# Heat source overview

<table>
<thead>
<tr>
<th>Main source</th>
<th>Sub-category</th>
<th>Heat generation/rejection</th>
<th>Availability of locations in the UK (excl. Scotland) and number of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical distribution networks</strong></td>
<td>Cable tunnels (shafts)</td>
<td>Resistive heating of electrical cables</td>
<td>66km across UK (2 shafts per km) (5E, mainly London and Kent)</td>
</tr>
<tr>
<td></td>
<td>Sub-station transformers</td>
<td>Voltage transformation</td>
<td>4 DNOs (out of 7) (1055: GS (215), BS(760), Primary (80) above 60MVA)</td>
</tr>
<tr>
<td><strong>Low grade industrial/commercial</strong></td>
<td>Supermarkets</td>
<td>Condenser &amp; desuperheater</td>
<td>7000 in the UK, approx. half above 1000 m² retail sales area. Location &amp; size available from VOA.</td>
</tr>
<tr>
<td></td>
<td>Data centres</td>
<td>Chillers, CHW loop</td>
<td>Whole UK for managed and co-location (no enterprise). 475 data centres locations known</td>
</tr>
<tr>
<td></td>
<td>Food and drink</td>
<td>Refrigeration (condenser, desuperheating and oil cooling), boilers, direct heating from fuel combustion, motors, direct electrical heating, compressed air</td>
<td>1200 (larger sites), 8,000 if include small companies</td>
</tr>
<tr>
<td></td>
<td>Paper and pulp</td>
<td>Paper drying</td>
<td>Data from ten mills used, with focus on 5 sites at: Shotton (Wales); Irving, Scotland; Partington, Manchester; Kemsley, Kent; Watchet, Somerset (note now closed)</td>
</tr>
<tr>
<td></td>
<td>Cold stores</td>
<td>Condenser, desuperheater and oil cooling</td>
<td>306 larger stores in England, Wales and Scotland</td>
</tr>
<tr>
<td><strong>High grade industrial/commercial</strong></td>
<td>Crematoria</td>
<td>Cremation/flue gas exhaust</td>
<td>269 sites across the UK</td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td>Mainly from outdoor kilns used for processing cement</td>
<td>18 cement plants across the UK of which 12 have kilns</td>
</tr>
<tr>
<td></td>
<td>Steel</td>
<td>Pig iron and blast furnaces</td>
<td>Only two sites in the UK. Port Talbot, Wales and Scunthorpe, Lincolnshire</td>
</tr>
<tr>
<td></td>
<td>Petrochemical (oil refining)</td>
<td>Distillation (Heron)</td>
<td>Heron</td>
</tr>
<tr>
<td><strong>Wastewater</strong></td>
<td>Main, interceptor sewers</td>
<td>Wastewater heat energy within the sewer system</td>
<td>Arup model</td>
</tr>
<tr>
<td></td>
<td>Treatment works</td>
<td>Wastewater heat energy (i) immediately prior to or (ii) within the wastewater treatment plant (iii) after treatment before discharge</td>
<td>Whole UK</td>
</tr>
<tr>
<td><strong>Underground railways</strong></td>
<td>UR Ventilation shaft</td>
<td>Tunnel air warmed by the operation of the trains</td>
<td>London (113), Newcastle (5)</td>
</tr>
</tbody>
</table>
# Heat source overview

<table>
<thead>
<tr>
<th>Main source</th>
<th>Sub-category</th>
<th>Heat recovery medium</th>
<th>Typical source temperature [degC]</th>
<th>Typical heat output</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical distribution networks</strong></td>
<td>Cable tunnels (shafts)</td>
<td>Air</td>
<td>Up to 44</td>
<td>Up to 350 kW per shaft</td>
<td>kW/shaft</td>
</tr>
<tr>
<td></td>
<td>Sub-station transformers</td>
<td>Oil</td>
<td>Up to 80</td>
<td>128 kW above 60MVA at 50% loading</td>
<td>kW/MVA at 50% loading</td>
</tr>
<tr>
<td><strong>Low grade industrial/commercial</strong></td>
<td>Supermarkets</td>
<td>Refrigerant</td>
<td>21-27 (condenser) 37-53 (desuperheater)</td>
<td>Average size of store 1,400 m(^2) gross floor area which provides 75 kW of heat</td>
<td>kW/m(^2) retail sales area</td>
</tr>
<tr>
<td></td>
<td>Data centres</td>
<td>Water / Air</td>
<td>25-35</td>
<td>70 kW- Up to 56MW per data centre</td>
<td>MW of IT load</td>
</tr>
<tr>
<td></td>
<td>Food and drink</td>
<td>Refrigerant / water / air</td>
<td>Refrigeration and low temperature processes (~64% of total): ~75% @ average of ~22°C ~25% @ 60-90°C. Higher temperature processes (~36% of total): @~100-250°C</td>
<td>95-266 (for larger companies)</td>
<td>kW/m(^2)</td>
</tr>
<tr>
<td></td>
<td>Paper and pulp</td>
<td>Air / water</td>
<td>85-358 (Heron)</td>
<td>4.2 MW/site</td>
<td>MW/tonnes of paper</td>
</tr>
<tr>
<td></td>
<td>Cold stores</td>
<td>Refrigerant</td>
<td>~75% @ average of ~22°C ~25% @ 60-90°C</td>
<td>803 kW/store</td>
<td>kW/m(^3)</td>
</tr>
<tr>
<td><strong>High grade industrial/commercial</strong></td>
<td>Crematoria</td>
<td>Flue gas???</td>
<td>750-1000</td>
<td>400 kW/site</td>
<td>kW/number of cremations</td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td>???</td>
<td>(Heron 338)</td>
<td>21MW/site</td>
<td>kW/tonnes of cement</td>
</tr>
<tr>
<td></td>
<td>Steel</td>
<td>Water / air / flue gasses?</td>
<td>&gt;1500</td>
<td>980MW/site</td>
<td>kW/tonnes of steel</td>
</tr>
<tr>
<td><strong>Wastewater</strong></td>
<td>Main, interceptor sewers</td>
<td>Sewage</td>
<td>Up to 25</td>
<td>200-800kW</td>
<td>Arup</td>
</tr>
<tr>
<td></td>
<td>Treatment works</td>
<td>Sewage</td>
<td>12-23</td>
<td>Up to 150MW</td>
<td>kW/1000 pe</td>
</tr>
<tr>
<td></td>
<td>Underground railways</td>
<td>UR Ventilation shaft</td>
<td>Air</td>
<td>Up to 1000kW</td>
<td>kW/m(^3)/s flow</td>
</tr>
</tbody>
</table>
SUBSTATIONS

Headline numbers (considering only substation with capacity ≥ 60 MVA):

- 1150 substations in England, Wales, N Ireland (excl. sites in Scotland)
- Energy: 3.2 TWh/year for substations ≥ 60 MVA
- Average heat output per site: ca. 313 kW for substations ≥ 60 MVA

Locations of GSP substations within the operating area of 2 DNOs (SSEN and WPD)
Wastewater

Results:

1. From the analysis:
   • Total of 1877 sites across the UK;
   • These represent the largest sites;
   • Population and hence wastewater to the site varies greatly;
   • The more people connected to a site the more waste heat available from the wastewater.

2. TOTAL energy available is 2,920 MW (~2.9GW)

3. Number of sites and energy available (please see Figure 1)

4. From a population perspective:
   • Number of sites that serve >100,000 people is 148 i.e. 7.9% of all sites (as presented in Figure 2);
   • These sites generate 1,843 MW i.e. 62.9% of the available waste heat.
Data centres

Process:

- **Known number of data centres (DCs) in UK as of 2018:**
  1. 25 Managed Services (MSDC);
  2. 450 Colocation (CDC);
  3. 11500 Enterprise (EDC) (Dodd et al., 2020).

- **Decision to focus on MSDCs and CDCs** based on two main factors, namely:
  1. the availability of data, as specifications of EDCs are rarely disclosed to the public, and;
  2. the fact that CDCs and MSDCs would typically yield a larger heat output than EDCs, considering the larger average white space area per site, as presented in Figure 3.

- **30x Schneider Electric DC reference designs** used to draw conclusions on typical proportional relationships (combined footprint of IT racks vs Floor space / White space) – please see Figure 4 for definitions.
Data centres

Process:

• Four methods developed to estimate heat output per DC based on:
  i. Total floor space;
  ii. White space area;
  iii. Total power capacity available + declared PUE (power usage effectiveness);
  iv. Total power capacity available + average PUE for DCs in UK.

• Data for 265 MSPs and CDCs was found in public domain.

• Methods tested on 24 DCs and results compared against the declared IT load (as seen in Figure 5).

• Methods applied to the 265 DCs in priority order, based on availability of data.

Results:

• Estimated heat output from 265 sites is 1939.7 MW

• This represents 44.2% of the MSP & CDC sector in 2018 (475 / estimated 4387.4 MW)
HEAT FUEL PROJECT

- Average of **740 kW** of heat recovered from the London Underground
- Upgraded by a **1 MW** heat pump
- Can also provide cooling when operating in Supply Mode
- Heat FUEL investigates both the heating and cooling benefits
- EES model has been developed to calculate system efficiency and outputs
HEAT FUEL PROJECT

- EES model predicts coil condition
- Outputs used for cooling investigation
- Collaboration with TfL
- Subway Environment Simulation (SES)

Diagram details:
- **Coils** in City Road in Supply
- **Q_{system}**
- **Q_{soil}**
- **Q_{vent}**
- **Q_{trains}**
- **Q_{lights}**
- **Q_{braking}**
- **Q_{power}**
- Groundwater level:
  - Southbound: ~25m
  - Northbound: ~25m

Locations:
- Southbound: Old Street
- Northbound: Angel

**Subway Environment Simulation (SES)**

**London South Bank University**
Next steps:

• Early stage results
• Optimisation
• Publications
• TM on secondary heat – CIBSE?