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Information paper – 28
CHP types and efficiencies

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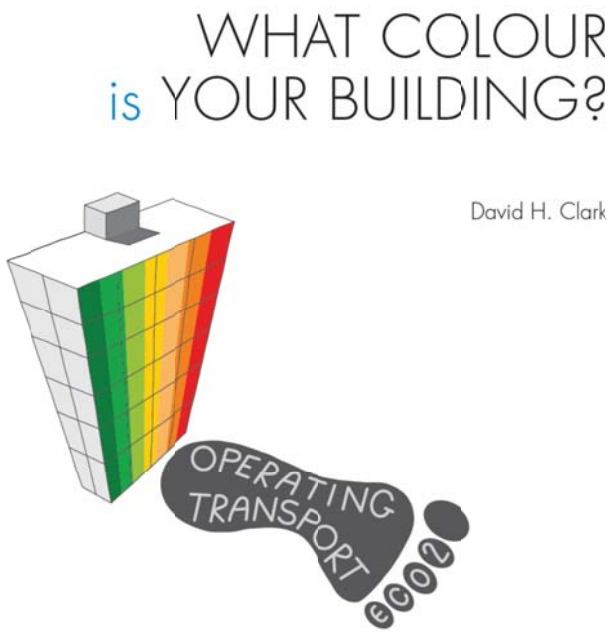
A paper referenced in the book:



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This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

CHP types and efficiencies

This information paper provides a brief overview of the types of combined heat and power (CHP) systems used in buildings in the UK and their typical efficiencies.

1. THE USE OF CHP IN THE UK

The Digest of UK Energy Statistics[1] provides data on energy supply, generation and consumption in the UK each year. In 2011 there was 6,111 MWe of installed CHP capacity in the UK, which generated 27,191 GWh of electricity and 48,627 GWh of heat. The 69 schemes larger than 10 MWe represented over 80% of electrical capacity, while the 1,559 schemes less than 1 MWe represented less than 5% capacity. Over three quarters of fuel used in CHP systems was from natural or refinery gas. Almost 90% of CHP schemes (by electrical capacity) are found in the industrial sector, primarily the chemical and oil refinery sectors.

Table 1 (based on Table 7C in DUKES 2012) provides a summary of the 1,160 schemes installed in the commercial sector, public sector and residential buildings, ranked by electrical capacity. 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 (e.g. diesel) or gas turbines.

	No. of schemes		Electrical capacity (kWe)		Heat capacity (kW_{heat})	
Health	193	17%	137	35%	147	36%
Universities	48	4%	64	16%	65	16%
Leisure	398	34%	51	13%	51	12%
Retail	172	15%	38	10%	3	1%
Hotels	248	21%	36	9%	38	9%
Residential Group Heating	39	3%	27	7%	59	14%
Offices	18	2%	15	4%	11	3%
Government Estate	17	1%	14	4%	18	4%
Education	25	2%	11	3%	18	4%
Airports	2	0%	1	0%	1	0%
Total	**1,160**		**394**		**411**	

Table 1 Number and capacity of CHP schemes installed in buildings by sector in 2011 (source: DUKES 2012)

Health, leisure, residential group living, university campuses and hotels are facilities which all have a high annual base load demand for heat (e.g. domestic hot water and/or swimming pools), and these sectors account for 80% of the total number of schemes, 80% of the electrical capacity and 88% of the heat capacity of CHP schemes installed in UK buildings. The retail sector

represents 10% of electrical capacity but only 1% of heat capacity, the lowest of any sector. The CHP schemes in health, residential group living and university sectors will often serve multiple buildings or users.

The number of CHP schemes in offices and schools is relatively small, because their base annual heat load, or their hours of operation, or both, are too small to make CHP financially viable.

2. TYPICAL CHP EFFICIENCIES

Table 2 (Table 7D in DUKES 2012) provides a summary of the performance of all CHP schemes (measured on a gross calorific value basis) operating in the UK in 2011. The average electrical efficiency of reciprocating engine CHP schemes, the type most commonly used in buildings, was 27% and the average heat efficiency was 41%, giving an overall average of 68% and a heat to power ratio of 1.5.

	Average operating hours per annum (Full load equivalent)	Average electrical efficiency	Average thermal efficiency	Average overall efficiency	Average heat to power ratio
Back pressure steam turbine	4,613	12%	59%	71%	5.1
Pass out condensing steam turbine	3,929	16%	43%	58%	2.7
Gas turbine	5,052	21%	52%	73%	2.4
Combined cycle	4,602	27%	40%	67%	1.5
Reciprocating engine	**3,533**	**27%**	**41%**	**68%**	**1.5**
All schemes	4,450	24%	43%	67%	1.8

Table 2 Average measured CHP efficiencies in the UK in 2011 (source: DUKES 2012)

The Carbon Trust in the UK has published typical CHP outputs and efficiencies for different packaged CHP sizes.[2] These are summarised in Table 3. The median values, calculated by the author, suggest a typical efficiency of 76% and a heat to power ratio of 1.4.

Electrical Output (kW)	60	100	300	600	1000	**Median**
Heat Output (kW)	115	130	430	880	1300	
Gas Input (kW)	215	310	990	1950	3000	
Electricity efficiency	28%	32%	30%	31%	33%	**31%**
Heating efficiency	53%	42%	43%	45%	43%	**43%**
Systems Losses	19%	26%	26%	24%	23%	**24%**
Heat to power ratio	1.9	1.3	1.4	1.5	1.3	**1.4**

Table 3 Typical packaged CHP performance from Carbon Trust

The CHP calculations in Chapter 7 and Appendix I of the book use the efficiencies shown in Table 4. These generic values are reasonably consistent with the values shown in Tables 3 and more efficient than the measured DUKES data for reciprocating engines in Table 2. Some manufacturers may supply equipment with higher efficiencies.

	Average electrical efficiency	Average thermal efficiency	Average overall efficiency	Average heat to power ratio
CHP unit in Building X and Hotel Y	30%	45%	75%	1.5

Table 4 **Efficiency of a 'typical' CHP system used in Chapter 7 and Appendix I calculations**

3. THE EMERGENCE OF FUEL CELLS?

Fuel cells use a non-mechanical process to generate electricity. They convert hydrogen and oxygen into water and in doing so generate electricity and heat – basically hydrolysis in reverse. There are many different types – some are suited to vehicles, others to space craft (NASA have been using them since the 1960s) while others can be used to generate power for buildings.

The hydrogen to supply a fuel cell in a building is typically obtained by passing natural gas through a fuel processor called a reformer. So from the outside its similar to a conventional gas CHP system – gas goes in, heat and electricity comes out – refer to Figure 1.

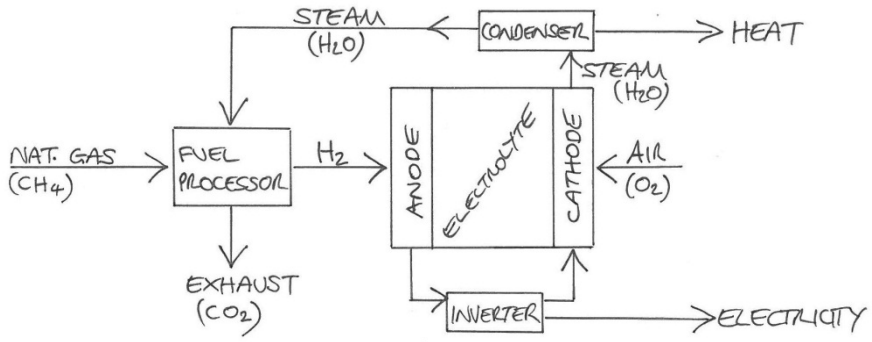

Fig 1 **Typical fuel cell schematic**

Commercial CHP fuel cells are still an emerging technology and are potentially suited to use in buildings because they can produce roughly equal amounts of electricity and heat and are quieter. The key barrier to their widespread use is capital cost.

Transport for London (TfL) installed a £2.4m trigeneration system in the Palestra HQ building, London in 2010 as part of a green retrofit.[3] This comprised a 200 kWe fuel cell CHP, a 834 kWe CHP engine, a 500 kW absorption chiller and a 75 m^3 thermal storage tank. The fuel cell CHP has an electrical efficiency of around 36% and delivers 263 kWh_{heat} giving a heat to power ratio of 1.3 and a system efficiency around 80%. The phosphoric acid fuel cell is connected to the buildings UPS system to provide essential power if the grid electricity fails.

3. DISTRICT HEATING & LARGE SCALE CHP

If CHP is connected to district heating networks then large scale CHP systems can be used instead of package CHP systems in individual buildings. These include:

- **Biomass CHP** – biomass is used to generate steam (through combustion) or gas (through pyrolysis or gasification) to drive a turbine which produces electricity. The minimum system size is around 1 MWe.
- **Waste-to energy CHP** – waste is converted into a gas (by anaerobic digestion and/or gasification) which is used to power a turbine. These need scale (> 5MWe) and a reliable source of waste, which is far more than a commercial building itself can supply. Usually located at or near to waste transfer stations or rubbish tips.

District heating is not widely used in the UK. Figure 2 shows the proportion of heat from district systems in residential, public and commercial buildings for 32 countries.[4] The UK has 1% compared to the average across all countries of 7.5%.

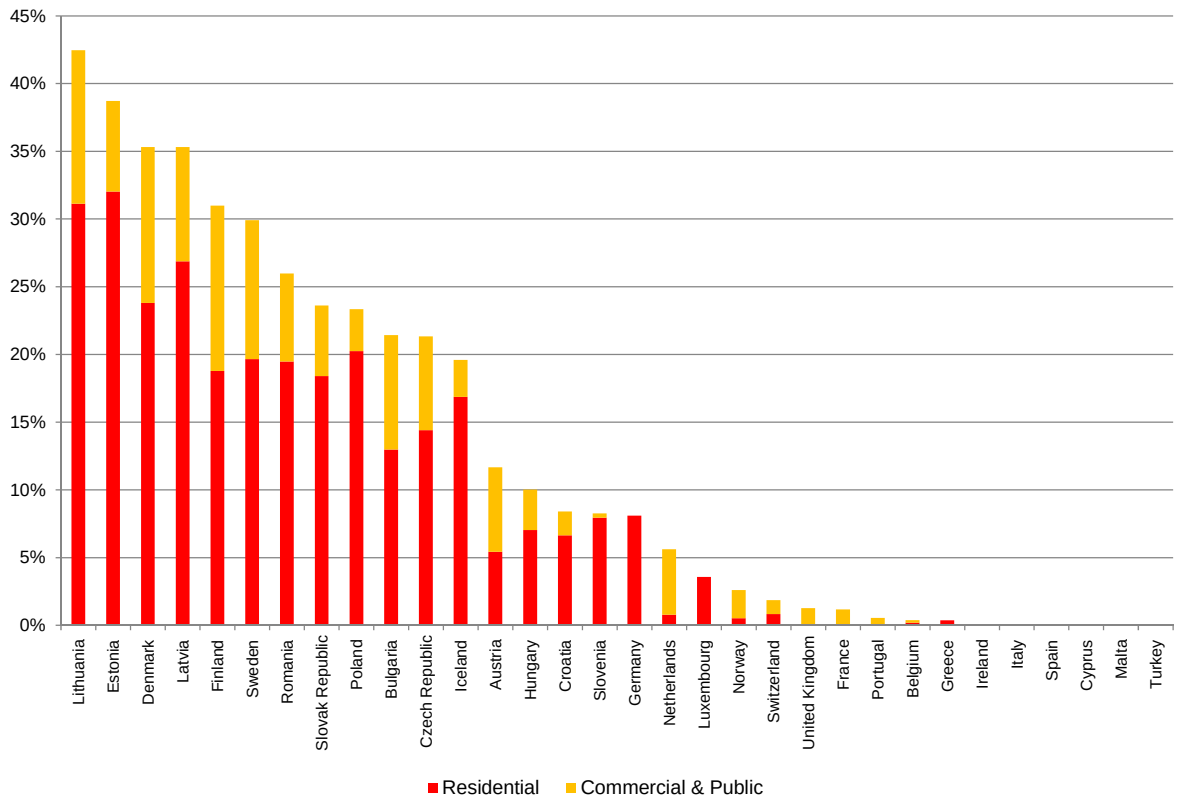

Fig 2 **Proportion of heat supplied from District Heating Networks in European Countries (source: Euroheat & Power)**

Notes

All websites were accessed on 20 July2013 unless noted otherwise.

1. Digest of United Kingdom Energy Statistics 2012, Department of Energy and Climate Change. All data reproduced in this paper is Crown Copyright. www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes

2. *Introducing combined heat and power*, Carbon Trust Technology Guide CTV044, published September 2010.

3. http://www.cibse.org/content/Events/FM06/Andy%20Stanton.pdf and www.fuelcellmarkets.com/logan_energy/news_and_information/3,1,27362,1,28524.html

4. Data from Tables 10 & 11 of Ecoheatcool Work Package 1 – The European Heat Market Final Report – 2006. http://www.euroheat.org/Files/Filer/ecoheatcool/documents/Ecoheatcool_WP1_Web.pdf