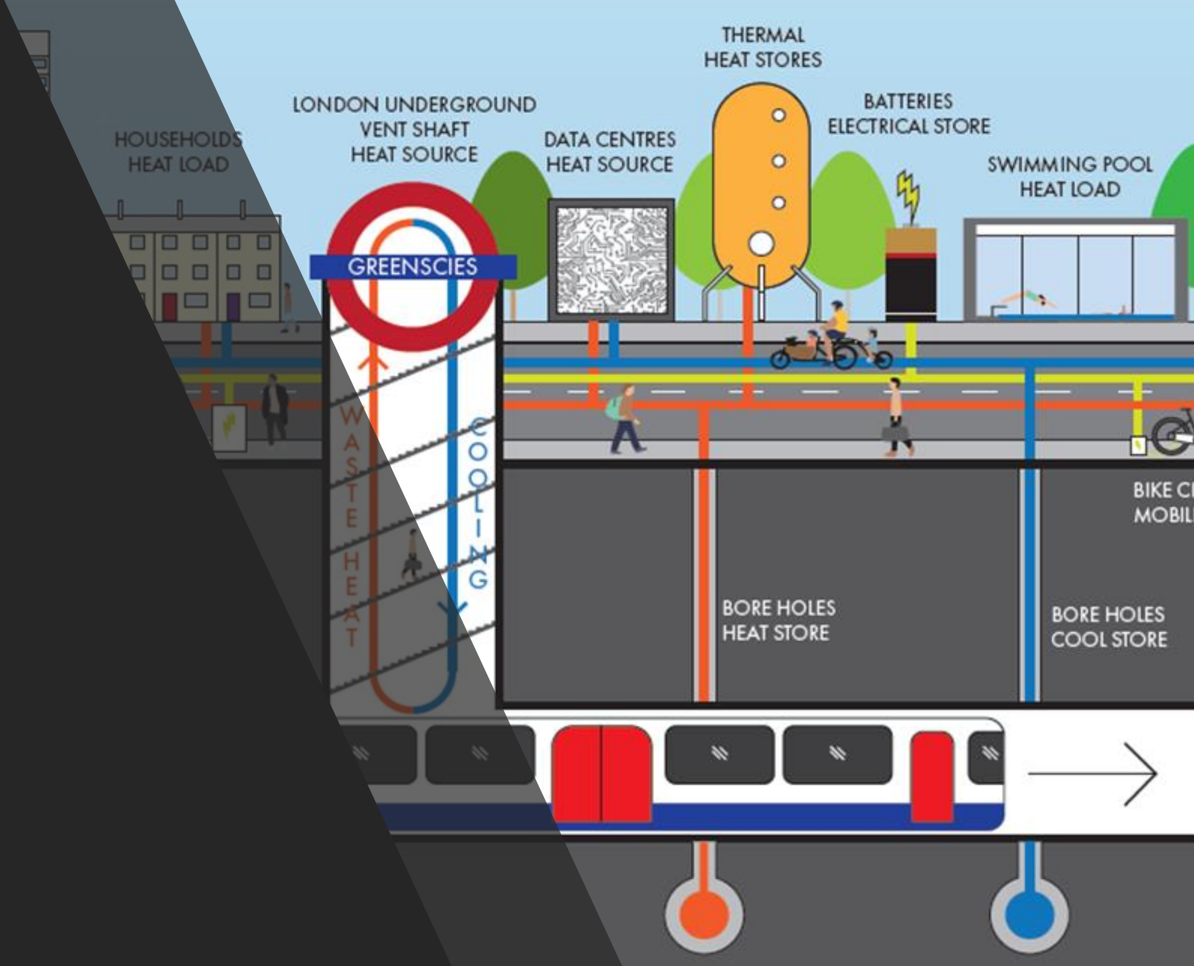
Waste heat integration into heat networks

Akos Revesz & Graeme Maidment

London South Bank University
EST 1892



Summary

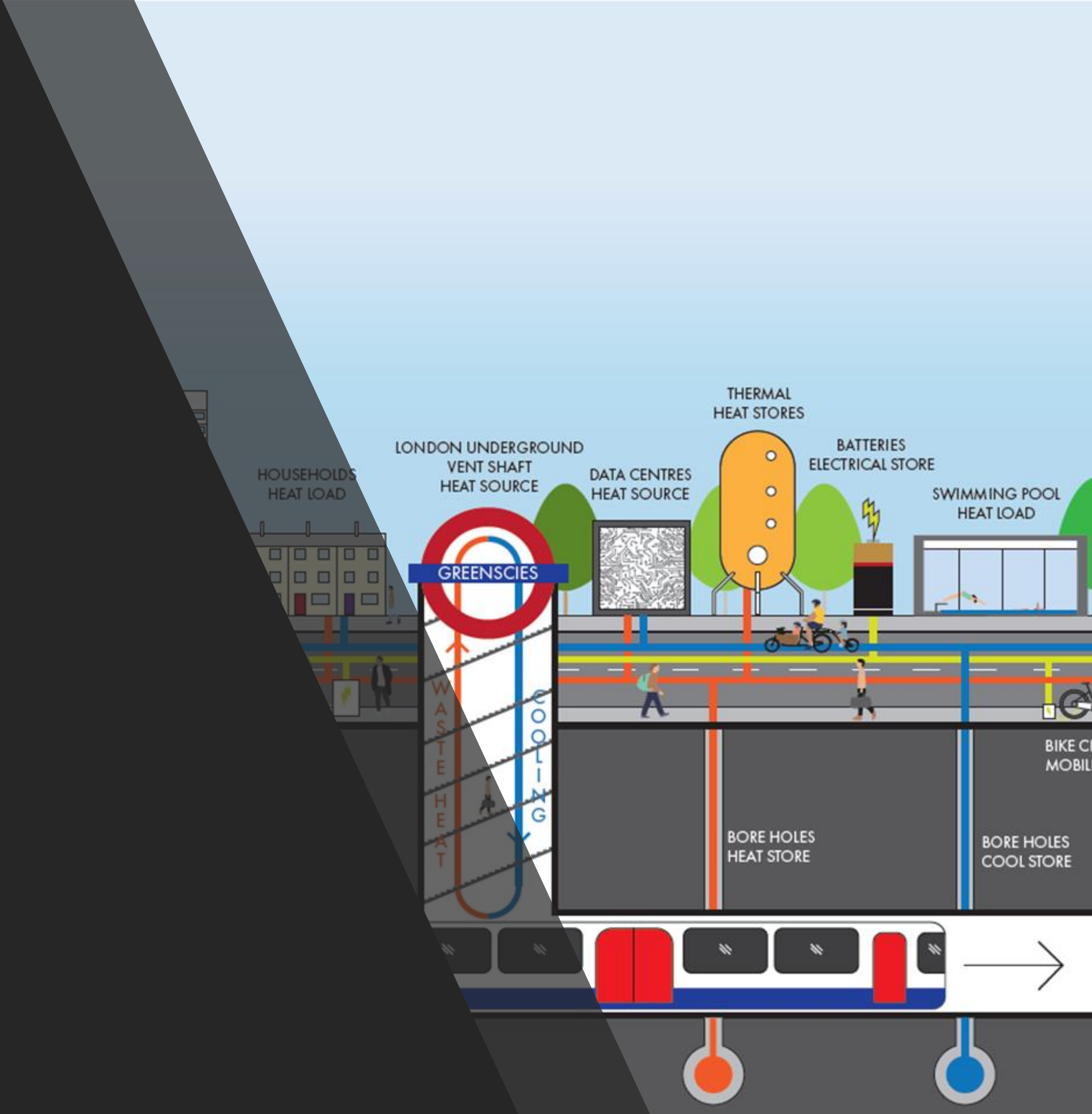
UK net zero emissions targets

Why waste heat?

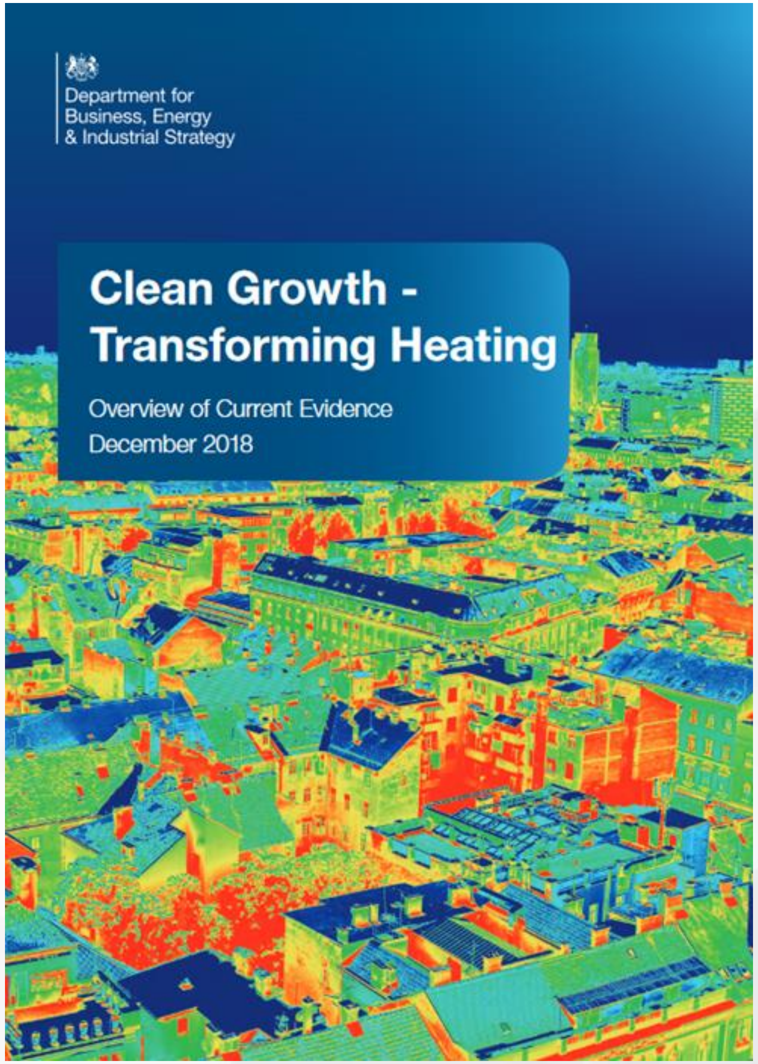
Specific waste heat sources?

How do they compare?

Conclusions



EMISSIONS FROM HEATING IN UK



21%

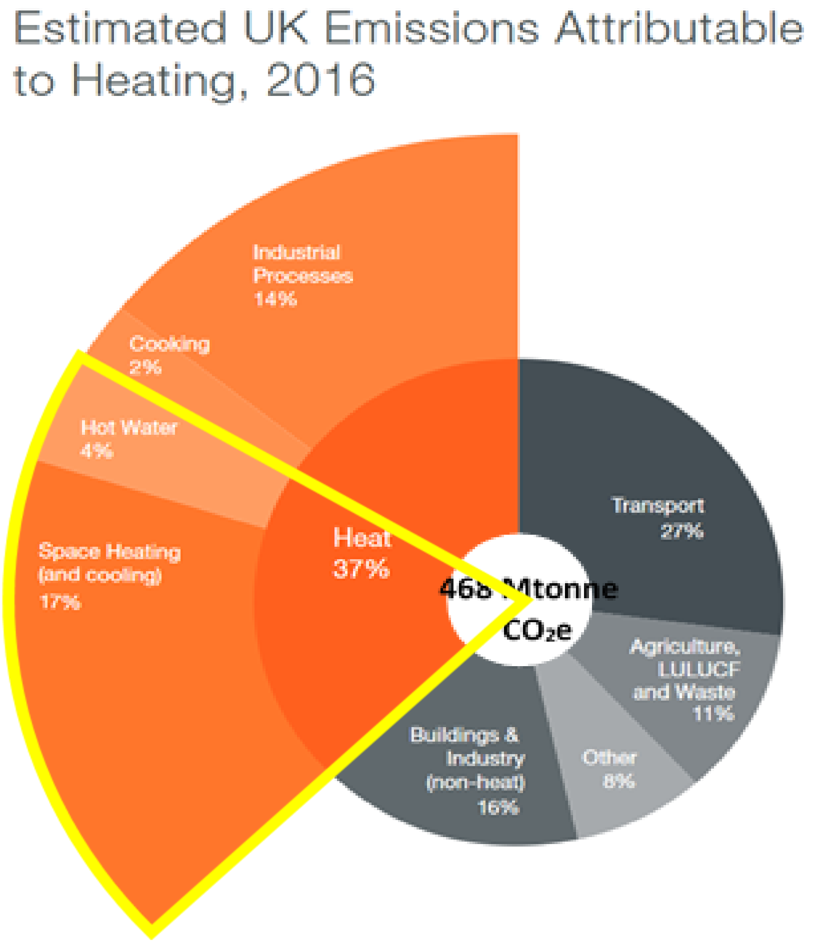
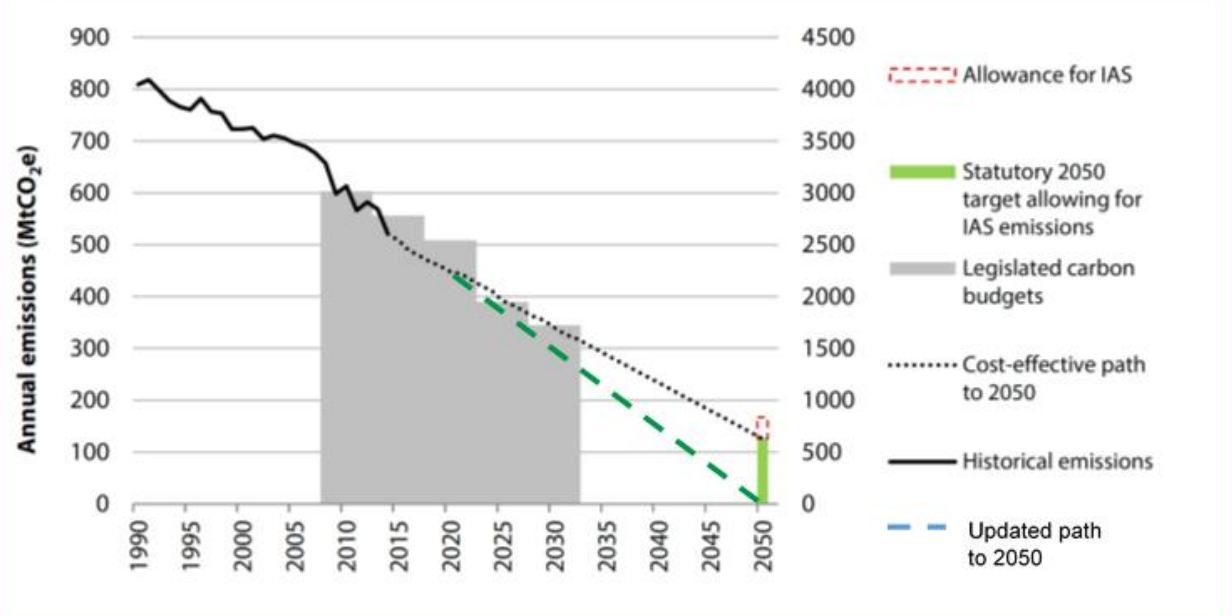


Figure 2.1 UK emissions in 2016 across different sectors[4]

London South Bank
University

UK NET ZERO CARBON TARGET

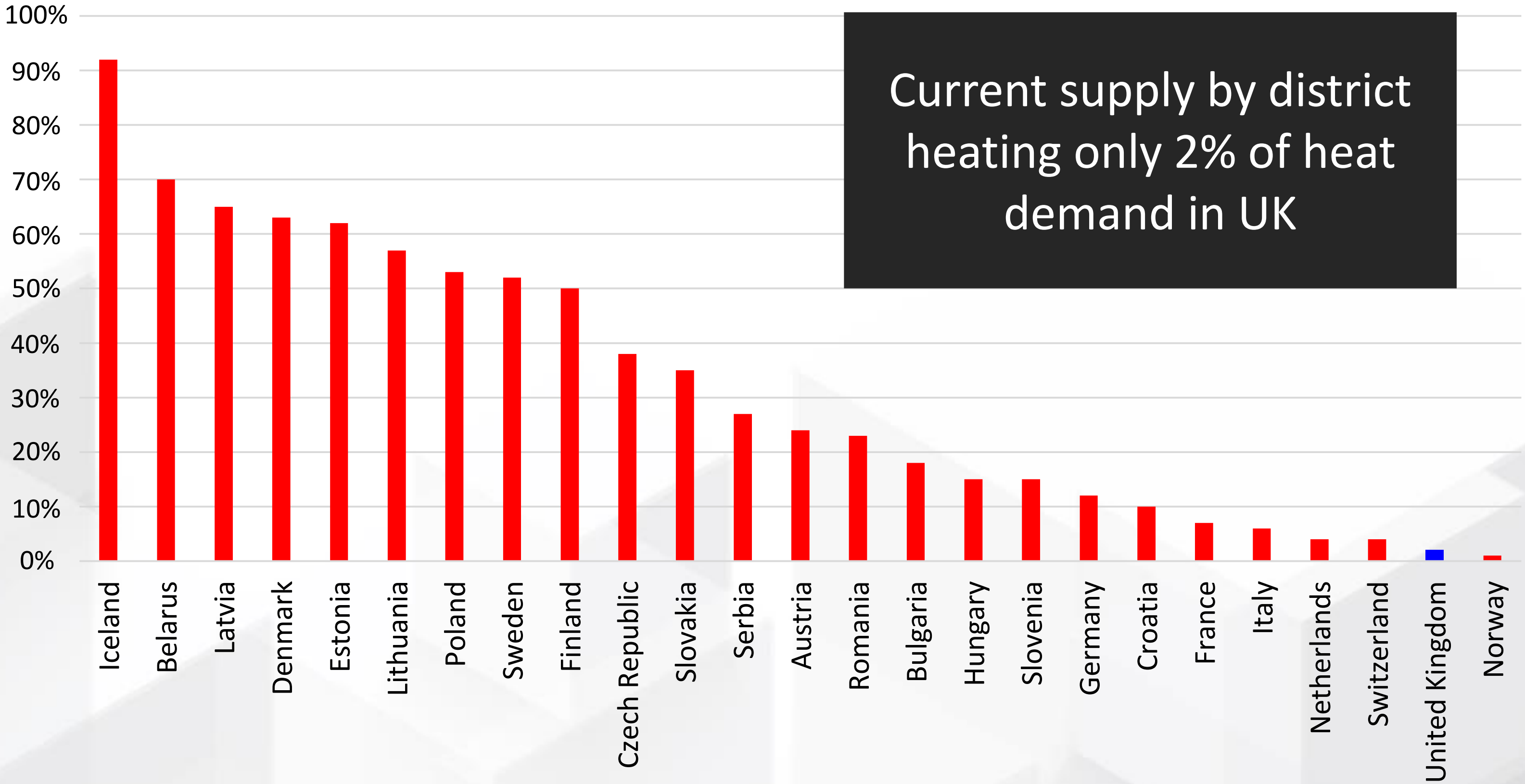
Figure 1.2. The UK's existing long-term emissions target (set in 2008) has guided the setting of earlier targets and actions to deliver them



Source: Adapted from CCC (2015) *Fifth Carbon Budget Advice*. Based on DECC (2015) *Final UK greenhouse gas emissions national statistics: 1990-2013*; CCC analysis.
Notes: This chart is from the CCC's 2015 fifth carbon budget report. GHG emissions shown are the actual emissions, while carbon budgets represent the emissions under the net carbon account; IAS stands for International Aviation and Shipping, which are included in the 2050 target but not the carbon budgets.

"We conclude that net-zero is necessary, feasible and cost-effective"

THE ROLE OF HEAT NETWORKS

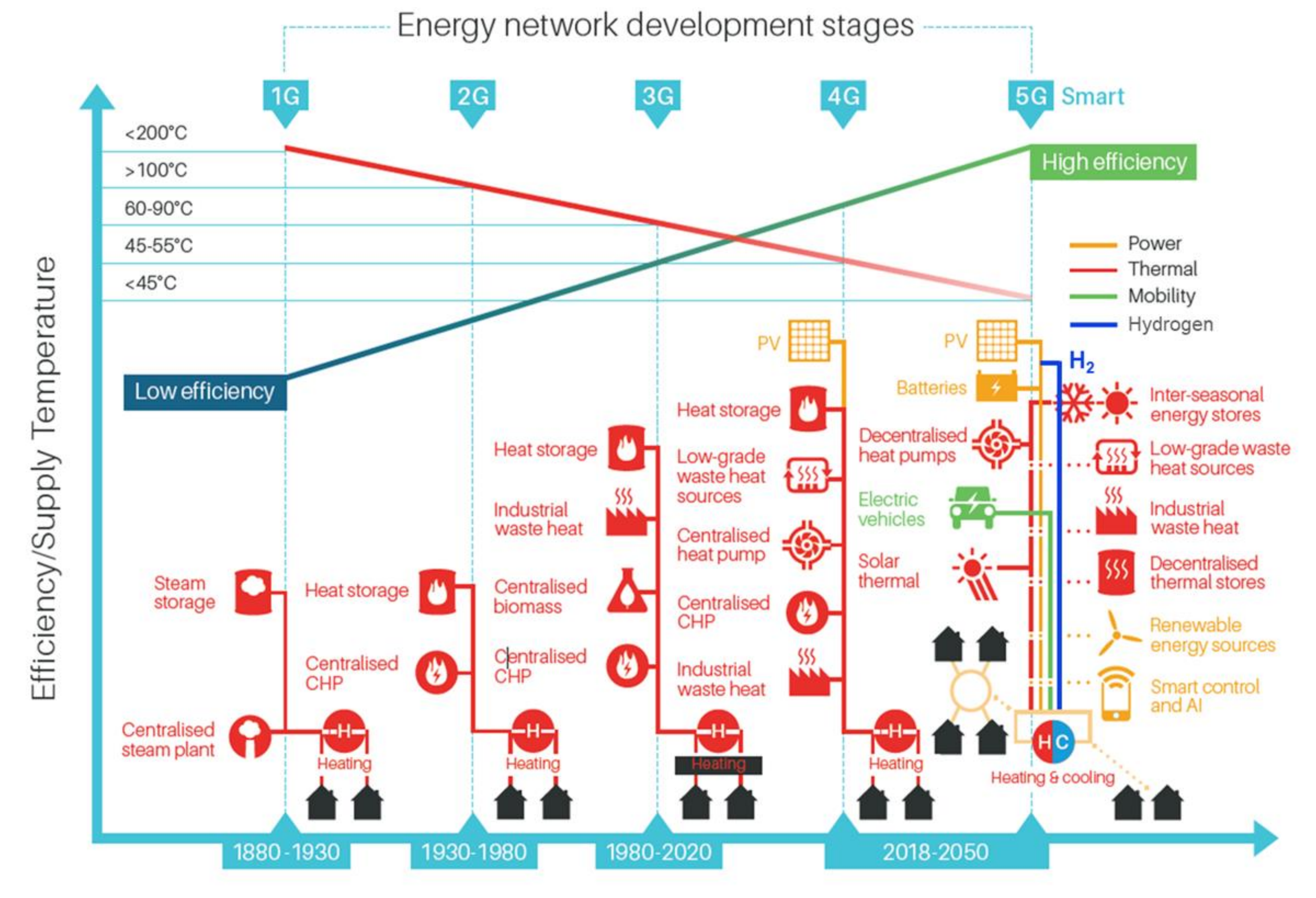


Current supply by district heating only 2% of heat demand in UK

The **Clean Growth Strategy** sets out a significant role for **energy networks** as a low-regrets component of meeting our decarbonisation commitments.

Net-zero emissions by 2050

5TH GENERATION NETWORKS



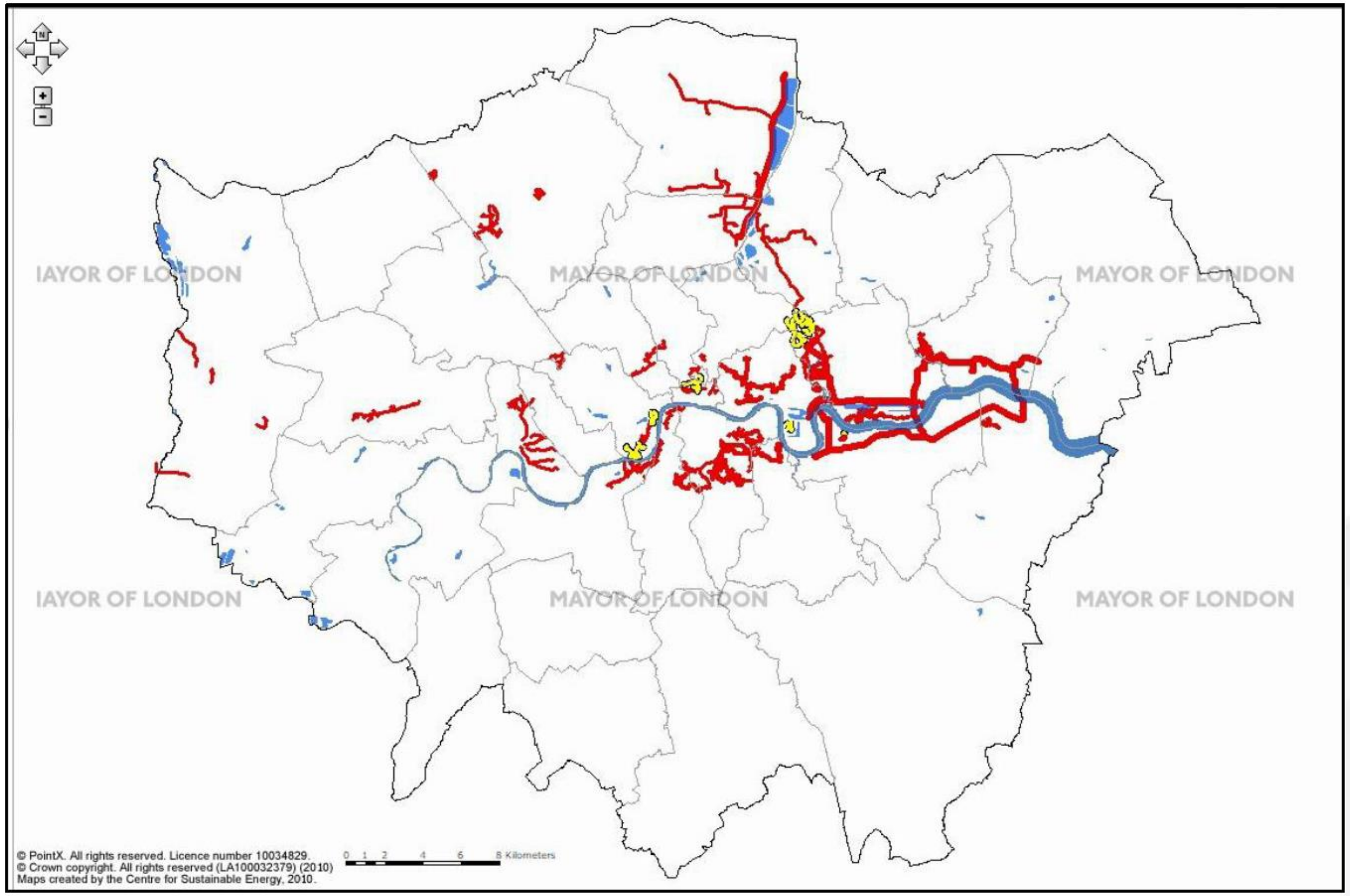
Ambient heat networks

Opportunities for capturing/sharing heat

Opportunities for flex/ renewable energy

London South Bank University

HEAT STRATEGY FOR LONDON



- Annual heating demand of 66TWh/year
- Increasing number & scale of district heating networks
- 25% of London's heating from secondary sources by 2030
- 50 TWh/year (70%) secondary heat sources

London South Bank University

WHAT'S THE BEST SOURCE?

- Substations
- Waste water
- Data centres
- Ventilation shafts
- Crematoria
- Cable tunnels
- Supermarkets
- Cold stores
- Mine water
- Iron and steel
- Paper and pulp
- Ceramics and cement

- How big is it?
- How easy it to access?
- How much is available?
- What's the proximity to heat?
- What are the benefits?
- What are the costs?
- What are the barriers?

London South Bank University

HEAT SOURCE OVERVIEW

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

HEAT SOURCE OVERVIEW

Main source	Sub-category	Heat recovery medium	Typical source temperature [degC]	Typical heat output	Metric
Electrical distribution networks	Cable tunnels (shafts)	Air	Up to 44	Up to 350 kW per shaft	kW/shaft
	Sub-station transformers	Oil	Up to 80	128 kW above 60MVA at 50% loading	kW/MVA at 50% loading
Low grade industrial/ commercial	Supermarkets	Refrigerant	21-27 (condenser) 37-53 (desuperheater)	Average size of store 1,400 m^2 gross floor area which provides 75 kW of heat	kW/m^2 retail sales area
	Data centres	Water / Air	25-35	70 kW- Up to 56MW per data centre	MW of IT load
	Food and drink	Refrigerant / water / air	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	95-266 (for larger companies)	kW/m^2
	Paper and pulp	Air / water	85-358 (Heron)	4.2 MW/site	MW/tonnes of paper
	Cold stores	Refrigerant	~75% @ average of ~22°C ~25% @ 60-90°C	803 kW/store	kW/m^3
High grade industrial/ commercial	Crematoria	Flue gas???	750-1000	400 kW/site	kW/number of cremations
	Cement	???	(Heron 338)	21MW/site	kW/tonnes of cement
	Steel	Water / air / flue gasses?	>1500	980MW/site	kW/tonnes of steel
Wastewater	Main, interceptor sewers	Sewage	Up to 25	200-800kW	Arup
	Treatment works	Sewage	12-23	Up to 150MW	kW/1000 pe
Underground railways	UR Ventilation shaft	Air	17-32	Up to 1000kW	kW/m^3/s flow

SUBSTATIONS

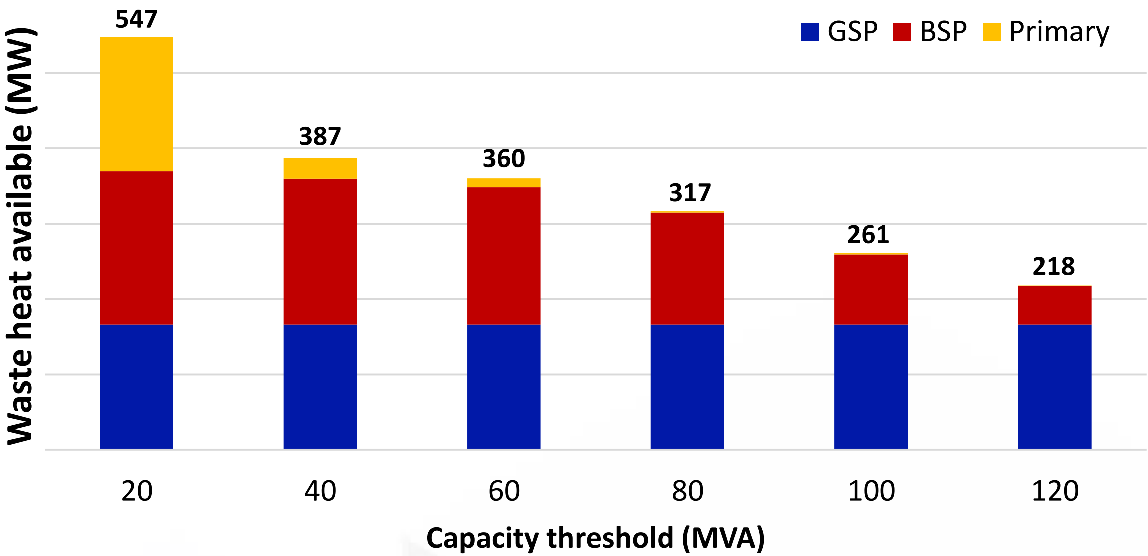
Headline numbers (considering only substation with capacity ≥ 60 MVA) :

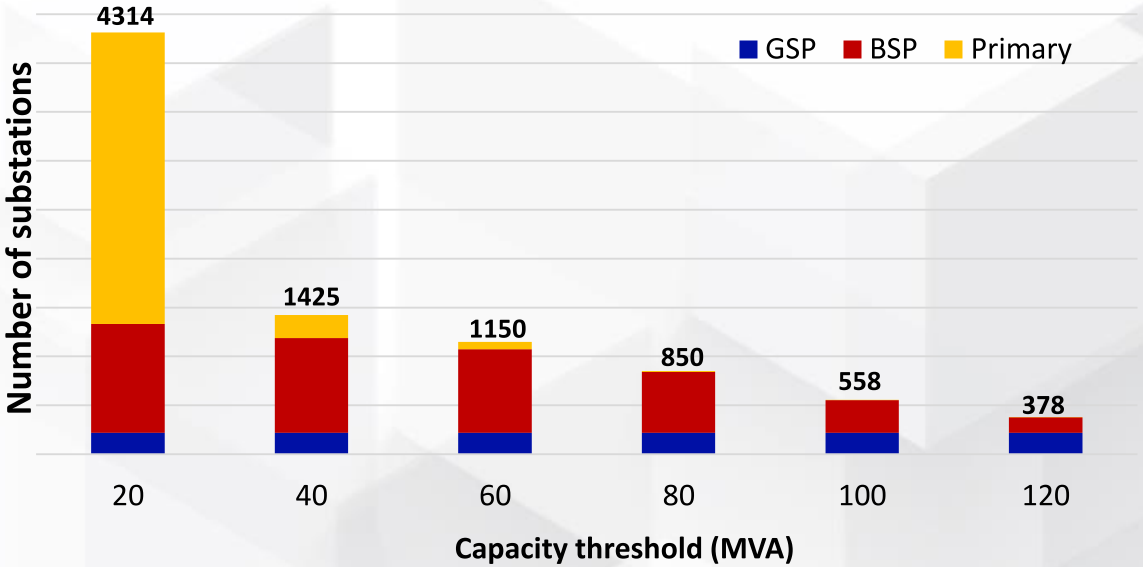
1150 substations in England, Wales, N Ireland (excl. sites in Scotland)

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.

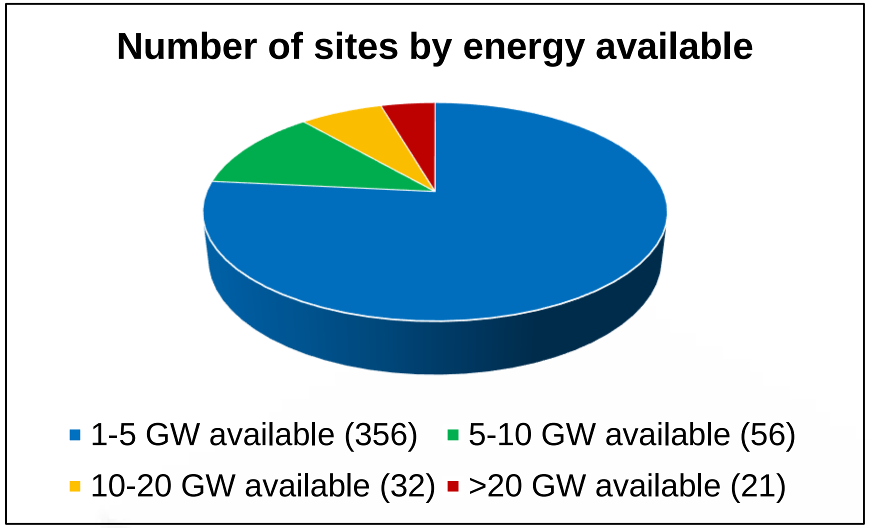


Figure 1 showing the number of sites and energy available

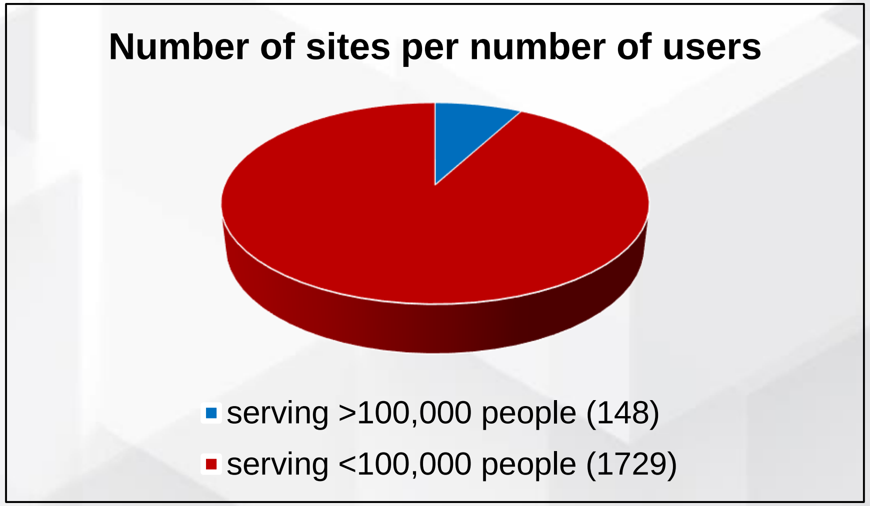


Figure 2 showing the number of sites by number of users

DATA CENTRES

Process:

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

- **Decision to focus on MSDCs and CDCs** based on two main factors, namely:
  i. the availability of data, as specifications of EDCs are rarely disclosed to the public, and;
  ii. 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.

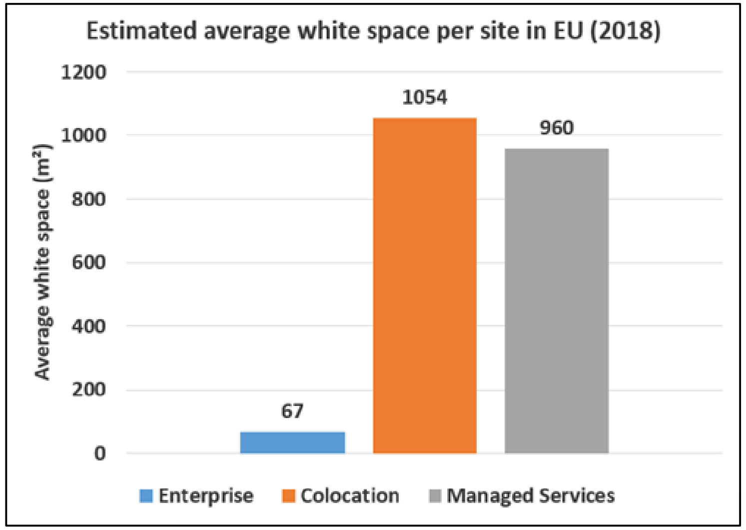


Figure 3 showing the comparison between the estimated average area of white space per site in the three types of data centres in EU (data from Dodd et al., 2020)

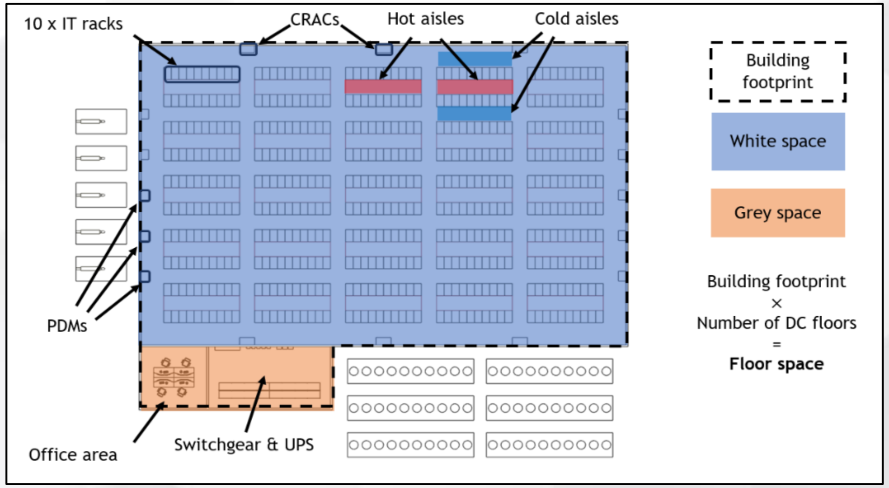


Figure 4 showing the components of a typical data centre

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.

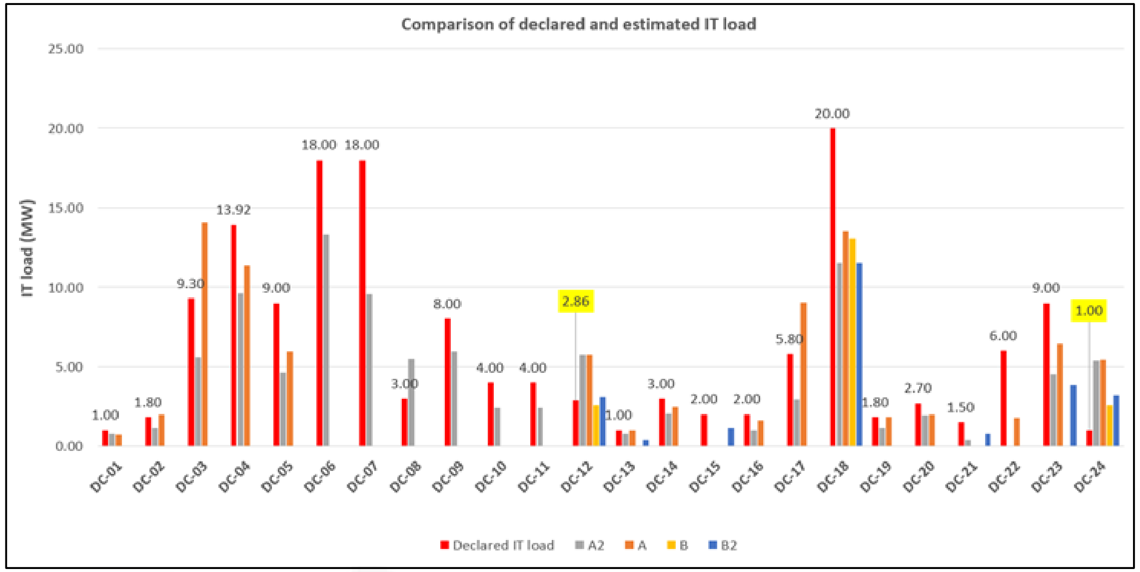


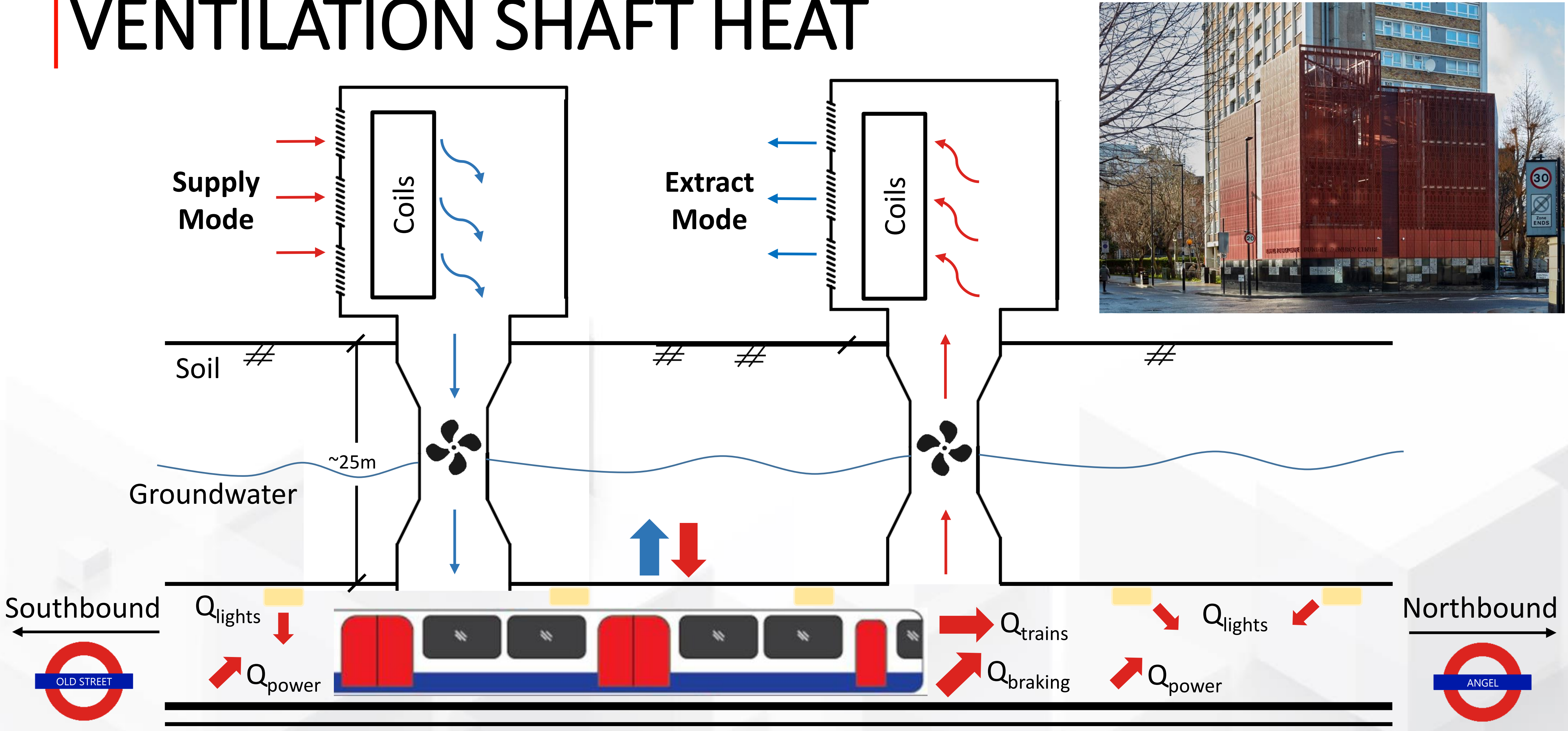
Figure 5 showing the comparison of IT load estimated for 24 data centres against the declared IT load

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)

VENTILATION SHAFT HEAT



London South Bank University

VENTILATION SHAFT HEAT

Headline numbers:

123 ventilation shafts in London and Newcastle

Energy: ~510 GWh/year for both cities

Average heat output per site: ca. 472 kW per ventilation shaft

Locations of ventilation shafts in central Newcastle

Potential waste heat output

London:

113 shafts * 40 m^3/s per shaft * 11.57 kW/(m^3/s) =

52.3 MW

Newcastle:

10 shafts * 50 m^3/s per shaft * 11.57 kW/(m^3/s) =

5.8 MW

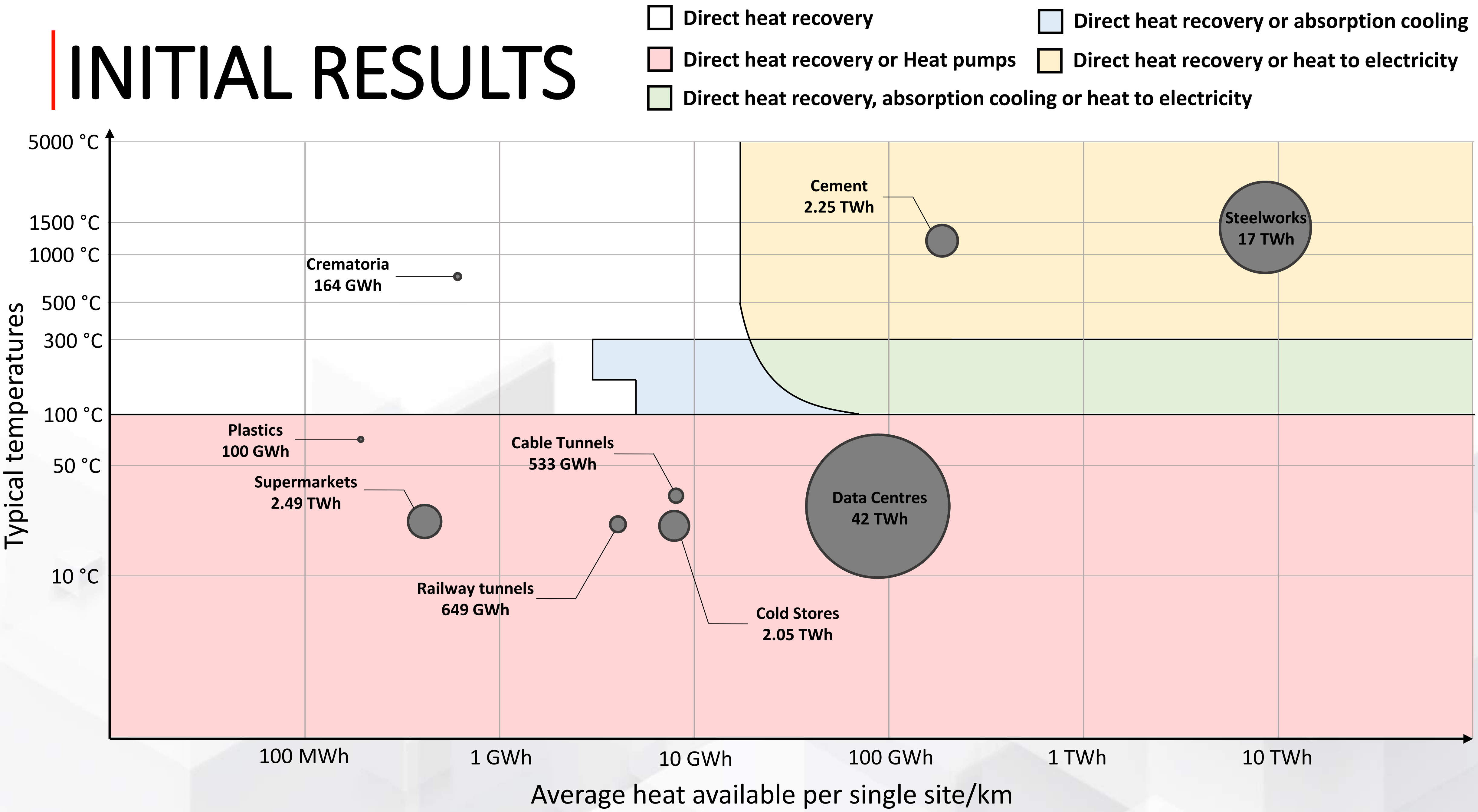
Total waste heat available:

58.1 MW

*Calculations based on two case studies and typical measured flow rates from the London Underground.

London South Bank University

INITIAL RESULTS



CONCLUSIONS

Early Stage Results

Project is still at an initial stage

Source Size

Some sources are much bigger and easier to access than others

Secondary Benefits

What secondary benefits are involved in waste heat recovery?

Cost

What's the cost to recover this heat?
Levelised cost of capture

NEXT STEPS

London South Bank University

QUESTIONS?

Akos Revesz
revesz2a@lsbu.ac.uk

Graeme Maidment
maidmegg@lsbu.ac.uk

The authors would like to acknowledge the support received from the following colleagues:
Henrique Lagoeiro
Matt Wegner
Judith Evans
Helen Turnell
Alan Foster
Gareth Davies

London South Bank University
EST 1892

Department for Business, Energy & Industrial Strategy