LoT-NET

Advisory Board Meeting 5th October 2021

Heat Capture

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Low Temperature Heat Recovery and Distribution Network Technologies

The big questions

- How big
- Where are they
- How to capture
- What's the benefit
- How do they compare

Waste heat source	**Number of heat sources > 250kW**	**Waste heat recovery site/medium**	**Waste heat temperature(s) (°C)**	**Total thermal energy (heat) output (GWh.a^{-1})**
Data centres	475	IT server exhaust air	30 to 40°C	9712
		Chilled water heat rejection	10 to 20°C	
Electrical substations	394	Transformer cooling system	40 to 70°C	2511
Wastewater	985	Final WWTP effluent	12 to 23°C Average 17.6°C	22515
Mine water	18584	Water	12 to 40°C	512807
Supermarkets	4853	Condenser heat rejection	21 to 27°C	6270
		Desuperheater	53°C	
Cold stores	306	Condenser heat rejection	15 to 30°C	4537
		Desuperheater	60 to 90°C	
Underground railway tunnels	65	Ventilation shaft air	11.5°C to 28°C	290
Cremations	161	Combustion exhaust gases	800 to 1000°C	146

Example : Food cold stores

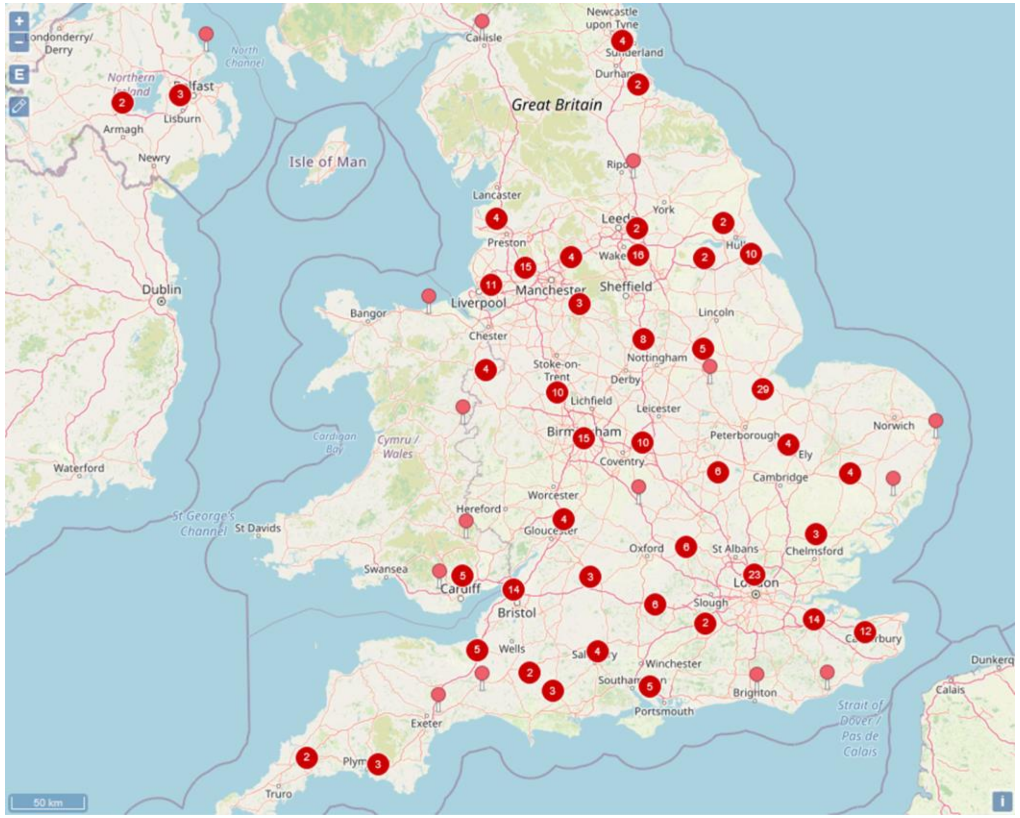
Headline numbers:

306 'large' stores in England, Wales, N Ireland (stores in Scotland removed)

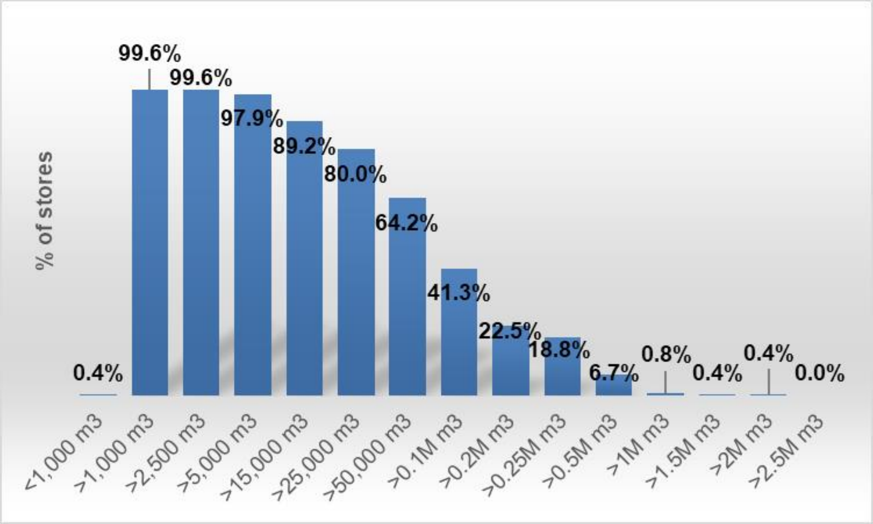
Volume: 46,842,880 m^3 for all 306 stores

Energy: 2.7 TWh/yr for all 306 stores

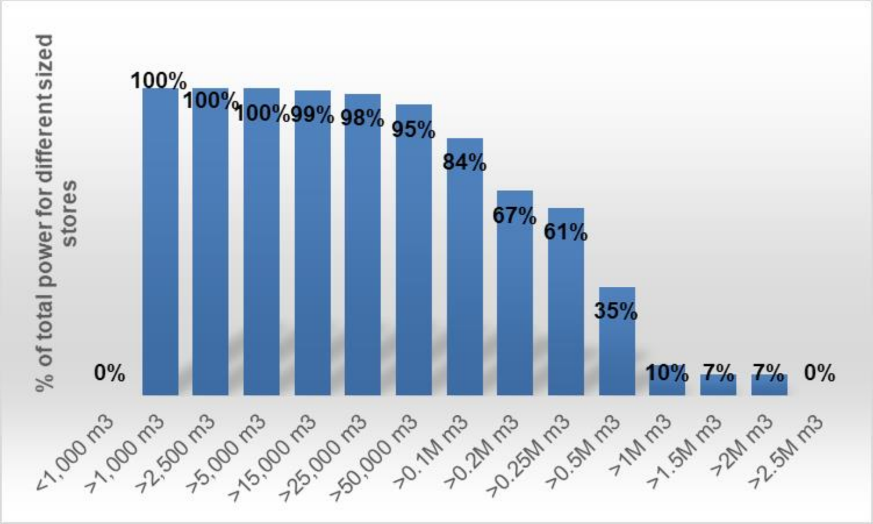
Average power: 1,017 kW/store



Map showing all cold store locations (numbers indicate multiple stores at location)



Volume of cold stores (all stores)



% of total power used by different store sizes (all stores)

Food cold stores: evidence and methodology

Energy benchmark(s) used

58.2 kWh/m^3/y. Mean SEC for chilled and frozen stores (Evans et al, 2014)

Assumptions:

All stores had average SEC

Reference:

Evans et al. Specific energy consumption values for various refrigerated food cold stores. Energy and Buildings (2014). Volume 74, May 2014, Pages 141–151

UK numbers/volume (excl Scotland)

306 'large' stores identified in Fikiin et al (2017)

241 had data on volume

Volume for stores with missing volume was pro-ratered based on type of store (chilled/frozen/mixed)

Energy use was based on SEC (see left)

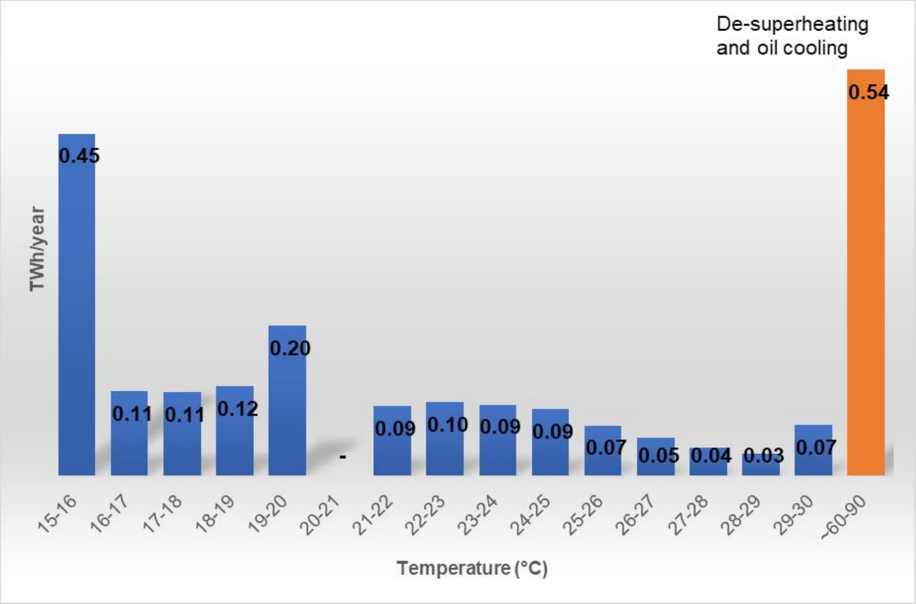
Total energy used/year (all stores) = 2.7 TWh/year

Assumptions:

Pro-ratering the stores is valid

References:

Fikiin et al. D2.1. Report on refrigerated food facility mapping. 2017.



Potential waste heat output

Calculated using:

- COSP of 1.5
- 60% of energy in stores used for refrigeration (excludes offices, fans, pumps etc)

Stores with >250 kW heat output extracted

- 84% (by number) of stores >250 kW heat output
- Volume for stores with heat output >250 kW = 36,932,612 m^3
- Total energy used/year (>250 kW stores) = 2.1 TWh/year
- 2.1 TWh of heat/year
- 25% at 60-90°C (desuperheating and oil cooling)
- 75% at 15-30°C (condenser)

Assumptions:

COSP of 1.5 is valid (based on survey and audit data from Evans et al, 2014 and confidential data from cold store surveys)

60% of store energy is used for refrigeration (based on survey and audit data from Evans et al, 2014 and confidential data from cold store surveys)

Minimum saturated condensing tempertaure of 15°C is required for hot gas defrosting (Clark and Gillies; Stoeker)

Detailed heat levels available (see left) based on detailed ambient data for Filton, Bristol. 8°C td for evaporative condenser based on confidential data from cold store surveys

That all desuperheating is available, it may already be used for underfloor heating or water heating in some stores

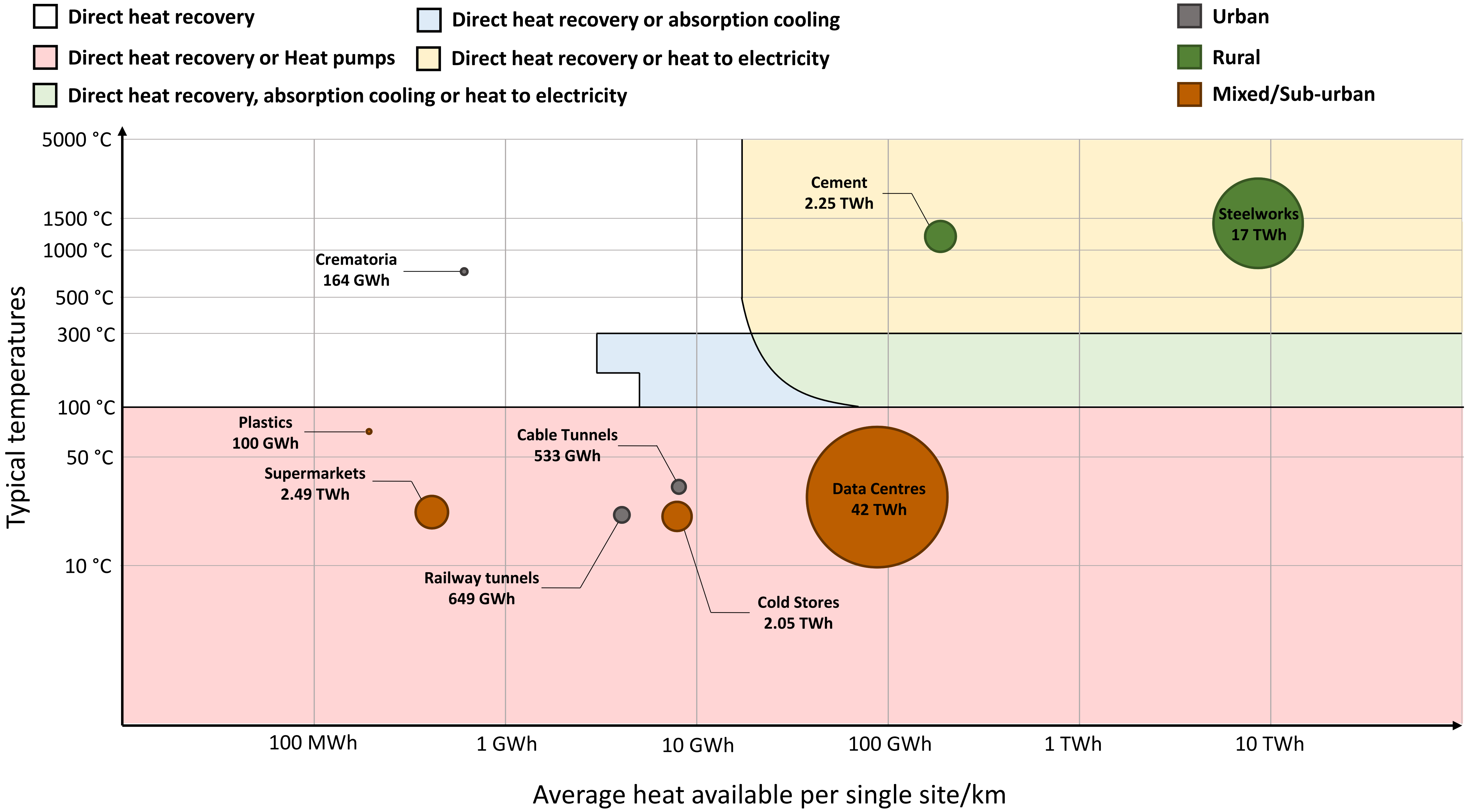
25% of heat from desuperheating based on confidential data from cold store surveys based on several ammonia plants

Reference:

Clark and Gillies, Comparison of evaporative and air cooled condensers in industrial applications, Proc. Inst. R. 2014-15. 3-1

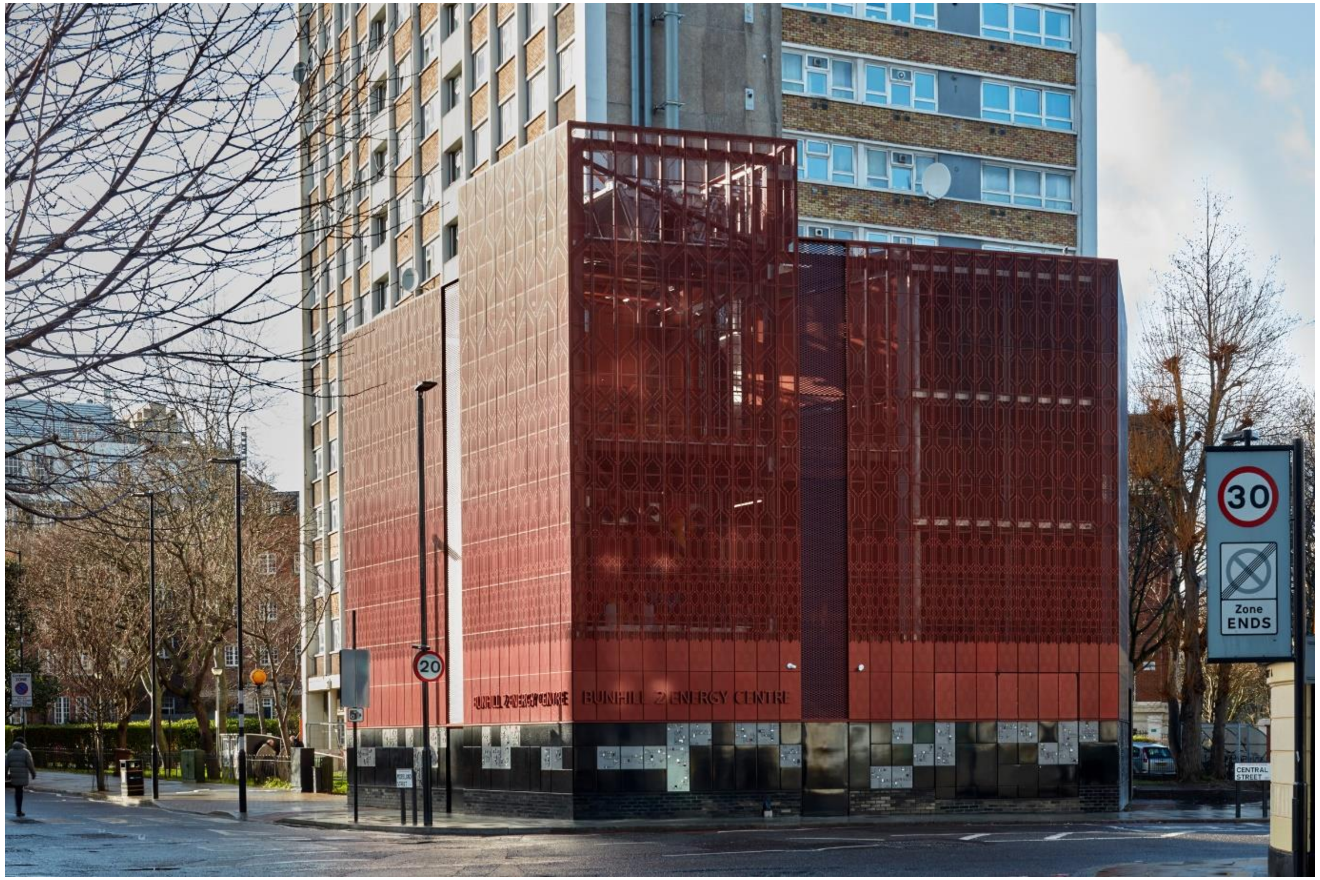
Evans et al. Assessment of methods to reduce the energy consumption of food cold stores. Applied Thermal Engineering 62 (2014) 697-705

Stoecker. Ind Refrig Handbook, McGraw Hill. 1998


Direct heat recovery
Direct heat recovery or absorption cooling
Urban
Direct heat recovery or Heat pumps
Direct heat recovery or heat to electricity
Rural
Direct heat recovery, absorption cooling or heat to electricity
Mixed/Sub-urban
5000 °C
1500 °C
1000 °C
500 °C
300 °C
100 °C
50 °C
10 °C
Typical temperatures
Cement
2.25 TWh
Steelworks
17 TWh
Crematoria
164 GWh
Plastics
100 GWh
Cable Tunnels
533 GWh
Supermarkets
2.49 TWh
Data Centres
42 TWh
Railway tunnels
649 GWh
Cold Stores
2.05 TWh
100 MWh
1 GWh
10 GWh
100 GWh
1 TWh
10 TWh
Average heat available per single site/km

HEAT FUEL PROJECT

- Average of **770 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



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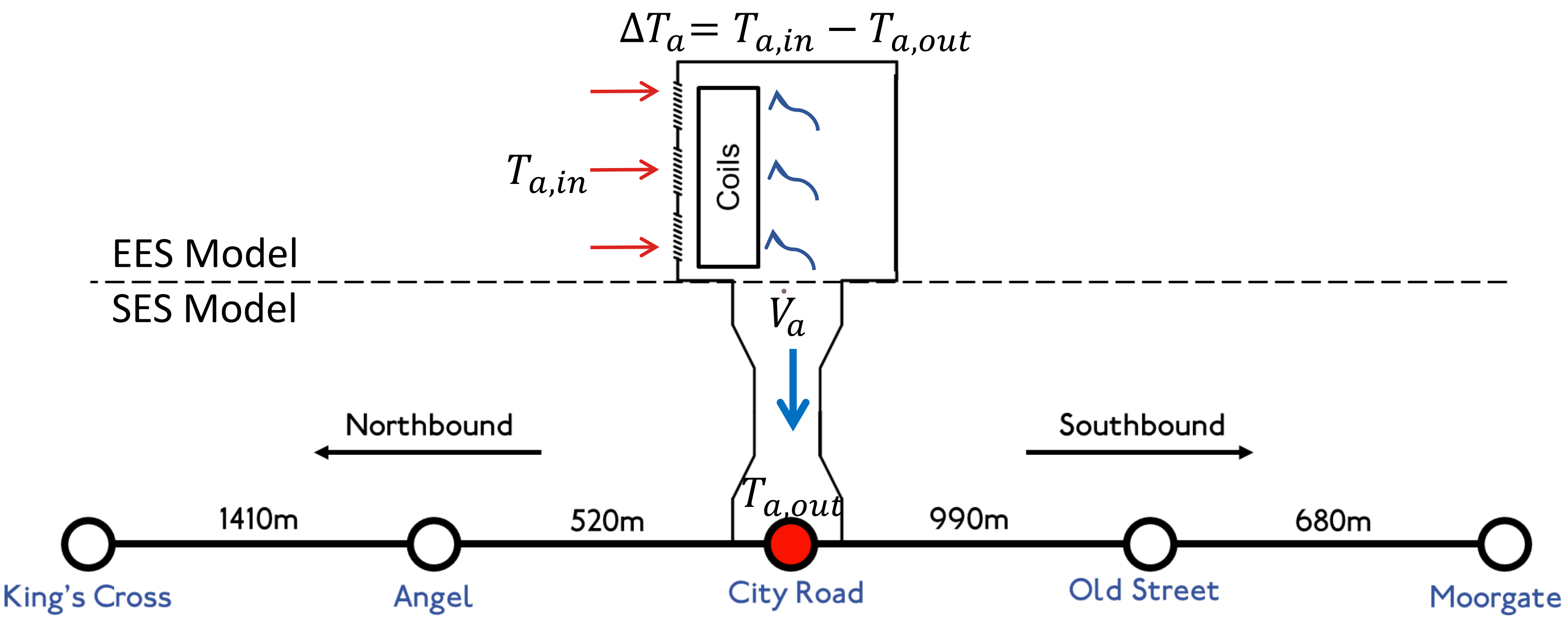
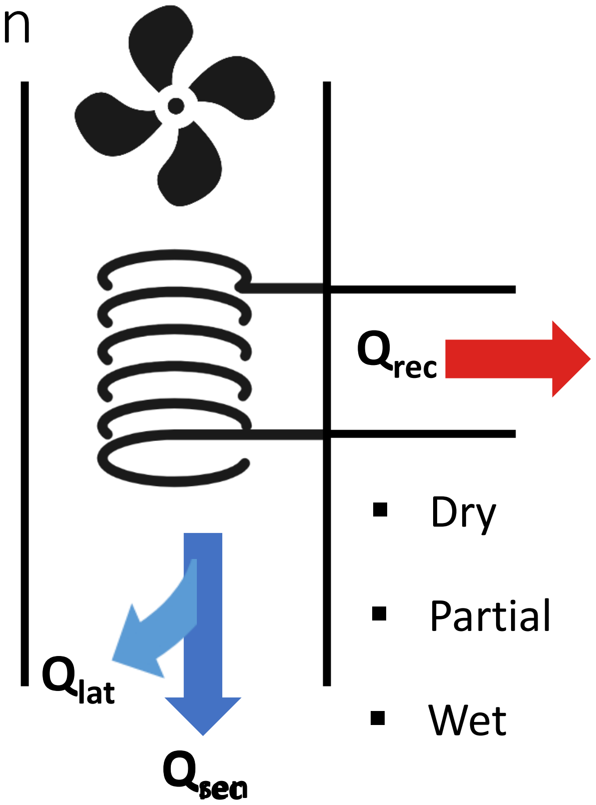
EST 1892

COOLING THE UNDERGROUND

The EES model outputs are used as inputs to the SES investigation





$Q_{rec} = Q_{lat} + Q_{sen}$

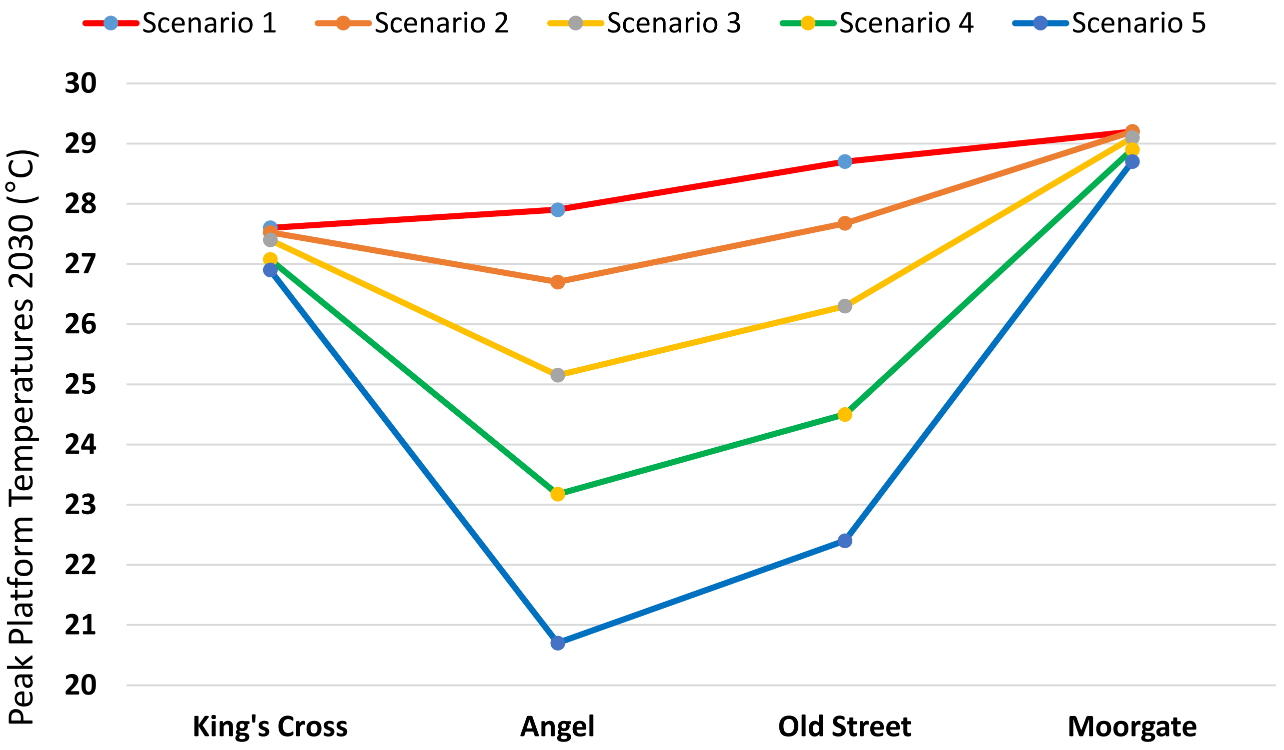
Outlet temperature and RH are supplied by EES model

EES model is able to account for condensation

Latent and sensible shares are used as inputs to SES

COOLING THE UNDERGROUND

Significant temperature reductions could be achieved at adjacent stations



		Peak platform temperatures (°C)				Cooling delivered (MWh/yr)
		King's Cross	Angel	Old Street	Moorgate	
Scenario 1 (12E/0S)		27.6	27.9	28.7	29.2	-
Scenario 2 (9E/3S)		27.5	26.7	27.7	29.2	1,618
Scenario 3 (6E/6S)		27.4	25.2	26.3	29.1	3,170
Scenario 4 (3E/9S)		27.1	23.2	24.5	28.9	4,530
Scenario 5 (0E/12S)		26.9	20.7	22.4	28.7	5,875

Average ΔTs of **1.1**, **2.6** and **4.5°C** for scenarios **2**, **3** and **4** at adjacent stations

~**5.9 GWh** of cooling/year would lead to an average ΔT of **6.8°C** at adjacent stations and **+23%** energy consumption

DATA CENTRES

- **Known number of data centres in UK as of 2018**:
  - 25 Managed Service;
  - 450 Colocation;
  - 11500 Enterprise.
- **Decision to focus on Managed Service and Colocation DCs** based on:
  - Availability of data, as specifications of Enterprise DCs are rarely disclosed to the public;
  - Colocations and Managed Services would typically yield a larger heat output, considering the larger average white space area per site (Figure 1).

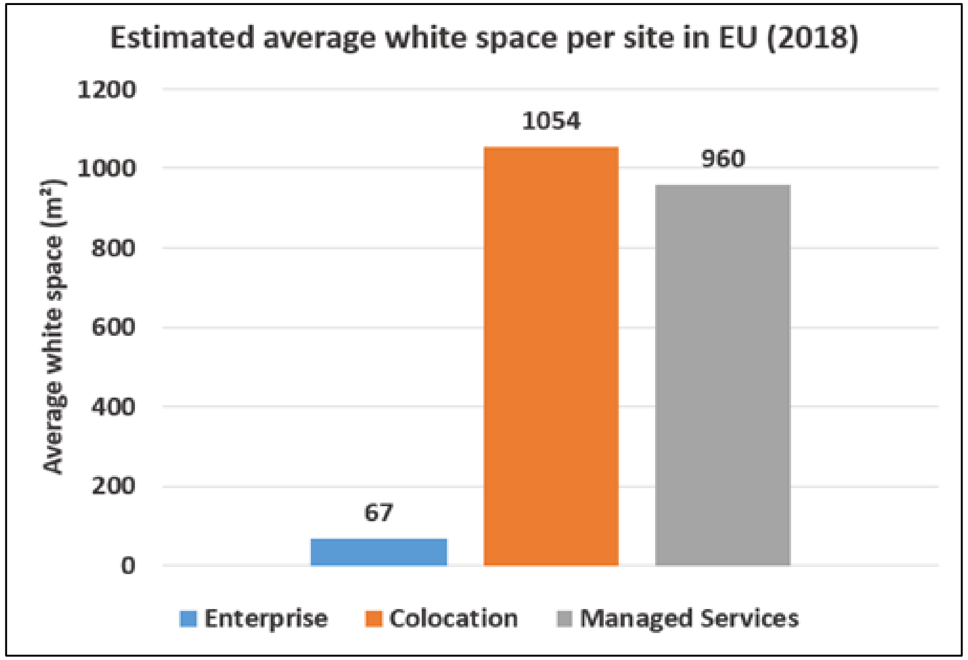


Figure 1

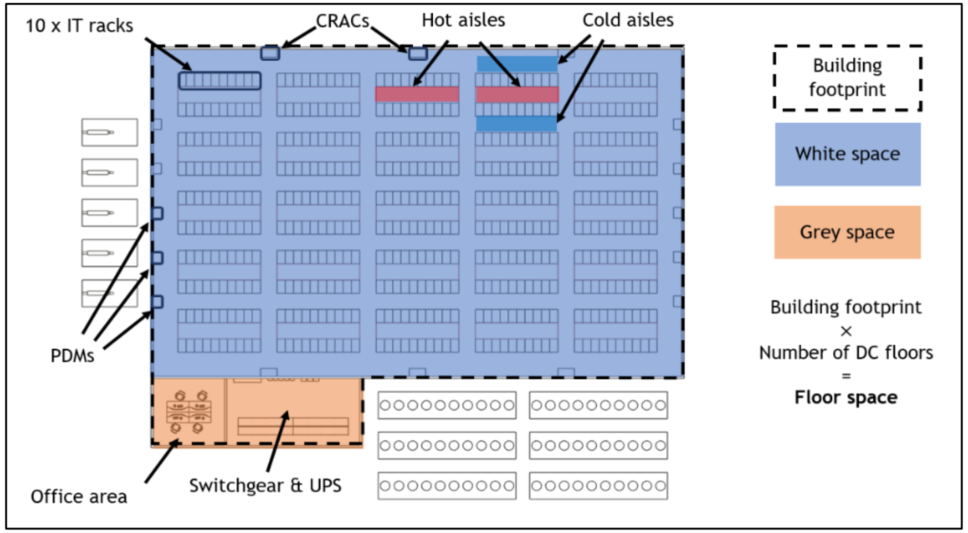


Figure 2 showing the components of a typical data centre

DATA CENTRES

- **Estimated heat output from 265 sites is 1939.7 MW**
- This represents 44.2% of the Managed Services and Colocation sector in 2018 (475 / estimated 4387.4 MW)

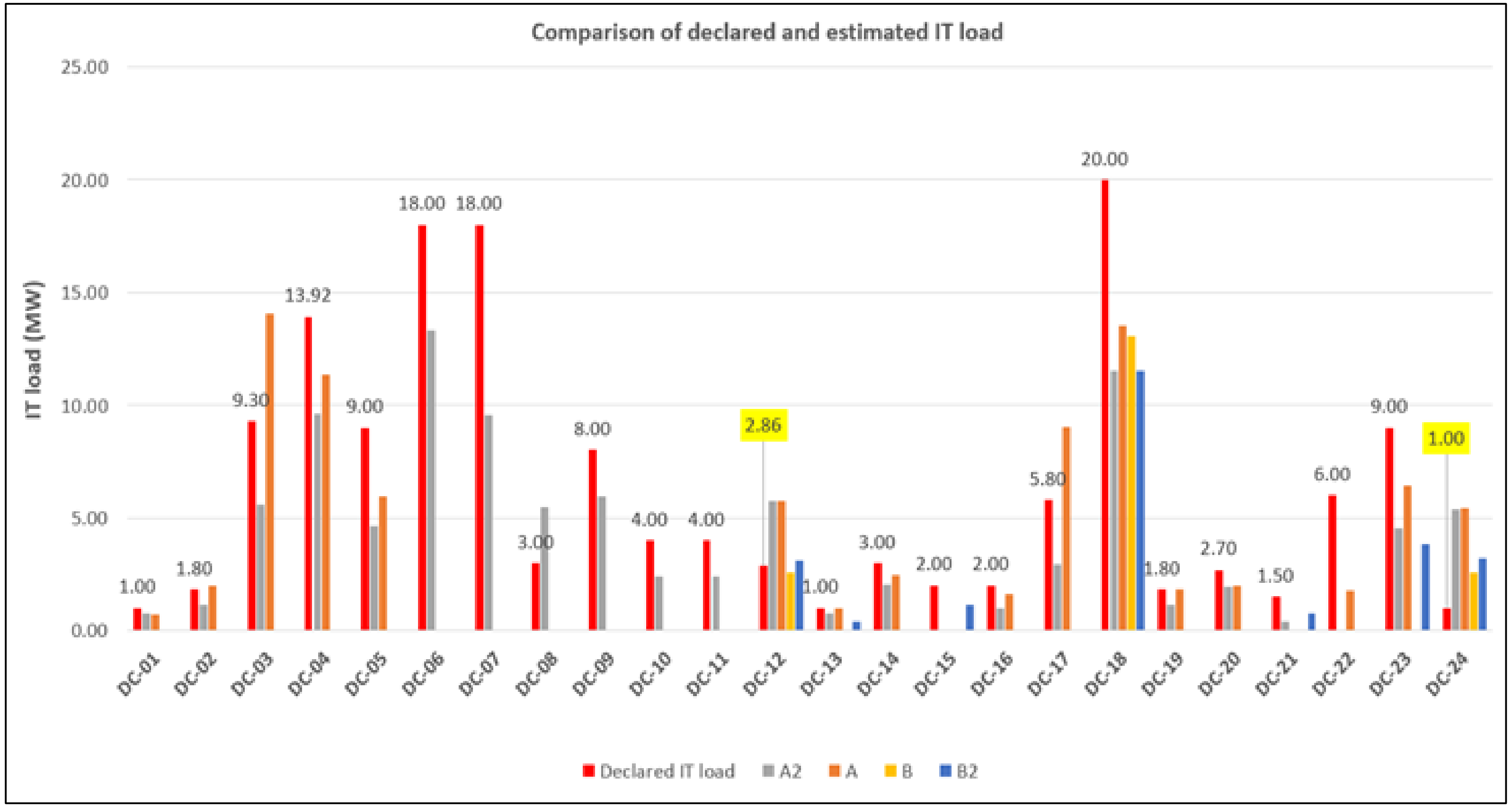
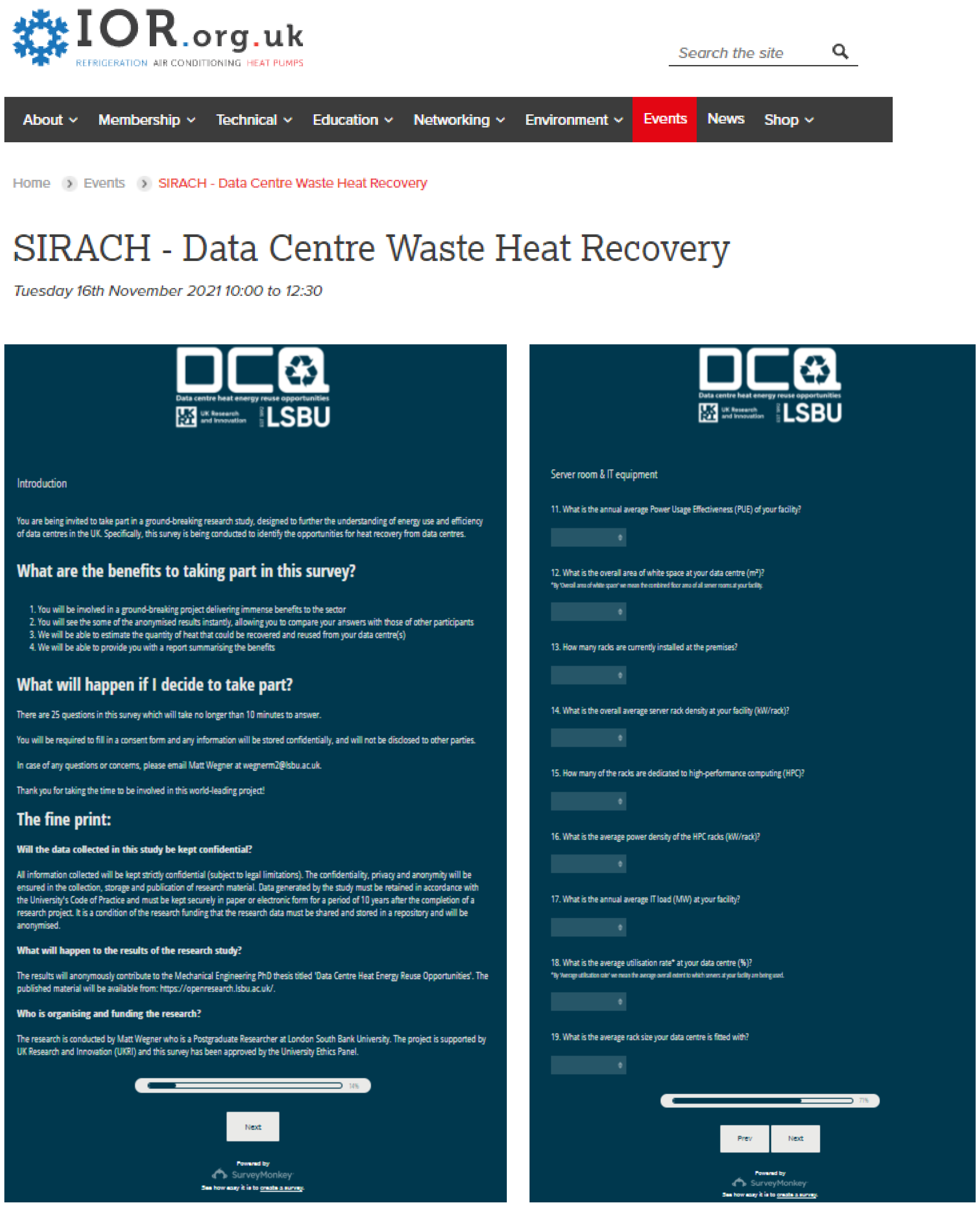


Figure 3 showing the comparison of IT load estimated for 24 data centres against the declared IT load

Data centre heat energy reuse opportunities

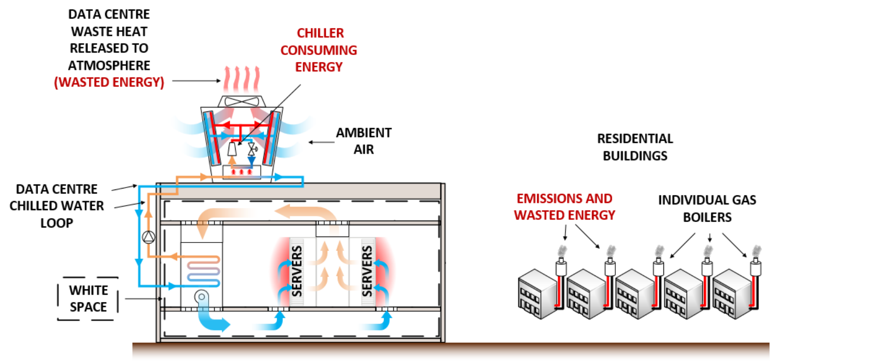
Online survey aiming to:

- Overcome the lack of transparency within the sector
- Help establish generic factors between facilities
- Invite data centre owners and operators to participate in the project (case study data)
- Investigate the industry’s attitude towards waste heat recovery

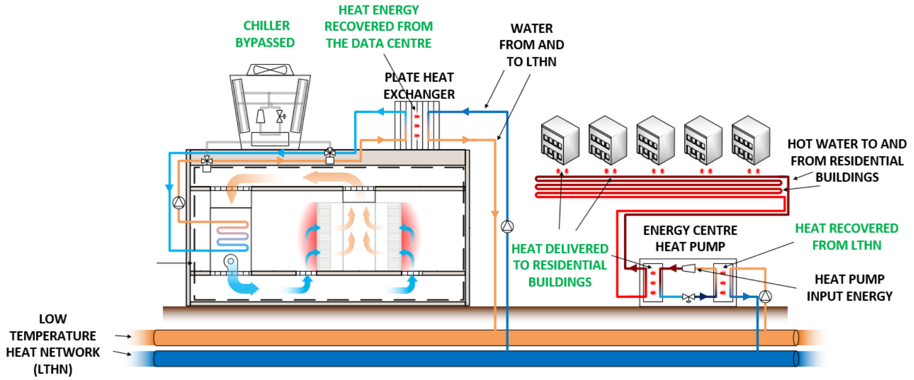


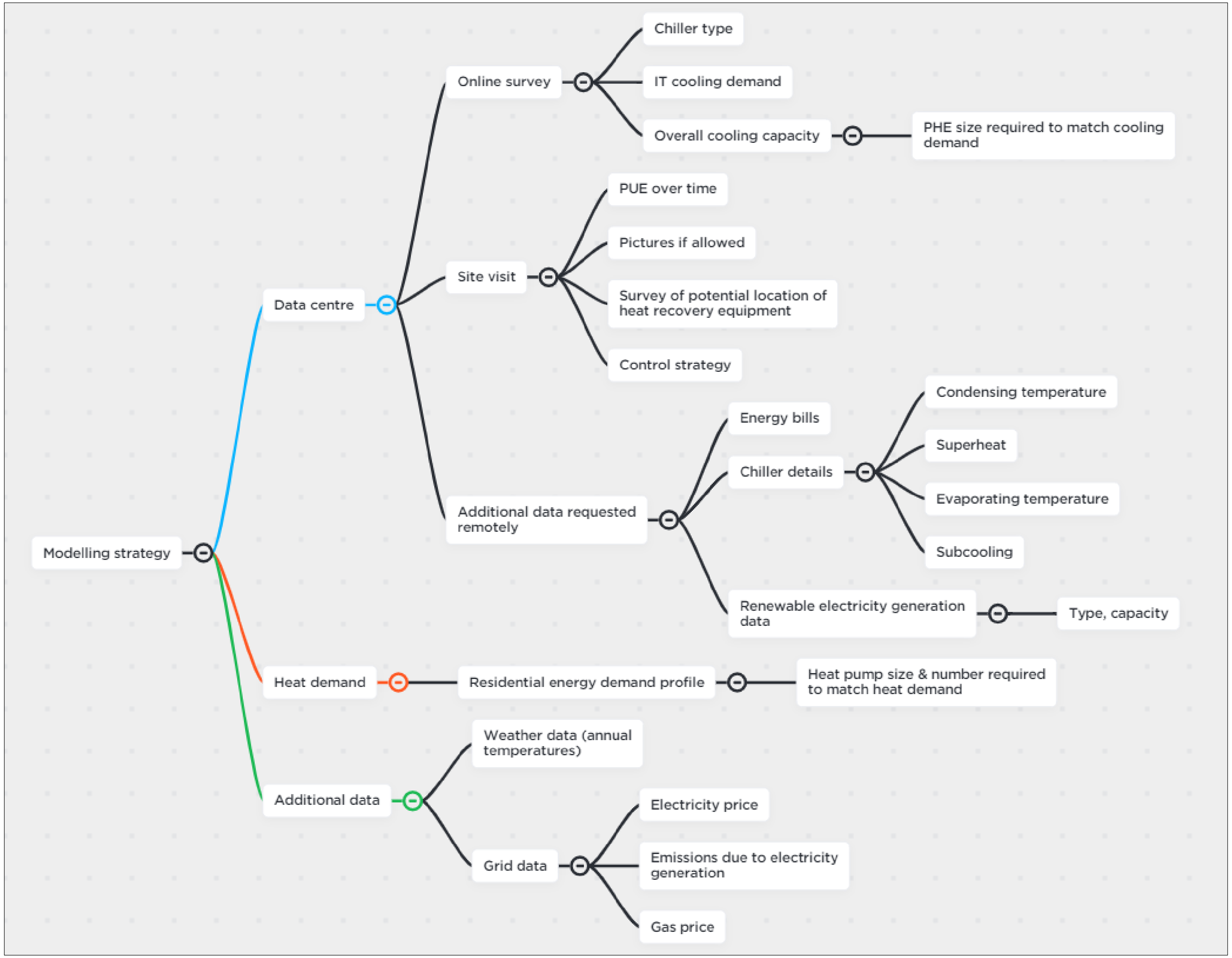
Data centre heat energy reuse opportunities

Business as usual:



Heat recovery:





Publications

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