At the start of 2013 the spark spread started to increase and did so each quarter until the middle of 2016. Between 2016 and 2018 the spark gap fluctuated in magnitude up and down. However, since 2018 the spark gap has increased steadily and at an accelerated rate during 2019. By Q4 2019 it stood at 5.6, the highest level since Q2 of 2000[3].

7.5 The effect of the introduction of a specific solid biomass CHP Renewable Heat Incentive (RHI) tariff for installations commissioned after May 2014 has encouraged the commissioning of a growing number of units based on Organic Rankine Cycle (ORC) and steam screw expander technologies. Statistics tables 7.3 to 7.7 now include a specific entry for schemes based on ORC technology, reflecting this development. These technologies are described in paragraph 7.37.

Use of CHPQA in producing CHP statistics

7.6 The CHPQA programme is the major source for CHP statistics. CHPQA schemes accounted for 91 per cent of the capacity reported in this chapter for 2019. The following factors need to be considered when using the statistics produced:

- Through CHPQA, scheme operators have been given guidance on how to determine the boundary of a CHP scheme (what is regarded as part of the CHP installation and what is not). A scheme can include multiple CHP prime movers[4], along with supplementary boilers and generating plant, subject to appropriate metering being installed to support the CHP scheme boundaries proposed, and subject to appropriate metering and threshold criteria. (See CHPQA Guidance Note 11 available at www.gov.uk/chpqa-guidance-notes). This point is relevant when considering the figures in Table 7D, where the power efficiencies, heat efficiencies and heat to power ratios stated in that table for 2019 are those of the scheme, which may not be just the prime mover.

- The output of a scheme is based on gross power output. This means that power consumed by parasitic plant such as pumps and fans is included in the power output of the scheme.

- The main purpose of a number of CHP schemes is the generation of electricity including export to other businesses and to the grid. There may not be demand for all of the available heat from such schemes. In such cases, the schemes' total electrical capacity and electrical output have been scaled back using the methodologies outlined in CHPQA (see www.gov.uk/chpqa-guidance-notes). Only the power output from highly-efficient or "Good Quality" schemes is counted in this chapter. Consistent with this, the fuel reported in this chapter is only that which is considered to have generated the Good Quality power output and the heat. This means that where a scheme's power output has been scaled back the fuel reported in this chapter is less than the total fuel input to the scheme. Chapter 5 includes all CHP capacity, fuel inputs and power outputs, for both highly-efficient, or "Good Quality", and less efficient schemes, under the categories "Other generators".

- There are two load factors presented in Table 7A. Load Factor (CHPQA) is based on the Good Quality Power Output and Good Quality Power Capacity reported in this Chapter. Load Factor (Actual) is based on the Total Power Capacity and the Total Power Output. The Load Factor (CHPQA) is lower than the Load Factor (Actual) for schemes that have been scaled back on the power outputs. The load factor gives an indication of the degree to which the power generating capacity is utilized. Between 2007 and 2013 Load Factor (CHPQA) steadily declined, but has undergone a steady increase every year since then. In 2016 there was an appreciable upturn in Load Factor (Actual), which was due to a number of large CHP generators in the Chemicals and

[3] Based on fuels purchased by manufacturing industry, QEP 3.1.2 www.gov.uk/government/statistical-data-sets/prices-of-fuels-purchased-by-manufacturing-industry

4 The CHP prime mover is the heart of a CHP system and is a mechanical machine which drives the electricity generator or develops mechanical power for direct use

Oil Refineries sectors increasing their production of electricity. Load Factor (Actual) in 2019 was again high (59 per cent), which is the second highest since 2008 (with the exception of 2016).

Table 7A: A summary of the recent development of CHP[(1)]

	Unit	2015	2016	2017	2018	2019
Number of schemes		2130	2224	2406	2497	2547
Net No. of schemes added during year (2)		59	94	182	91	50
Electrical capacity (CHP_{QPC})	MWe	5708	5625	5919	6063	6050
Net capacity added during year		-179	-83	294	144	-13
Capacity added in percentage terms	Per cent	-3.0	-1.5	5.2	2.4	-0.2
Heat capacity	MWth	20091	19785	20586	20934	20690
Heat to power ratio *(3)*		2.06	1.99	1.95	1.87	1.78
Fuel input *(4)*	GWh	82576	85132	91257	93480	92591
Electricity generation (CHP_{QPO})	GWh	19534	20406	21771	22945	23461
Heat generation (CHP_{QHO})	GWh	40234	40671	42500	42836	41697
Overall efficiency *(5)*	Per cent	72.4	71.7	70.4	70.4	70.4
Load factor (CHPQA) *(6)*	Per cent	39.1	41.4	42.0	43.2	44.3
Load factor (Actual) *(7)*	Per cent	51.0	60.0	56.3	57.1	59.1

(1) Data in this table for 2018 have been revised since last year's Digest as more up to date information on the performance and status of some CHP schemes has become available.
(2) Net number of schemes added = New schemes – Decommissioned existing schemes.
(3) Heat to power ratios are calculated from the qualifying heat output (QHO) and the qualifying power output (QPO).
(4) Fuel input is the fuel deemed to have generated the qualifying power output (QPO) and qualifying heat output (QHO).
(5) Overall efficiencies are calculated using qualifying power output (QPO), qualifying heat output (QHO) and fuel input. Fuel input is expressed in Gross Calorific Value (GCV) terms. When fuel input is expressed in Net Calorific Value (NCV) terms, efficiencies will be higher.
(6) The load factor (CHPQA) is based on the qualifying power output (QPO) and qualifying power capacity (QPC) and does not correspond exactly to the number of hours run by the prime movers in a year.
(7) The load factor (Actual) is based on the total power generated and total power capacity.

Efficiency of CHP schemes

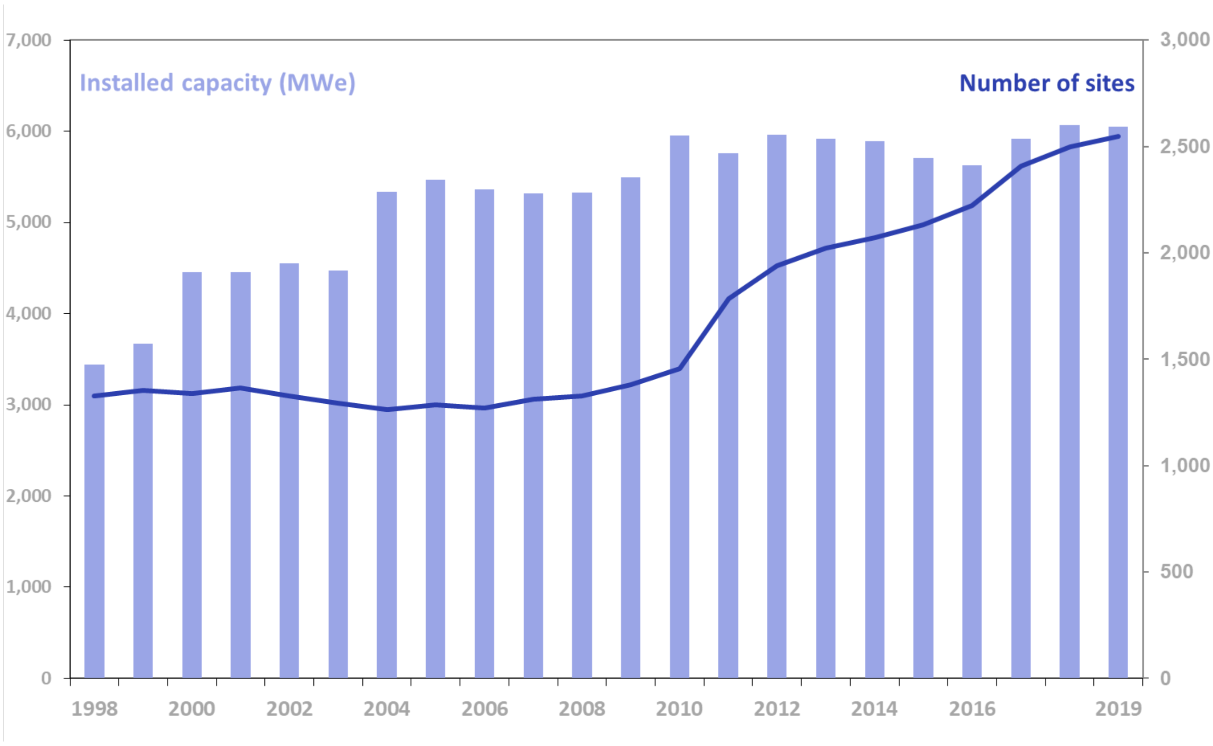
7.7 Good Quality CHP denotes schemes that have been certified as being highly efficient through the UK's CHP Quality Assurance (CHPQA) programme. The criteria used are in line with the requirements for high efficiency CHP set down in the Energy Efficiency Directive (2012/27/EU). A Good Quality CHP scheme, with installed capacity ≥1 MWe, must achieve 10 per cent primary energy savings compared with the EU reference values for separate generation of heat and power i.e. via a boiler and power station. Good Quality CHP schemes with installed capacity <1 MWe must achieve primary energy savings greater than zero per cent.

Changes in CHP capacity

7.8 Chart 7.1 shows the change in installed CHP capacity since 2001, when the CHPQA programme began. Installed capacity at the end of 2019 stood at 6,050 MWe, a decrease of 13 MWe (0.2 per cent) compared to 2018. There was a net increase of 50 (2.0 per cent) in the number of schemes between 2018 and 2019. Overall, between 2018 and 2019, there were 63 new schemes included in the database and a removal of 13 schemes. There have been revisions to the capacity figures for 2018 shown in the previous edition of the Digest, as more up to date information on the performance and operational status of some schemes has become available.

7.9 Included in the statistics are a number of CHP schemes fuelled by biogas generated by anaerobic digesters which do not submit to CHPQA. These particular schemes are included on the basis that food waste makes up part of the composition of the feedstock and that, therefore, pasteurisation of the feedstock, or digestate, is required. As stated in paragraph 7.1, where data from sources other than CHPQA are used, the CHPQA methodology is nevertheless used to determine the qualifying capacities, fuel inputs, power and heat outputs, which are reported in this chapter. Under CHPQA, heat is only counted if it is deemed "useful heat". Useful heat from CHP is heat that is demonstrably utilised to displace heat that would otherwise be supplied from other sources. In the absence of CHP heat, heat to carry out the necessary pasteurisation of the feedstock or digestate, where the feedstock includes food waste, would have to come from another source. As such, at least some of the heat output from these particular CHP schemes is deemed useful heat, and so these schemes are included in the statistics. It is possible to include these schemes as robust information has become available about the composition of the feedstock to the digesters. These schemes are included in the statistics for years of operation 2017, 2018 and 2019 and have not been added retrospectively for earlier years.

Chart 7.1: Operating CHP capacity 1998 - 2019



7.10 Table 7A gives a summary of the overall CHP market. In 2019, CHP schemes generated 23,461 GWh of Good Quality electricity, 2.2 per cent higher than in 2018. This generated electricity represents 7.1 per cent of the total electricity generated in the UK. The quantity of Good Quality electricity generated in industry rose by 1.1 per cent between 2018 and 2019. Good Quality electricity output rose in all industrial sectors between 2018 and 2019 with the exception of Chemicals and Mineral Products. In Chemicals, it fell by a significant 16 per cent and in Mineral Products it fell by 7.8 per cent. The fall in Chemicals was due to a fall in the heat generated rather than a fall in the total electricity generated; for a given level of electricity generated, the proportion of this which is deemed Good Quality decreases as the heat recovered decreases. A very large proportion of this effect in Chemicals was due to a fall in heat recovered at one large CHP scheme. The fall in Mineral Products was due to a fall in all electricity generated, not just Good Quality. The Transport, Commerce and Administration (TCA) sector continued the rise in Good Quality electricity outputs seen over a number of years, with an increase of 5.7 per cent between 2018 and 2019. There was another increase in Good Quality electricity output from the Other sector (5.9 per cent).

7.11 Table 7A shows that CHP schemes supplied a total of 41,697 GWh of heat in 2019. This was a decrease of 2.7 per cent (1,140 GWh) compared to 2018. All of this fall took place within industry, where there were falls in heat output in the Chemicals, Oil and Gas, Food and Drink and Mineral Product sectors. The most significant fall was within the Chemicals sector, where the heat output decreased by 12 per cent (1,183 GWh) between 2018 and 2019. As explained above, there was a significant fall in heat output at one CHP scheme in Chemicals. There were increases in heat output in the non-industrial sectors, with increases of 4.6 per cent (155 GWh) in Other and 1.4 per cent (53 GWh) in Transport, Commerce and Administration (TCA).

7.12 In terms of electrical capacity by size of scheme, schemes larger than 10 MWe represent 70 per cent of the total electrical capacity of CHP schemes, as shown in Table 7B. Schemes less than 1 MWe constitute the majority of scheme numbers (79 per cent), but just 6.7 per cent of the total capacity. However, over time the proportion of total capacity accounted for by schemes over 10 MWe has decreased steadily, and was 78 per cent in 2014.

Table 7B: CHP schemes by capacity size ranges in 2019

Electrical capacity size range	Number of schemes	Share of total (per cent)	Total electricity capacity (MWe)	Share of total (per cent)
Less then100 kWe	700	27.5	45	0.7
100 kWe - 1 MWe	1,320	51.8	358	5.9
1 MWe - 2 MWe	207	8.1	306	5.1
2 MWe - 10 MWe	252	9.9	1,126	19
> 10 MWe +	68	2.7	4,216	70
Total	**2,547**	**100**	**6,050**	**100**

7.13 Table 7.5 shows that 50 per cent of total electrical capacity operates in combined cycle gas turbine (CCGT) mode and 28 per cent is from reciprocating engines. Simple cycle gas turbines accounted for 12 per cent of installed capacity in 2019. Over time there has been a steady decrease in the proportion of total installed capacity taken up by CCGT and a steady increase in the proportion of this taken up by reciprocating engines. For example, in 2006 these proportions were 75 per cent (CCGT) and 11 per cent (reciprocating engines). Over the last few years there has been an absolute fall in the capacity of CCGT schemes, with the large majority of this capacity being lost from the Chemicals and Paper sectors. Over the same period, there has been an absolute increase in the installed capacity of reciprocating engines, with a large proportion of these additions taking place within the TCA and Other sectors. While the capacity of back-pressure steam turbines has been decreasing over the years, in recent years there has been an increase in the capacity of pass-out condensing steam turbine scheme as new biomass and waste fuelled CHP schemes have been developed .The relatively inefficient and inflexible nature of back pressure steam turbines means that this technology is falling out of favour.

7.14 Excluded from the statistics tables presented in this chapter are a number of very small CHP schemes (micro-CHP) installed since 2010 in response to the Feed-in Tariff (FiT) scheme. The overwhelming majority of these schemes are domestic. At the end of 2019 there were 531 such schemes registered with Ofgem for FiTs with a total installed capacity of 582 kWe. There are no data on electricity generation or fuel consumption for these schemes and, consequently, they have been left out of the statistics tables. However, if included, there would have a negligible impact upon the capacity and generation figures presented in the statistics tables.

7.15 Table 7.7 provides data on heat capacity for each type of CHP installation. Starting in the 2013 edition of the Digest, there has been a change implemented in how the heat capacity has been derived. Prior to this, for a number of schemes, the data held on heat capacity were either not complete or were not a true reflection of the capacity of the scheme to generate heat in CHP operating mode. To allow for this, a standard methodology was developed and applied for the first time in the 2013 edition of the Digest for the determination of the heat capacity. This is applied to new schemes and schemes undergoing a change in plant. Details of this methodology may be found in the CHP methodology note which is available from the following link:
www.gov.uk/government/publications/combined-heat-and-power-statistics-data-sources-and-methodologies

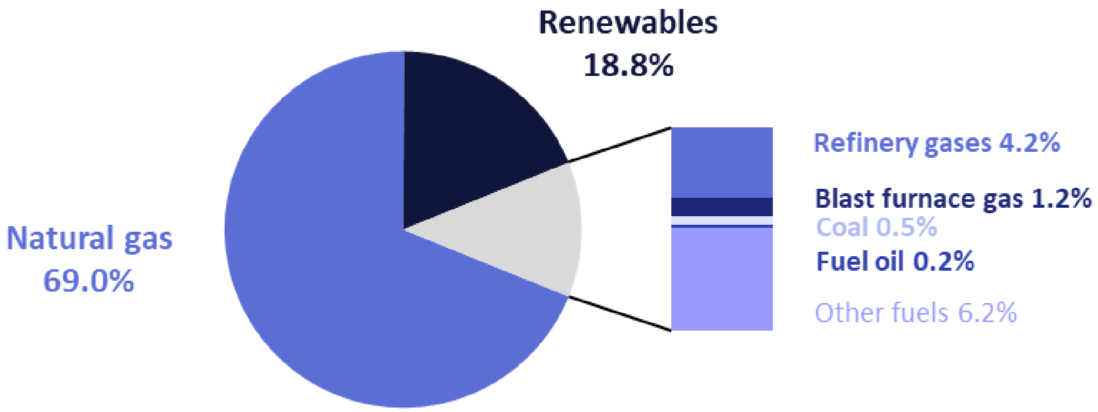
Fuel used by types of CHP installation

7.16 Table 7.2 shows the fuel used to generate electricity and heat in CHP schemes (see paragraphs 7.38 to 7.40 below for an explanation of the convention for dividing fuel between electricity and heat production). Table 7.3 gives the overall fuel used by types of CHP installation (which are explained in paragraph 7.37). Total fuel use is summarised in Chart 7.2. In 2019, 69 per cent of the total fuel use was natural gas and this is same as in 2018. CHP schemes accounted for 7.9 per cent of UK gas demand in 2019 (see Table 4.3). Coal and fuel oil only account of 0.7 percent of overall CHP fuel use.

7.17 The proportion of total fuel consumption that was renewable was 19 per cent in 2019. This is a 1 percentage point increase compared to 2018. Solid biomass fuels accounted for the largest share of renewable fuel (58 per cent), followed by gaseous renewable fuels (41 per cent) and liquid renewable fuels (1.7 per cent).

7.18 Fuels which are liquids, solids or gases that are by-products or waste products from industrial processes, or are renewable fuels, accounted for 29 per cent of all fuel used in CHP in 2019. This is 0.4 percentage points higher than in 2018. Over this period,there was a decrease in the consumption of waste heat as a energy input to CHP in the Chemicals sector.

Chart 7.2: Types of fuel used by CHP schemes in 2019



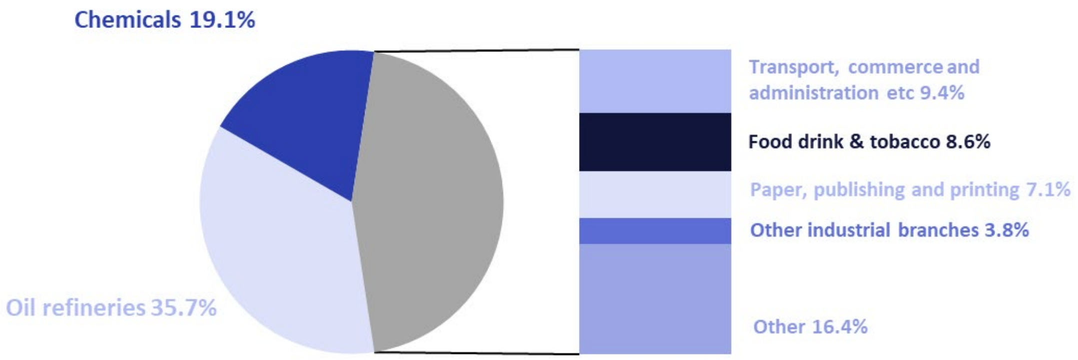
CHP capacity, output and fuel use by sector

7.19 In this chapter of the Digest, CHP is analysed by the sector using the heat or, where the heat is used by more than one sector, by the sector using the majority of the heat. This method of assigning a CHP scheme to a sector was rigorously applied for the first time in the 2008 edition of the digest and resulted in the movement of CHP schemes between sectors. One consequence of this was the removal of all schemes once allocated to the "electricity supply" sector and their distribution to other sectors. Full details of this reassignment are provided in paragraph 6.33 and Table 6J of the 2008 edition of the digest.

7.20 Table 7.8 gives data on all operational schemes by economic sector. A definition of the sectors used in this table can be found in Chapter 1, paragraph 1.59 and Table 1F:

- 426 schemes (77 per cent of electrical capacity) are in the industrial sector and 2,121 schemes (23 per cent of capacity) are in the agricultural, commercial, public administration, residential and transport sectors. The share of capacity in the industrial sector was lower in 2019 than in 2018 and this continues a long standing trend.
- The share of total installed Good Quality capacity taken up by each sector is shown in Chart 7.3. The Oil and gas terminals sector, which has been the largest sector since 2009, continues to have the largest share of total installed capacity, accounting for 36 per cent of all capacity. The Chemicals sector, which until 2008 had the largest share of capacity, had the second largest share in 2019 (19 per cent), followed by the "Other" sector (13 per cent) and Transport, commerce and administration (TCA) at 9.4 per cent. Between 2018 and 2019 the installed Good Quality capacity fell in Oil Refineries (2.1 per cent) and also slightly in Chemicals. In all of the other industrial sectors the capacity was either unchanged or increased slightly. The Good Quality capacity increased by 3.3 per cent and 2.4 per cent in the Other and TCA sectors, respectively.

Chart 7.3: CHP electrical capacity by sector in 2019



(1) Other sectors include agriculture, community heating, leisure, landfill and incineration
(2) Other industry includes textiles, clothing and footware, sewage treatment, metal machinery & equipment Iron steel & non ferrous metals and extraction/ agglom. of solid fuels

7.21 Table 7C gives a summary of the 1,747 schemes installed in the commercial sector, public sector and residential buildings. These schemes form a major part of the "Transport, commerce and administration" and "Other" sectors in Tables 7.8 and 7.9. The vast majority of these schemes are based on spark ignition reciprocating engines fuelled with natural gas, though the larger schemes use compression ignition reciprocating engines or gas turbines. The largest proportion of the capacity remains in the health sector (33 per cent). About half of all schemes installed in buildings are in leisure and hotel settings, reflecting the suitability of CHP for meeting the demand profiles for heating and hot water in these types of building. The high heat to power ratio in the health sector is a reflection of the acute need for security of heat supply at hospitals, provided by back-up boilers, rather than the heat to power capacity ratios inherent in the prime mover used for power generation (see Definitions of schemes under Technical notes and definitions).

Table 7C: Number and capacity of CHP schemes installed in buildings by sector in 2019

	Number of schemes	Electrical capacity (MWe)	Heat capacity (MWth)
Leisure	582	76	125
Hotels	289	42	66
Health	257	221	1271
Residential Group Heating	133	110	476
Universities	101	107	532
Offices	43	17	22
Education	59	23	66
Government Estate	38	15	48
Retail	241	49	71
Other *(1)*	4	3	19
Total	**1,747**	**663**	**2,696**

(1) All schemes under Other are at airports

7.22 According to the Energy Performance in Buildings Directive, District Heating and Cooling (DHC) is the distribution of thermal energy in the form of steam, hot water or chilled products from a centralised place of production through a network to multiple buildings or sites for space or process heating or cooling. For statistical purposes, EUROSTAT further stipulates that, as well as more than one building or site having to be supplied, there must also be more than one customer for the heating or cooling supplied. Comprehensive data on Community Heating (CH) and District Heating (DH) schemes in the United Kingdom became available for the first time in 2017 when data submissions, made to the Office of Public Safety and Standards, as required under Article 3 of The Heat Network (Metering and Billing) Regulations 2014, were processed. Using these data and updated information from CHPQA, and adopting the EUROSTAT definition of DH, in 2018 there were an estimated 244 DH schemes using CHP in the UK, with a heat capacity of 5,351 MWth and supplying 7,760 GWh of heat to their associated DH networks[5].

CHP performance by main prime mover

7.23 Table 7D gives a summary of the performance of schemes in 2019 by main prime mover type. In 2019 the prime mover type with the highest average operating hours was reciprocating engines followed by gas turbines.

7.24 In 2019, the average operating hours were 3,878 hours. The average operating hours in 2018 (revised) was 3,784 hours, indicating an increase in the utilisation of good quality capacity over the period. This continues an upward trend in the utilisation of good quality capacity which started in 2014.

7.25 In 2019, the average electrical efficiency was 25 per cent and the heat efficiency 45 per cent, giving an overall average of 70 per cent. This overall efficiency is essentially unchanged since 2018. Overall efficiency is simply the sum of the individual electrical and heat efficiencies.

Table 7D: A summary of scheme performance in 2019

	Average operating hours per annum (Full load equivalent)	Average electrical efficiency (% GCV)	Average heat efficiency (% GCV)	Average overall efficiency (% GCV)	Average heat to power ratio
Main prime mover in CHP plant					
Back pressure steam turbine	1,665	6.8	89	96	13.1
Pass out condensing steam turbine	3,594	16	35	50	2.2
Gas turbine	4,045	25	39	63	1.6
Combined cycle	3,876	27	49	76	1.8
Reciprocating engine	4,113	31	37	68	1.2
Organic Rankine Cycle	2,944	8.2	56	65	6.9
All schemes	**3,878**	**25**	**45**	**70**	**1.8**

CHP schemes which export and schemes with mechanical power output

7.26 Table 7E shows the electrical exports from CHP schemes between 2017 and 2018. Power export figures are based upon export meter data. The total power exported given below is therefore the value registered on the power export meter, with one adjustment made for some schemes. Where the value registered on a scheme's power export meter is greater than the Total Power Output (TPO) for the scheme, the total power exported is capped at the TPO of the scheme. This adjustment is necessary in some situations where schemes import power from another place and onward supply this power, with the onward supplied power passing through the power export meter. Mathematically, this is shown as:

TPO Exported = Value registered on power export meter

If Value registered on power export meter > TPO, then TPO Exported is set to equal TPO.

The QPO exported is the TPO exported that is deemed good quality. This is calculated by assuming that any power consumed by the scheme is good quality power (QPO). This means that only if the scheme's consumption of power is less than the QPO will QPO become available for export. Mathematically, the QPO exported is:

QPO Exported = QPO for the scheme – Electricity consumed by the scheme, where

Electricity consumed by the scheme = Total Power Output – TPO Exported

[5] When comparing these statistics with other sources, care is required to ensure that the same definition of District Heating (DH) is being used.

If QPO for the scheme < Electricity consumed by the scheme, then QPO Exported is set to zero.

Table 7E also sets out the recipients of exported power.

Table 7E: Electrical exports from CHP (TPO)

			GWh
	2017	2018	2019
To part of same qualifying group *(1)*	1,145	7,657(r)	7,626
To a firm NOT part of same qualifying group	9,720	10,752(r)	10,605
To an electricity supplier	15,740	9,605(r)	11,054
Total	**26,605**	**28,014(r)**	**29,285**

(1) A qualifying group is a group of two or more corporate consumers that are connected or related to each other, for example, as a subsidiary, or via a parent or holding company, or in terms of share capital.

Table 7F: Electrical exports from CHP (QPO)

			GWh
	2017	2018	2019
	2017	2018	2019
To part of same qualifying group *(1)*	274	1,377	902
To a firm NOT part of same qualifying group	4,408	4,656(r)	4,236
To an electricity supplier	3,787	3,424(r)	4,759

Since 2015, there has been a strong correlation between the TPO exported and the Load Factor (Actual) shown in Table 7A. This is because the very large schemes, which drive the Load Factor (Actual), also tend to be the exporters of electricity. Over this period there has also been a strong correlation between QPO exported and Load Factor (CHPQA) for broadly the same reasons.

7.27 In 2019, 69 large schemes exported heat, with some exporting to more than one customer. In 2018 there were also 69 schemes exporting heat. As Table 7G shows, these schemes supplied 9,582 GWh of heat in 2019, which is a 2.8 per cent lower than in 2018. This fall in exported heat is consistent with the fall in heat generated mentioned above, since large reductions in generated heat have occurred at schemes that are heat exporters.

Table 7G: Heat exports from CHP

			GWh
	2017	2018	2019
To part of same qualifying group *(1)*	973	1,050	1,103
To a firm NOT part of same qualifying group	8,764	8,733(r)	8,391
To an electricity supplier	66	80	87
Total	**9,802**	**9,863(r)**	**9,582**

(1) A qualifying group is a group of two or more corporate consumers that are connected or related to each other, for example, as a subsidiary, or via a parent or holding company, or in terms of share capital.

7.28 There are an estimated 10 schemes with mechanical power output. For those schemes, mechanical power accounts for 9 per cent of their total power capacity (Table 7H). These schemes are predominantly on petro-chemicals or steel sites, using by-product fuels in boilers to drive steam turbines. The steam turbine is used to provide mechanical rather than electrical power, driving compressors, blowers or fans, rather than an alternator. The statistics on schemes with mechanical power are unchanged from those for 2018, published in the previous edition of the Digest.

Table 7H: CHP schemes with mechanical power output in 2019

	Unit	
Number of schemes		10
Total Power Capacity of these schemes (CHP_{TPC})	MWe	2,173
Mechanical power capacity of these schemes	MWe	203

Emissions savings

7.29 The calculation of carbon emissions savings from CHP is complex because CHP displaces a variety of fuels, technologies and sizes of plant. The methodology and assumptions used for calculating carbon emission savings are outlined in Energy Trends June 2003[6] (www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx). The figures compare CHP with the UK fossil fuel basket carbon intensity and the UK total basket carbon intensity, which includes nuclear and renewable generation. The carbon emission savings from CHP in 2019 as compared to the fossil fuel basket were 10.47 $MtCO_2$, which equates to 1.73 Mt CO_2 per 1,000 MWe installed capacity. Against the total basket, CHP saved 4.33 Mt CO_2 which equates to 0.72 Mt CO_2 per 1,000 MWe installed capacity.

7.30 Corresponding figures for 2017 and 2018 are shown in Table 7I. The 2017 and 2018 CO_2 savings are revised based on revisions to the relevant data for these years in Tables 7.1, 7.4, 7.6 and 7.9 and revisions to the CO_2 intensity of grid electricity. Absolute savings ($MtCO_2$) are sensitive to both the levels of CHP heat and power output, the fuels used in CHP generation and, especially, the CO_2 factor attributed to grid electricity that CHP electricity displaces. Between 2017 and 2019 there was a slight increase in CHP heat and power outputs (1.4% per cent) and an increase in the share of all fuel that was renewable. However, in spite of this, when measured against the total basket of grid electricity (i.e. including nuclear and renewables), both the absolute and relative CO_2 savings delivered by CHP fell each year between 2017-2019. This happened against a background of an 8.1 per cent fall in the carbon intensity of the total basket of electricity between 2017 and 2019. The CO_2 savings delivered by CHP relative to the fossil fuel basket are more steady over time, since reductions in the carbon intensity of this basket have been far less significant.

Table 7I: Carbon dioxide savings due to CHP, absolute and per 1,000 MWe of installed good quality CHP capacity

	2017		2018		2019	
	$MtCO_2$	$MtCO_2$/1000 MWe	$MtCO_2$	$MtCO_2$/1000 MWe	$MtCO_2$	$MtCO_2$/1000 MWe
Carbon savings against all fossil fuels	10.27	1.73	10.42	1.76	10.47	1.73
Carbon savings against all fuels (including nuclear and renewables)	4.69	0.79	4.42	0.75	4.33	0.72

Note: (1) The CO_2 savings in Table 7I assume that CHP generated electricity avoids the transmission and distribution losses associated with its conventionally generated equivalent. These losses are assumed to be 1.5% in the case of transmission losses and 6.0% in the case of distribution losses.

(2) The CO_2 savings quoted above for 2019 are based on preliminary CO_2 intensities, for that year, for the fossil fuel basket and the total fuel basket of conventional electricity generation. As such, they are subject to revision at a later date. The CO_2 savings quoted above for 2017 and 2018 have also been revised in response to changes in the CO_2 intensity factors for electricity for these years since reporting in DUKES 2019.The figures have also been revised to reflect revisions to CHP electricity and heat output and fuel consumption.

Government policy towards CHP

7.31 There are a range of support measures to incentivise the growth of Good Quality CHP in the UK. These include:

- Exemption from the Climate Change Levy (CCL) of all fuel inputs to, and electricity outputs from, Good Quality CHP. This exemption has been in place since the introduction of the CCL in 2001.
- From April 2013, exemption from Carbon Price Support (CPS) on fuel to CHP consumed for the generation of heat
- From April 2015, exemption from Carbon Price Support (CPS) on fuel to CHP consumed for the generation of Good Quality CHP electricity which is consumed on site

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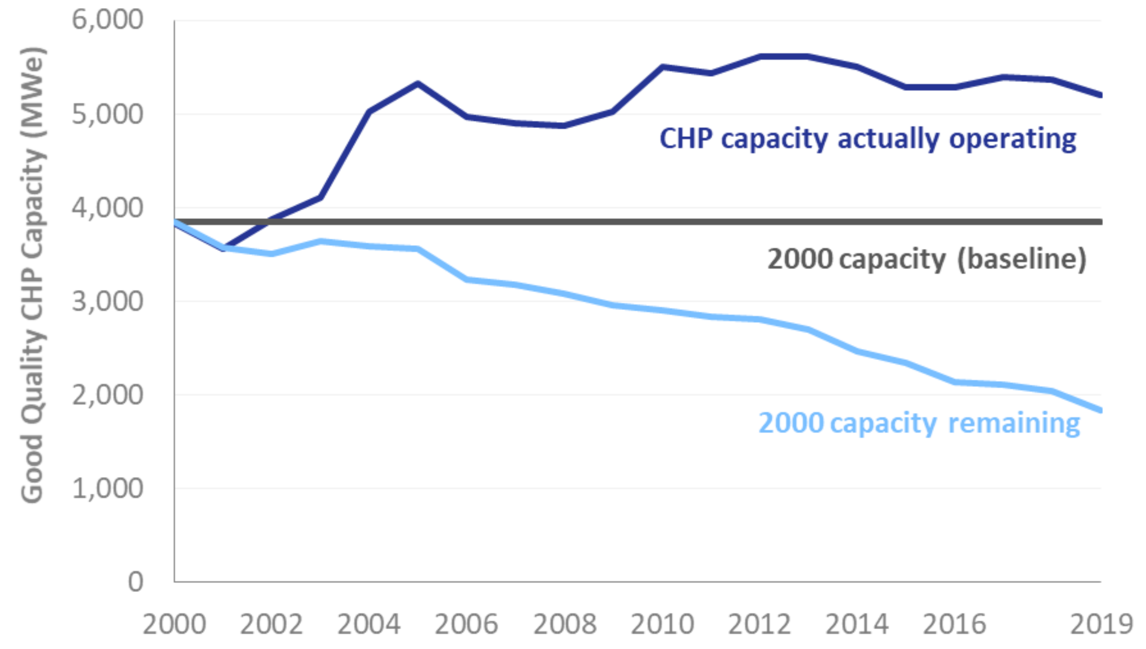
6 http://webarchive.nationalarchives.gov.uk/20060213234600/http:/www.dti.gov.uk/energy/inform/energy_trends/index.shtml

- Business Rates exemption for CHP power generation plant and machinery.
- Reduction of VAT (from 20 to 5 per cent) on domestic micro-CHP installations.
- Extension of the eligibility for Renewable Obligation Certificates (ROCs) to energy from waste plants that utilise CHP.
- Specific Renewable Heat Incentive (RHI) for biomass fuelled Good Quality CHP certified under CHPQA.
- Contract for Difference (CFD) for biomass fuelled CHP
- The zero-rating of heat under the Carbon Reduction Commitment Energy Efficiency Scheme (CRC), this means that allowances do not have to be purchased by a site covered by CRC for heat that it imports. This incentivises the use of CHP heat outputs.

7.32 Table 7.1 shows the installed Good Quality CHP capacity in each year. However, this table hides the underlying market activity that replaces older capacity as it is taken out of service over time. Chart 7.4 gives an idea of the scale of this activity since 2000 for CHP schemes certified under CHPQA. The baseline shows how much of the Good Quality CHPQA capacity that was in place in 2000 remained in place in subsequent years, while the upper line shows the actual Good Quality CHPQA capacity in place in each year. For any year since 2000, the gap between these two lines represents the new Good Quality CHPQA capacity installed between 2000 and that year. By 2018 there had been just over 3.4 GWe of new Good Quality CHPQA capacity installed since 2000.

Chart 7.4: Underlying market activity – operating Good Quality CHP versus retained Good Quality CHP, 2000 - 2019



International context

7.33 Phase III of EU ETS runs from 2013 until 2020. Under this phase there is no allocation made in respect of CO_2 emissions associated with the generation of electricity, including electricity generated by CHP. However, there is an allocation made in respect of EU ETS CO_2 emissions associated with measurable CHP heat consumption. The allocation is based upon harmonised benchmarks for heat production. In 2013 an EU ETS installation consuming CHP generated heat (not deemed at risk of carbon leakage) will have received a preliminary free allocation which is 80% of the allocation determined using this benchmark, declining linearly to 30% by 2020. Where the installation consuming the heat is deemed at significant risk of carbon leakage, then it will receive a preliminary free allocation which is 100% of the allocation determined using the benchmark for the duration of Phase III of EU ETS[7]. If the consumer of the heat is not an EU ETS installation, then the allocation is given to the heat producer. The benchmark for heat adopted by the European Commission is based on the use of natural gas with a conversion efficiency of 90% (N.C.V.). This means that the benchmark allocation made for each MWh of heat generated by a CHP scheme which is subsequently is 0.224 tCO2[8].

7 In determining the final free allocation received by the installation, the preliminary free allocation is multiplied by a factor known as the cross-sectoral correction factor. The cross-sectoral correction factor is applied to ensure that the total amount of free allocation does not exceed a certain cap. For EU ETS Phase III, the cross-sectoral correction factor is a factor that is less than 1 and declines linearly from 0.94 to 0.82 between 2013 and 2020. This means that the final free allocation is always less than the preliminary free allocation.

8 Where the CHP supplies heat to an EU ETS Phase III sub-installation or installation and the sub-installation or installation produces a product that is product benchmarked, then an allocation is not made in respect of the heat supplied but in respect of the product produced.

Technical notes and definitions

7.34 These notes and definitions are in addition to the technical notes and definitions covering all fuels and energy as a whole in Chapter 1, paragraphs 1.26 to 1.58.

Data for 2019

7.35 The data are summarised from the results of a long-term project undertaken by Ricardo Energy & Environment on behalf of the Department of Business, Energy and Industrial Strategy (BEIS). Data are included for CHP schemes installed in all sectors of the UK economy.

7.36 Data for 2019 were based on data supplied to the CHPQA programme, information from the Iron and Steel Statistics Bureau (ISSB), information from Ofgem in respect of "Renewables Obligation Certificates" (ROCs), information from the CHP Sales database maintained by the CHPA and from a survey of anaerobic digestion (AD) sites. Ninety-one per cent of the total capacity is from schemes that have been certified under the CHPQA programme. Sewage Treatment Works and other AD schemes that do not provide returns to CHPQA have been included based on ROCs and FITs information from Ofgem returns. The data from these sources accounts for approximately 6.1 per cent of total electrical capacity. The balance of the capacity is for schemes covered by ISSB sources (<1 per cent), CHPA Sales Database (<1 per cent) and for schemes not covered by the above sources which were interpolated from historical data (1 per cent).

Definitions of schemes

7.37 There are four principal types of CHP system:

- **Steam turbine,** where steam at high pressure is generated in a boiler. In **back pressure steam turbine systems**, the steam is wholly or partly used in a turbine before being exhausted from the turbine at the required pressure for the site. In **pass-out condensing steam turbine systems**, a proportion of the steam used by the turbine is extracted at an intermediate pressure from the turbine with the remainder being fully condensed before it is exhausted at the exit. (Condensing steam turbines without pass out and which do not utilise steam are not included in these statistics as they are not CHP). The boilers used in such schemes can burn a wide variety of fuels including coal, gas, oil, and waste-derived fuels. With the exception of waste-fired schemes, a steam turbine plant has often been in service for several decades. Steam turbine schemes capable of supplying useful steam have electrical efficiencies of between 10 and 20 per cent, depending on size, and thus between 70 per cent and 30 per cent of the fuel input is available as useful heat. Steam turbines used in CHP applications typically range in size from a few MWe to over 100 MWe.

- **Gas turbine systems**, often aero-engine derivatives, where fuel (gas or gas-oil) is combusted in the gas turbine and the exhaust gases are normally used in a waste heat boiler to produce usable steam, though the exhaust gases may be used directly in some process applications. Gas turbines range from 30 kWe upwards, achieving electrical efficiency of 23 to 30 per cent (depending on size) and with the potential to recover up to 50 per cent of the fuel input as useful heat. They have been common in CHP since the mid-1980s. The waste heat boiler can include supplementary or auxiliary firing using a wide range of fuels, and thus the heat to power ratio of the scheme can vary.

- **Combined cycle systems**, where the plant comprises more than one prime mover. These are usually gas turbines where the exhaust gases are utilised in a steam generator, the steam from which is passed wholly or in part into one or more steam turbines. In rare cases reciprocating engines may be linked with steam turbines. Combined cycle is suited to larger installations of 7 MWe and over. They achieve higher electrical efficiency and a lower heat to power ratio than steam turbines or gas turbines. Recently installed combined cycle gas turbine (CCGT) schemes have achieved an electrical efficiency approaching 50 per cent, with 20 per cent heat recovery, and a heat to power ratio of less than 1:1.

- **Reciprocating engine systems** range from less than 100 kWe up to around 5 MWe, and are found in applications where production of hot water (rather than steam) is the main requirement, for example, on smaller industrial sites as well as in buildings. They are based on auto engine or marine engine derivatives converted to run on gas. Both compression ignition and spark ignition firing is used. Reciprocating engines operate at around 28 to 33 per cent electrical efficiency with around 50 per cent to 33 per cent of the fuel input available as useful heat. Reciprocating engines produce two grades of waste heat: high grade heat from the engine exhaust and low grade heat from the engine cooling circuits.

- **Organic Rankine Cycle systems** operate on the same principle as steam turbines but, instead of using water steam as the working fluid, use organic substances with a lower boiling point and higher vapour pressure than water. This allows heat of a lower temperature to be converted into power via evaporation of the organic working fluid and expansion through a turbine. Low and medium temperature heat sources in the temperature range 80 to 350°C are exploited by ORC systems. The accessibility of low grade heat means that geothermal, industrial waste heat, biomass and solar heat sources can be exploited by ORC systems for the generation of power.

- **Steam screw expander systems** are based upon rotary screw expanders, rather than the turbine blades used in conventional steam turbine systems (see above). This allows power to be generated from wet steam, rather than the superheated dry steam that must be utilised in conventional steam turbines if turbine blade damage is to be avoided. Such systems can, for example, be installed in the place of pressure reduction valves in steam distribution systems, allowing the recovery of energy in the form of mechanical power and the onward supply of steam at the conditions desired downstream.

Determining fuel consumption for heat and electricity

7.38 In order to provide a comprehensive picture of electricity generation in the United Kingdom and the fuels used to generate that electricity, the energy input to CHP schemes has to be allocated between heat and electricity production. This allocation is notional and is not determinate.

7.39 The convention used to allocate the fuels to heat and electricity relates the split of fuels to the relative efficiency of heat and electricity supply. The efficiency of utility plant varies widely: electricity generation from as little as 25 per cent to more than 50 per cent and boilers from 50 per cent to more than 90 per cent. Thus it is around twice as hard to generate a unit of electricity as it is to generate a unit of heat. Accordingly, a simple convention can be implemented whereby twice as many units of fuel are allocated to each unit of electricity generated, as to each unit of heat supplied. This approach is consistent with the Defra Guidelines for Company Reporting on greenhouse gas emissions and for Negotiated Agreements on energy efficiency agreed between Government and industry as part of the Climate Change Levy (CCL) package. It recognises that, in developing a CHP scheme, both the heat customer(s) and the electricity generator share in the savings.

7.40 The assumption in this convention that it is twice as hard to generate a unit of electricity as heat, is appropriate for the majority of CHP schemes. However, for some types of scheme (for example in the iron and steel sector) this allocation is less appropriate and can result in very high apparent heat efficiencies. These, however, are only notional efficiencies.

The effects on the statistics of using CHPQA

7.41 Paragraph 7.6 described how schemes were scaled back so that only CHP_{QPC} and CHP_{QPO} are included in the CHP statistics presented in this Chapter. This is illustrated in Table 7J where it is seen that 446 schemes were scaled back for year of operation 2019. For information, in 2018, 431 schemes (revised) were scaled back.

7.42 In 2018, the power output from these schemes was scaled back from a total of 35,339 GWh to 12,772 GWh. The total fuel input to these schemes was 114,945 GWh of which 60,595 GWh was regarded as being for power only. For 2018, the total power output was scaled back from 34,872 GWh to 13,279 GWh.

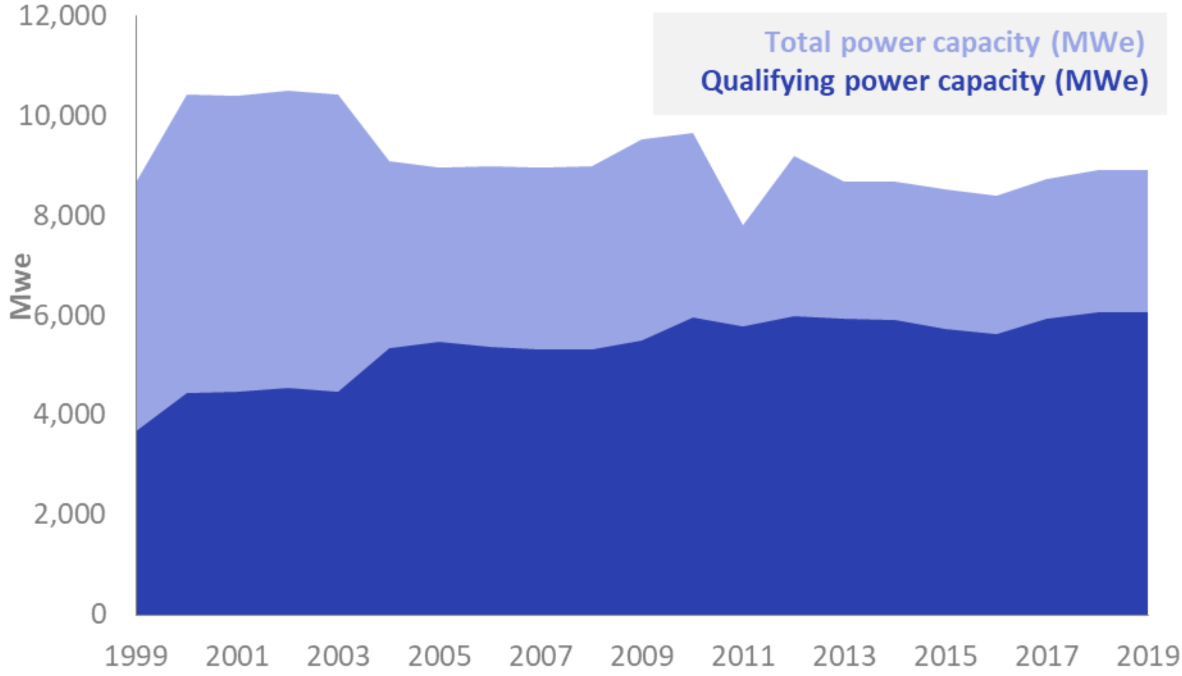
Table 7J: CHP capacity, output and fuel use which has been scaled back in 2019

	Units	
Number of schemes requiring scaling back		446
Total Power Capacity of these schemes (CHP_{TPC})	MWe	6,717
Qualifying Power Capacity of these schemes (CHP_{QPC})	MWe	3,877
Total power output of these schemes (CHP_{TPO})	GWh	35,339
Qualifying Power Output of these schemes (CHP_{QPO})	GWh	12,772
Electricity regarded as "Power only" not from CHP (CHP_{TPO} - CHP_{QPO})	GWh	22,567
Total Fuel Input of these schemes (CHP_{TFI})	GWh	114,945
Fuel input regarded as being for "Power only" use i.e. not for CHP	GWh	60,595

**This figure includes generation from major power producers*

7.43 The evolution of Total Power Capacity (TPC) and Qualifying Power Capacity (QPC) over time is shown in Chart 7.5.

Chart 7.5: Installed CHP capacity by year 1998 - 2019



Typical Power and Heat Efficiencies and Heat to Power Ratios of Prime Movers

7.44 The figures quoted above in Table 6D are for CHP schemes. These schemes may contain supplementary boilers, supplementary firing and auxiliary firing. The figures are, therefore, not reflective of the power and heat efficiencies and the heat to power ratios of the prime mover when it is considered in isolation.

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