Assessing low temperature waste heat integration in 5th Generation District Heating and Cooling

A case study evaluation in Clyde Gateway, Scotland

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This work was conducted during Orestis' PhD at the University of Glasgow, with the support of University of Edinburgh, Energy Technology Partnership and Ramboll.

27 May 2026

Agenda

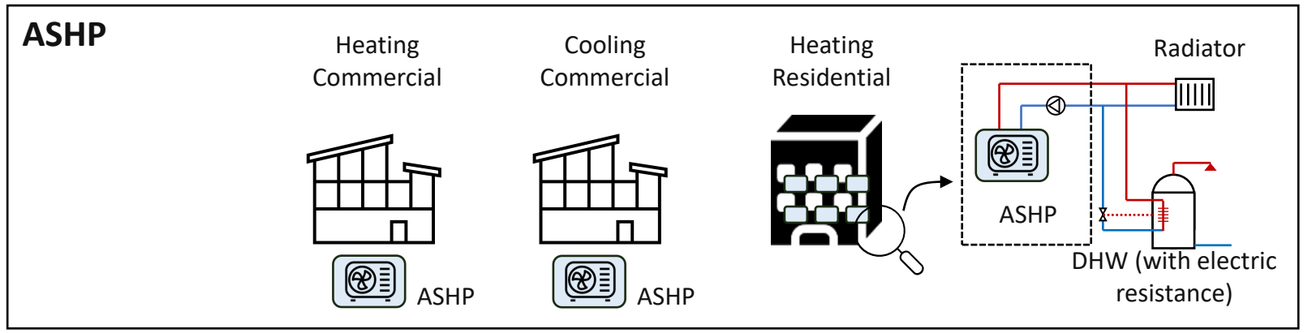
- Why decarbonise heat?
- Heat decarbonisation solutions.
- Demand overlap coefficient and low temperature waste heat.
- Case study.
- Techno-economic results.
- Conclusion.

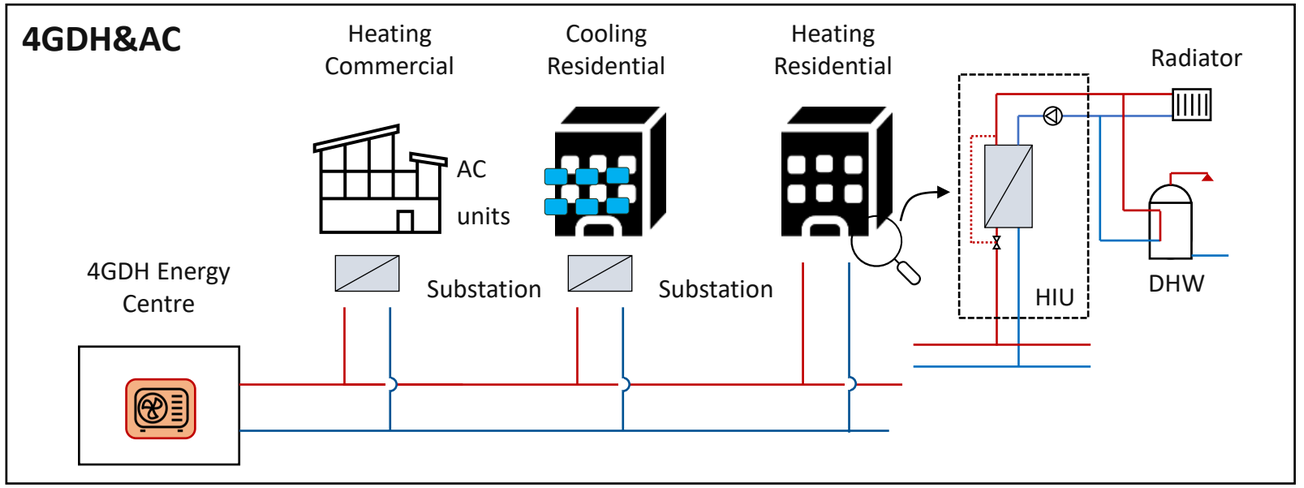
Why decarbonise heat

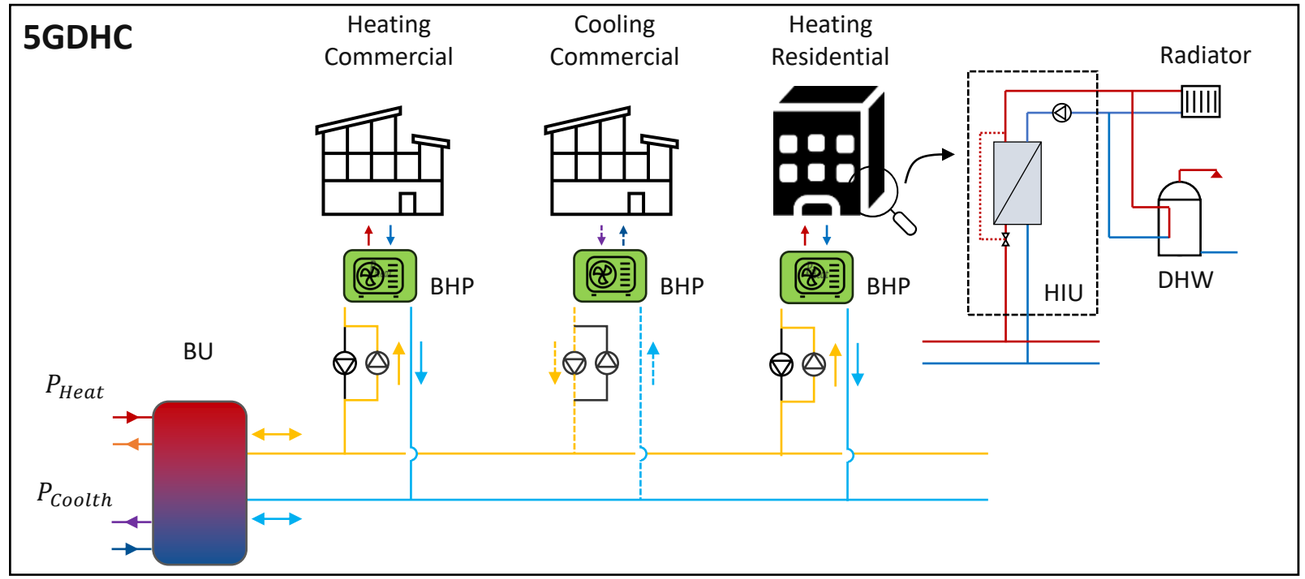
- About **a third** of UK's overall CO2 emissions come from **heating** (domestic, industrial and commercial sector) (Revesz et al., 2020).
- Fossil fuels dominate heating and cooling generation, with only 25% from Renewable Energy Systems (Eurostat, 2024), with higher electrification of heat needed.
- Finding pathways to interconnect the **electricity** and **thermal** utilities can prove key in the cost effective decarbonisation of heat.

Heat decarbonisation solutions; Which?

- Individual building level reversible Air Source Heat Pumps (**ASHPs**).
- 4th Generation District Heating (**4GDH**) with individual Air Condition (**AC**) units for cooling.
- 5th Generation District Heating and Cooling (**5GDHC**) meets heating and cooling demands through the same network, using decentralised booster heat pumps in district, building, or flat level.





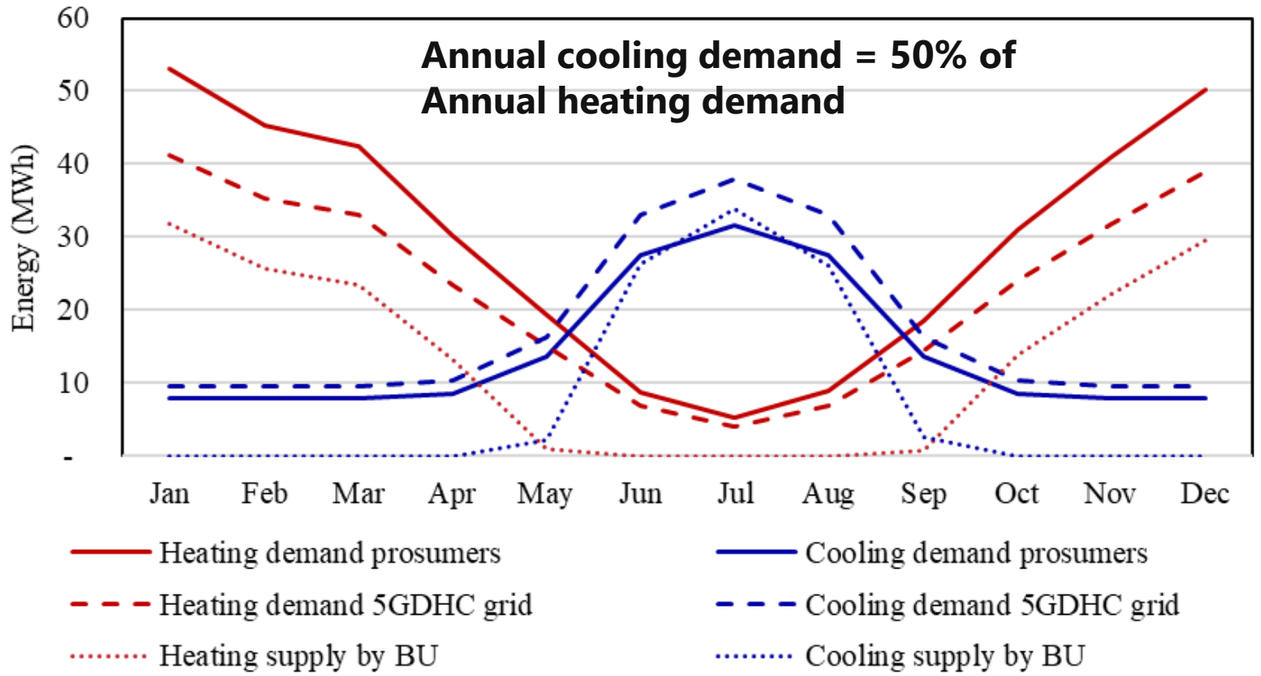


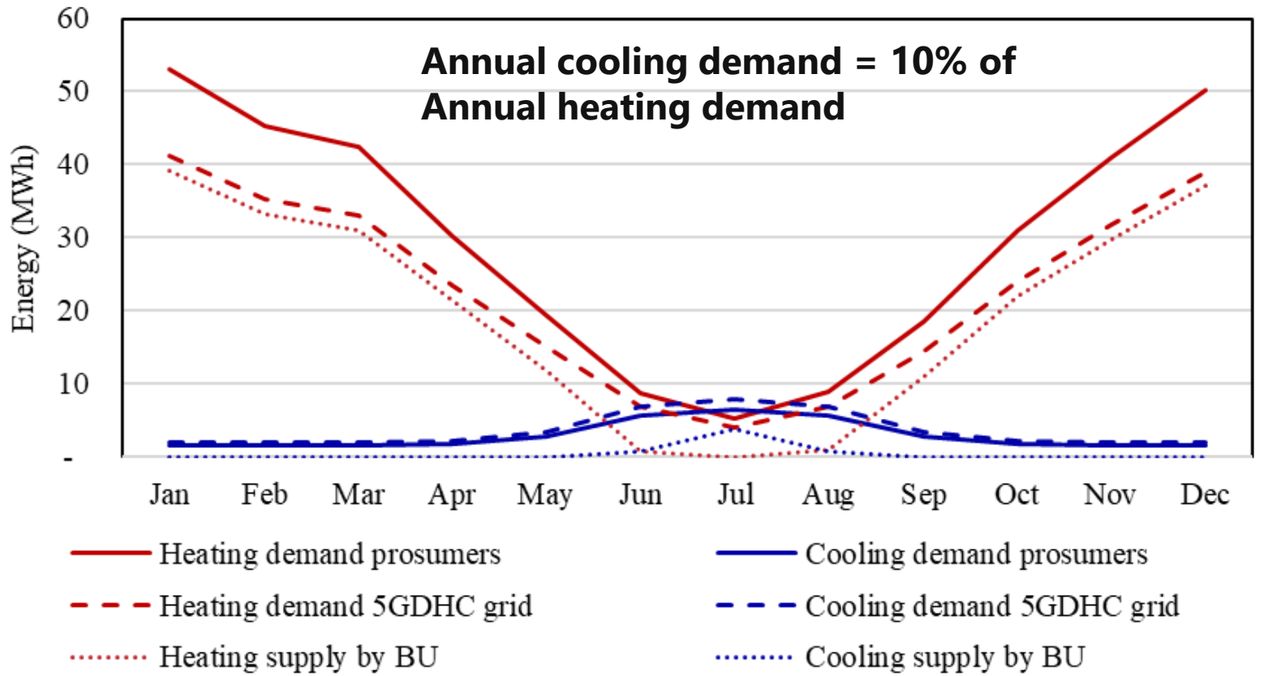
Heat decarbonisation solutions; Which?

- The primary potential advantage of **5GDHC** over these alternatives lies in its ability to facilitate energy reuse by satisfying both heating and cooling demands within the same network
- 5GDHC **economic viability** depends heavily on level of heating and cooling demand co-occurrence (overlapping heating and cooling demands at a point in time).
- But due to demand seasonality is rare to actually get high amounts of demand overlap, therefore the term **Demand Overlap Coefficient** is used.

Demand Overlap Coefficient

- The **Demand Overlap Coefficient (DOC)** depends on the hourly profiles of the demands rather than the annual benchmarks.

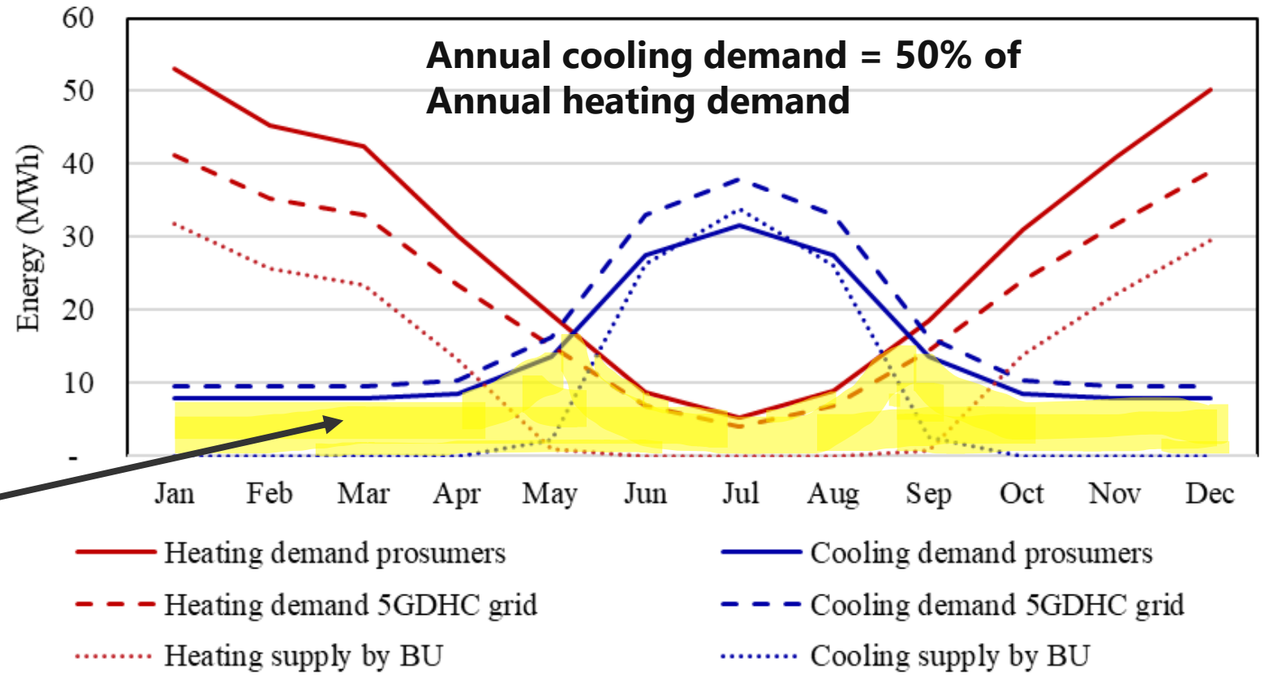




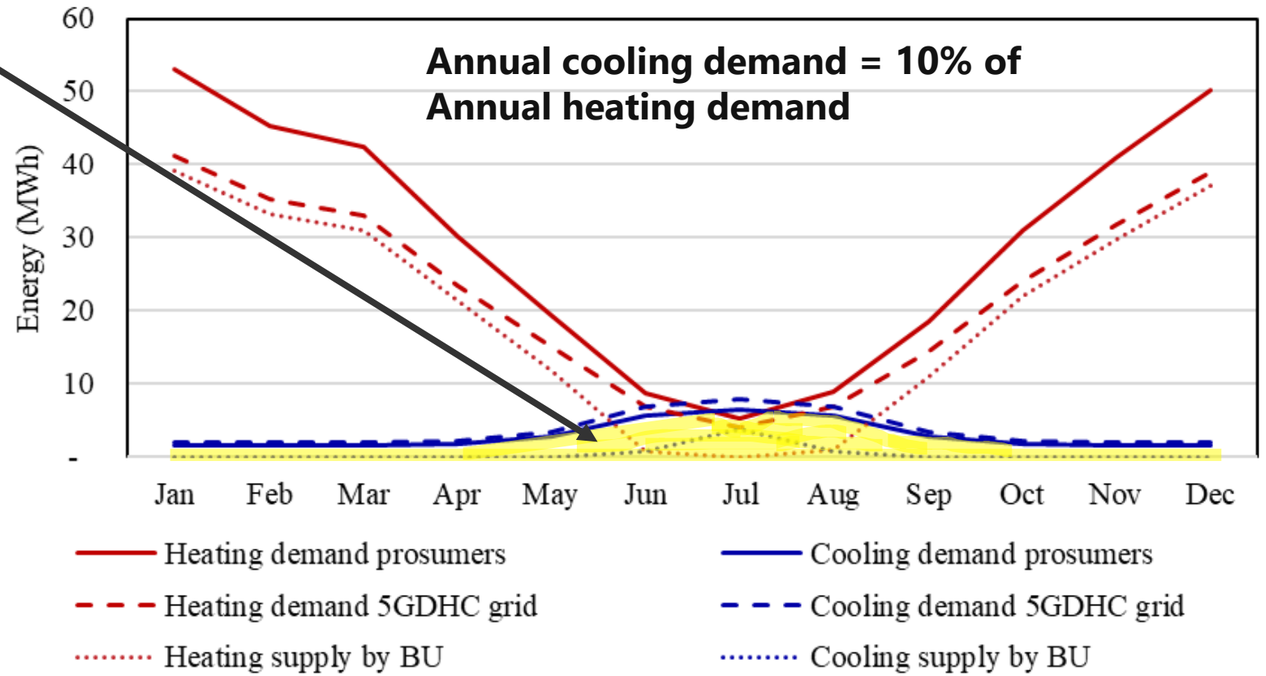
Demand Overlap Coefficient

- The **Demand Overlap Coefficient (DOC)** depends on the hourly profiles of the demands rather than the annual benchmarks.

Demand Overlap Coefficient = 21%



Demand Overlap Coefficient = 9%



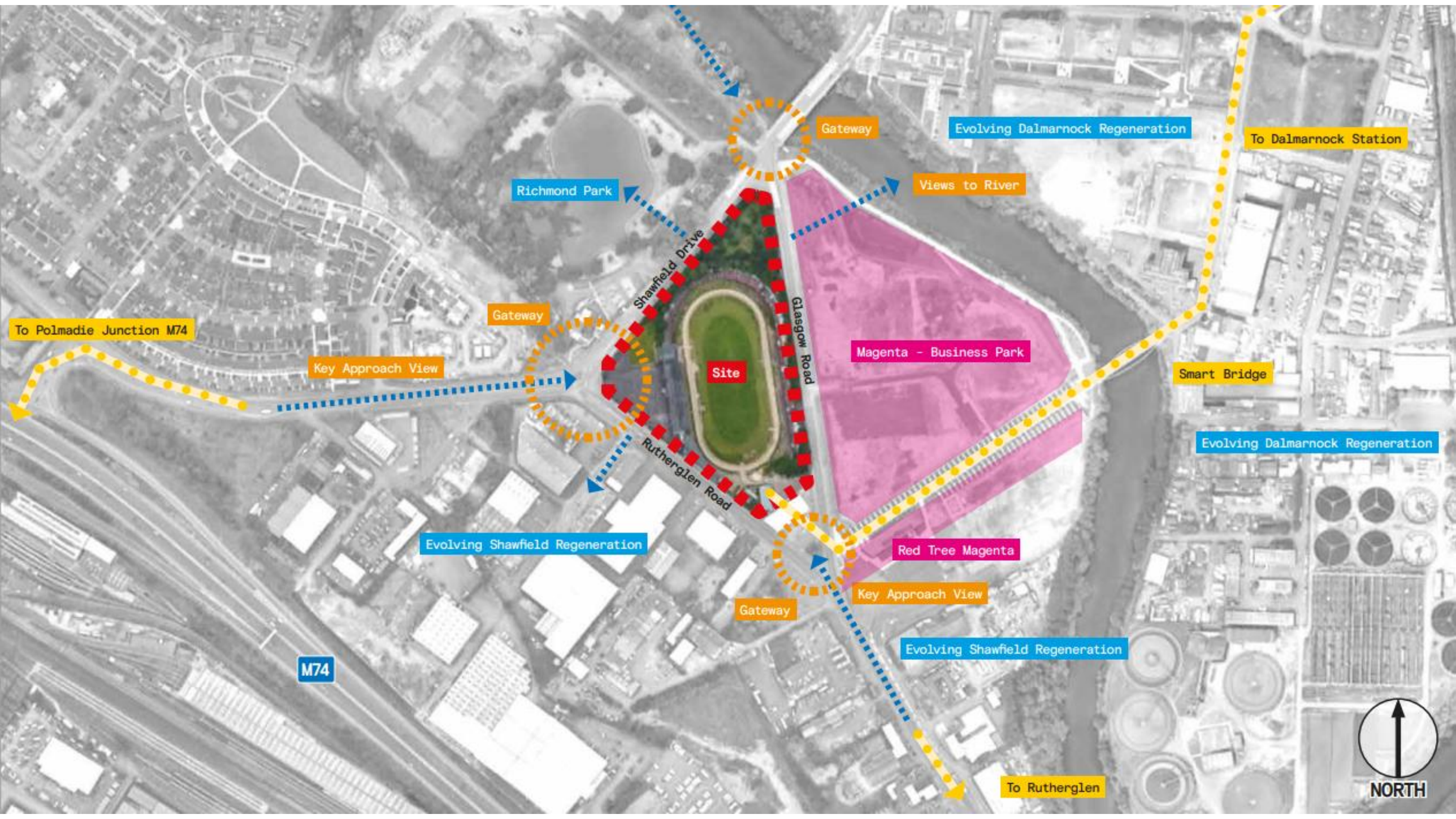
- A DOC of 20%-30% is reported as the minimum requirement for 5GDHC to start becoming economically competitive with other centralised systems.
- Zhang et al. (2023) is reporting that **only 0.1%** of the European building stock achieves a DOC greater than 30%, suggesting a restricted applicability for 5GDHC systems.

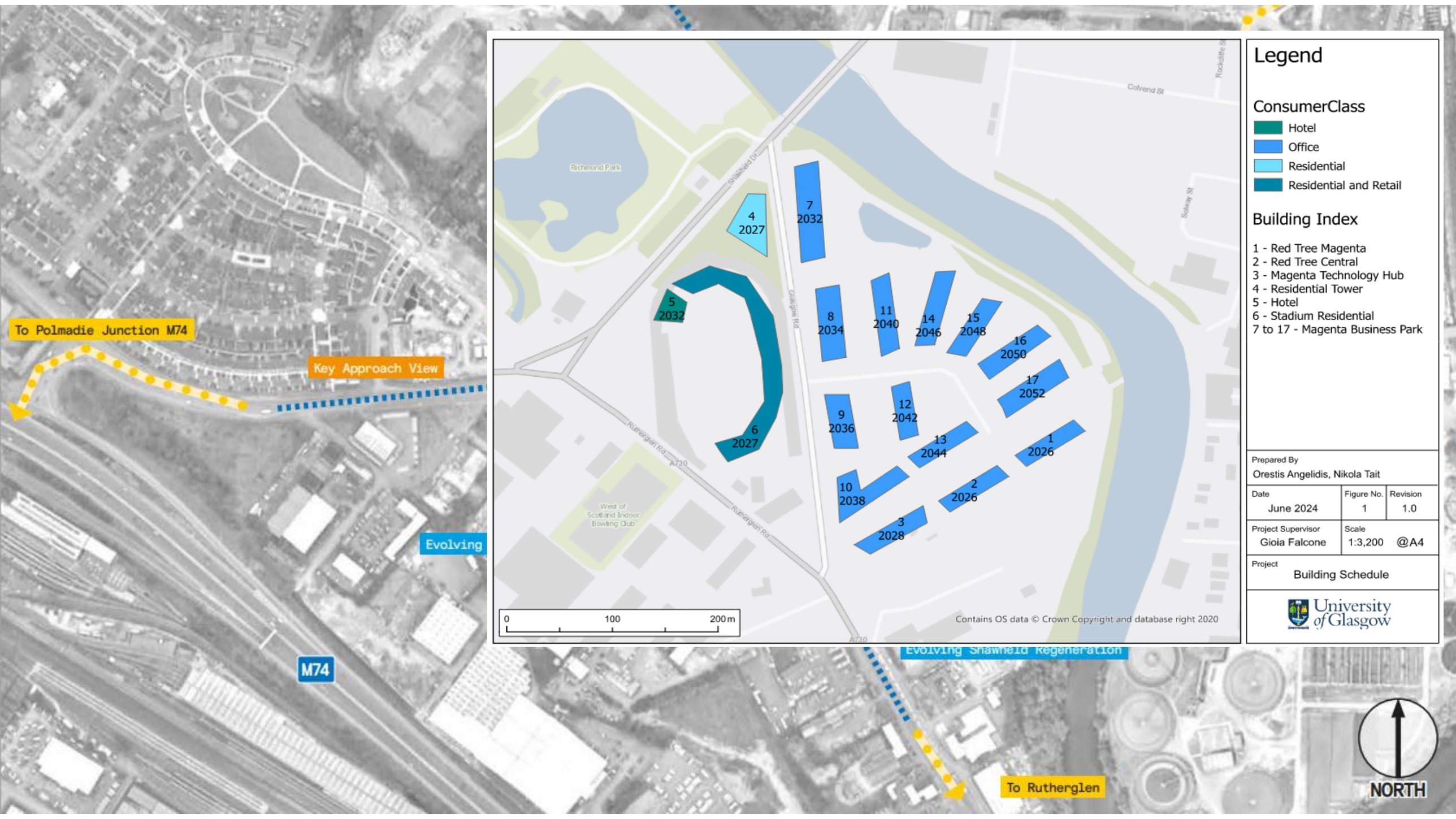
Low temperature waste heat

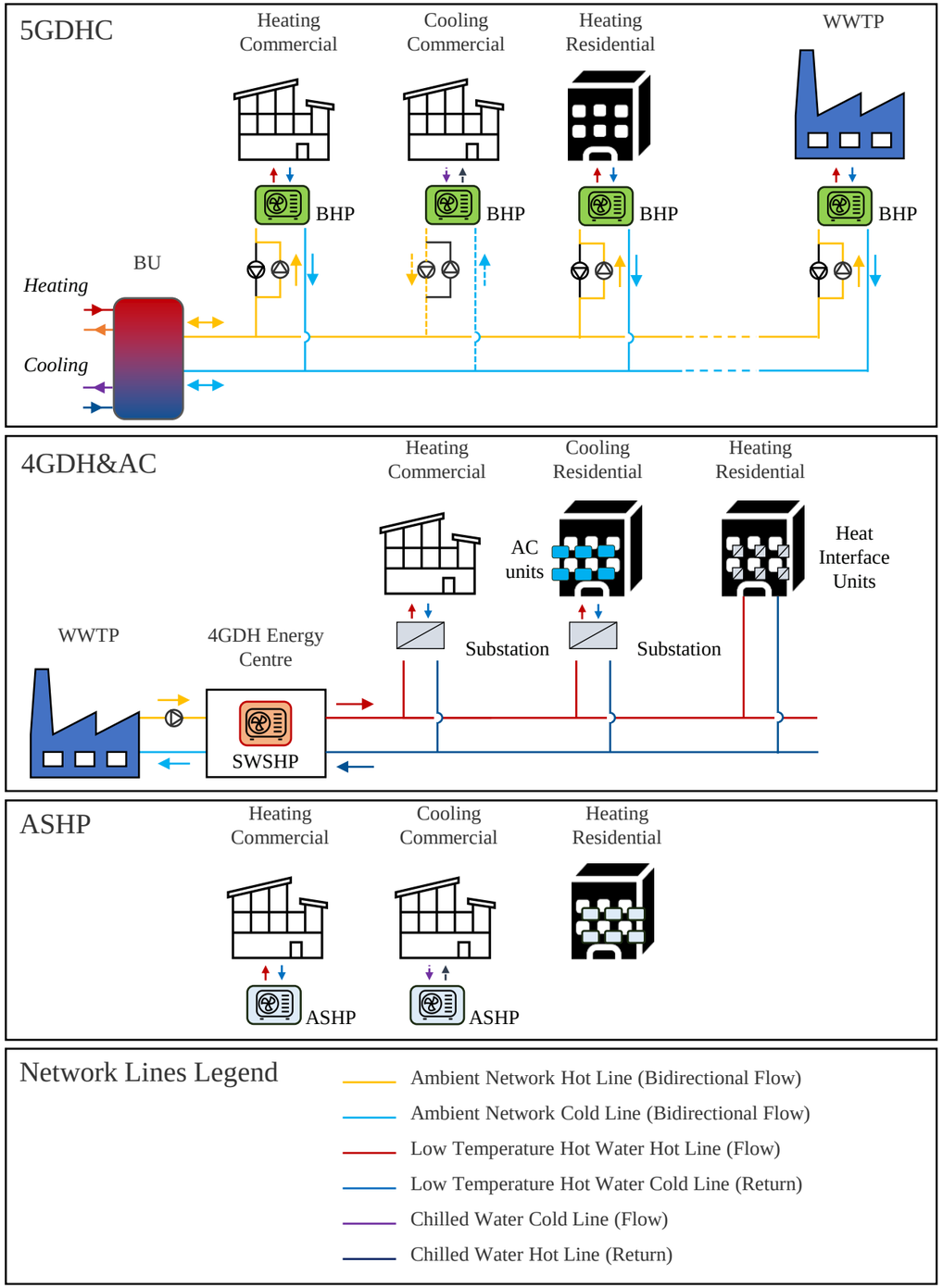
- Leveraging low temperature waste heat such as Waste-Water Treatment Plants (WWTP) as **a heat source/sink**, could help increase the amount of DOC in a system.
- What **system configurations** and **operational strategies** are most effective for integrating a low-temperature heat source/sink into a 5GDHC system?
- How does the techno-economic-environmental performance of 5GDHC systems utilising WWTPs as a dual source/sink compare to that of 4GDH and individual ASHP systems?
- What is the impact of these different 5GDHC designs (integrating WWTPs) on the local and wider electricity grid, particularly concerning grid capacity, when compared to 4GDH and individual ASHP systems?

Clyde Gateway Case Study



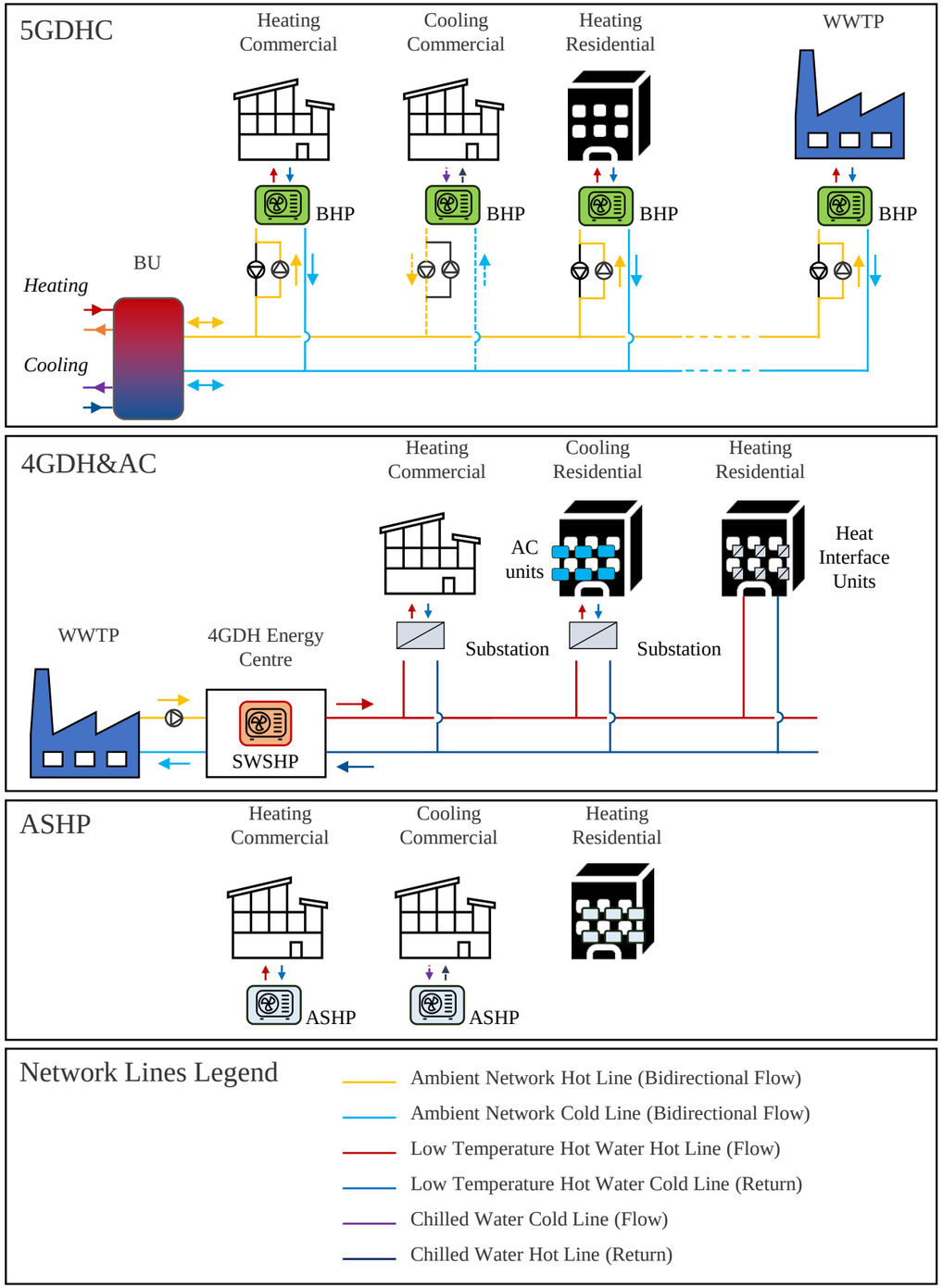

Gateway
Evolving Dalmarnock Regeneration
To Dalmarnock Station
Richmond Park
Views to River
Shawfield Drive
Glasgow Road
Gateway
To Polmadie Junction M74
Key Approach View
Site
Magenta - Business Park
Smart Bridge
Evolving Dalmarnock Regeneration
Rutherglen Road
Evolving Shawfield Regeneration
Red Tree Magenta
Key Approach View
Gateway
Evolving Shawfield Regeneration
M74
To Rutherglen
NORTH


To Polmadie Junction M74
Key Approach View
Evolving
M74
Evolving Shawfield Regeneration
To Rutherglen
NORTH
Richmond Park
Shawfield Dr
Glasgow Rd
Rutherglen Rd
A730
West of Scotland Indoor Bowling Club
Colvend St
Rockcliffe St
Solway St
4 2027
7 2032
5 2032
6 2027
8 2034
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Legend
ConsumerClass
Hotel
Office
Residential
Residential and Retail
Building Index
1 - Red Tree Magenta
2 - Red Tree Central
3 - Magenta Technology Hub
4 - Residential Tower
5 - Hotel
6 - Stadium Residential
7 to 17 - Magenta Business Park
Prepared By
Orestis Angelidis, Nikola Tait
Date
June 2024
Figure No.
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Project Supervisor
Gioia Falcone
Scale
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Project
Building Schedule
University of Glasgow



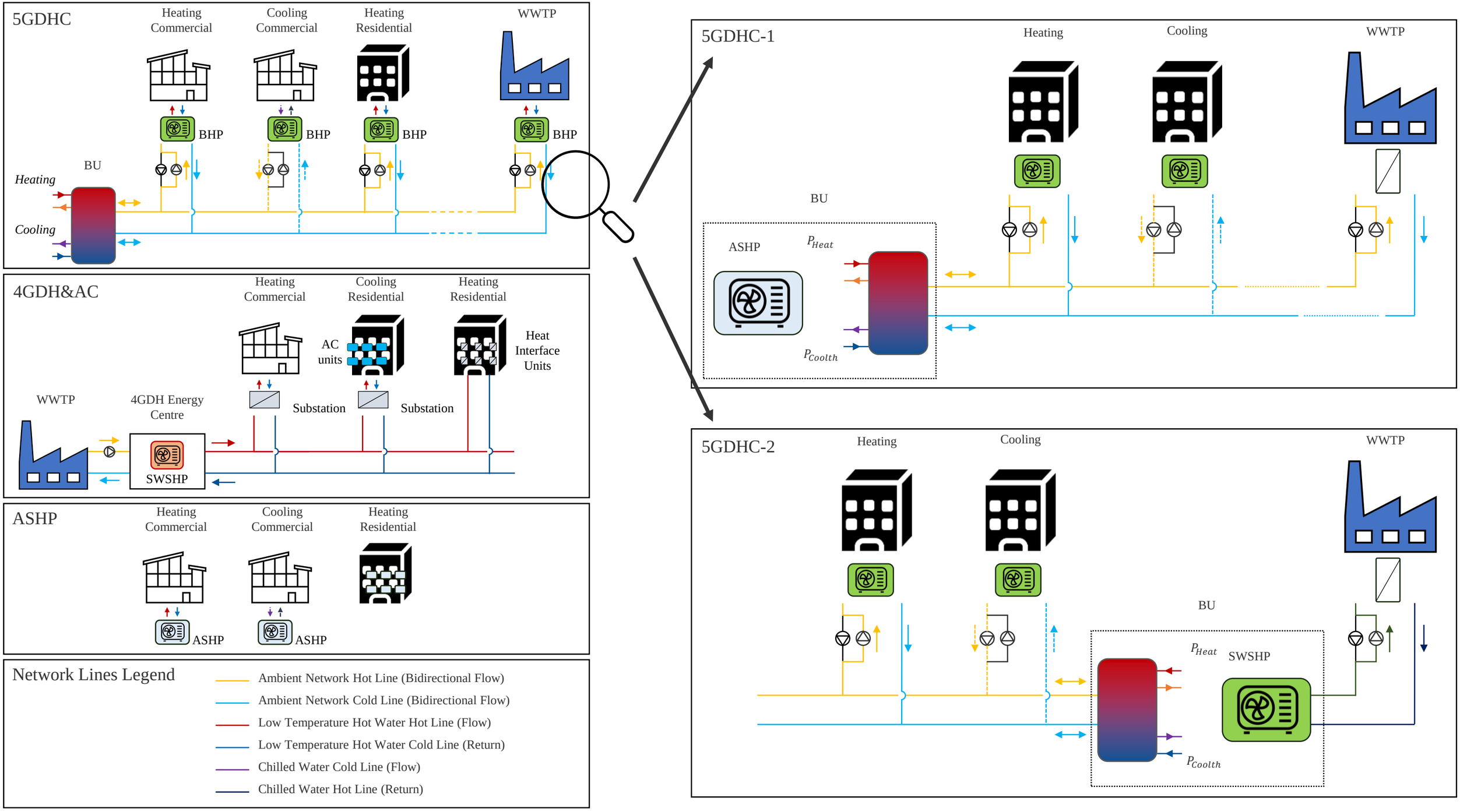
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- 4th Generation District Heating (4GDH) with individual Air Condition (AC) units for cooling.
- Individual building level reversible Air Source Heat Pumps (ASHPs).

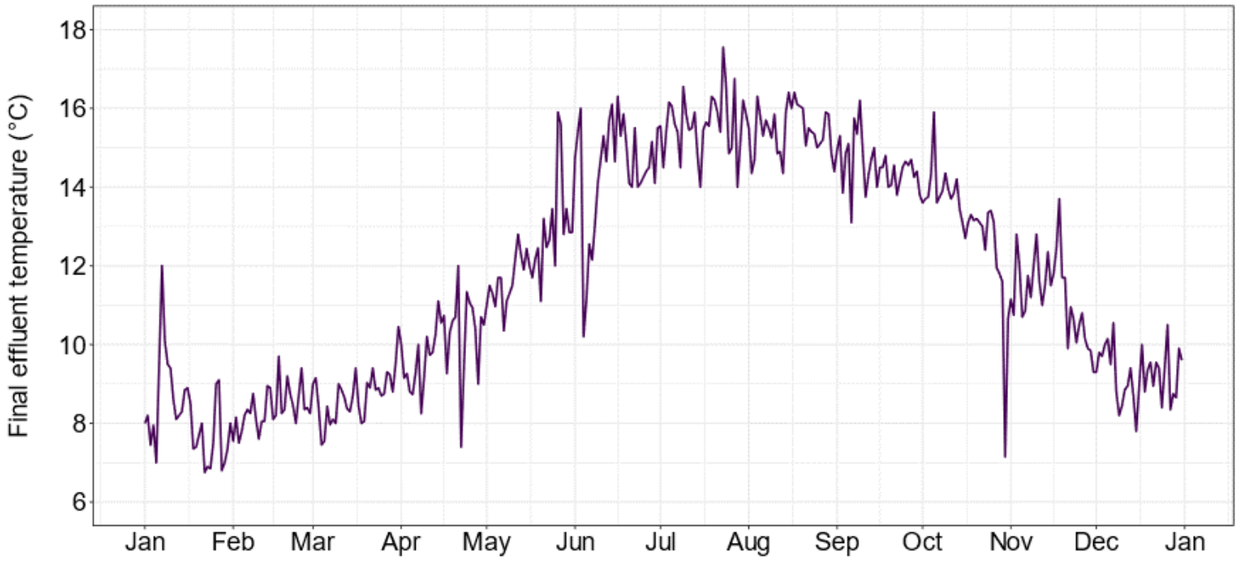


Heat decarbonisation solutions; Which?

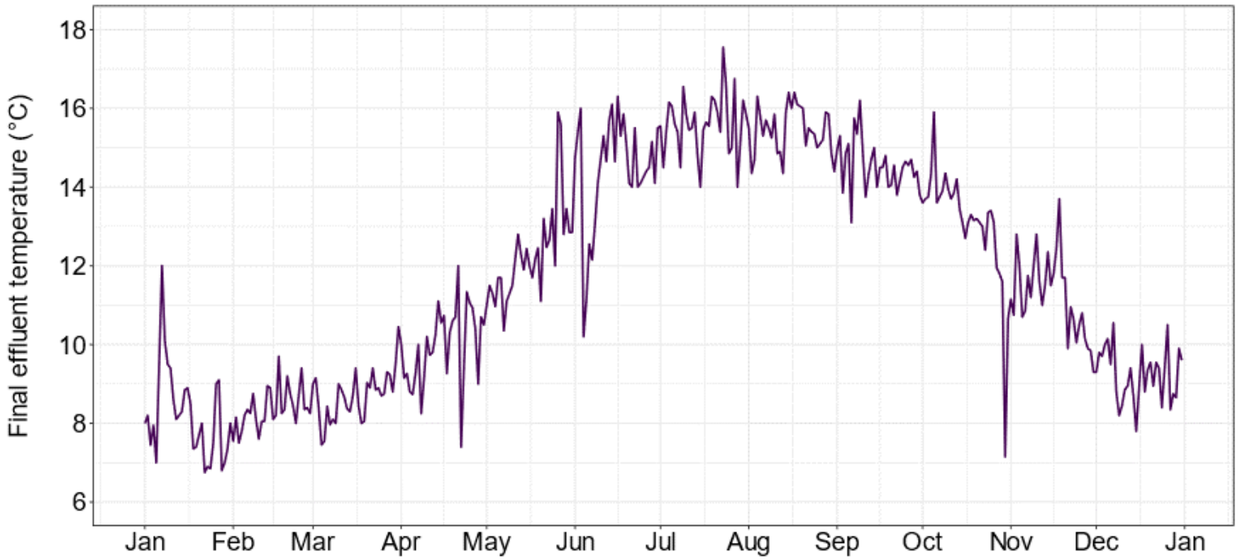
- **For 5GDHC two possible scenarios**
- **Scenario 1 (referred to as 5GDHC-1):** use of existing HEX at the WWTP plant. Appropriate network temperatures are needed to use the WWTP as a heat source during winter and as a heat sink during summer.
- **Scenario 2 (referred to as 5GDHC-2):** WWTP acts as a heat source/sink for a reversible SWSHP in the BU. The SWSHP acts as the main charging unit for the BU's TES.

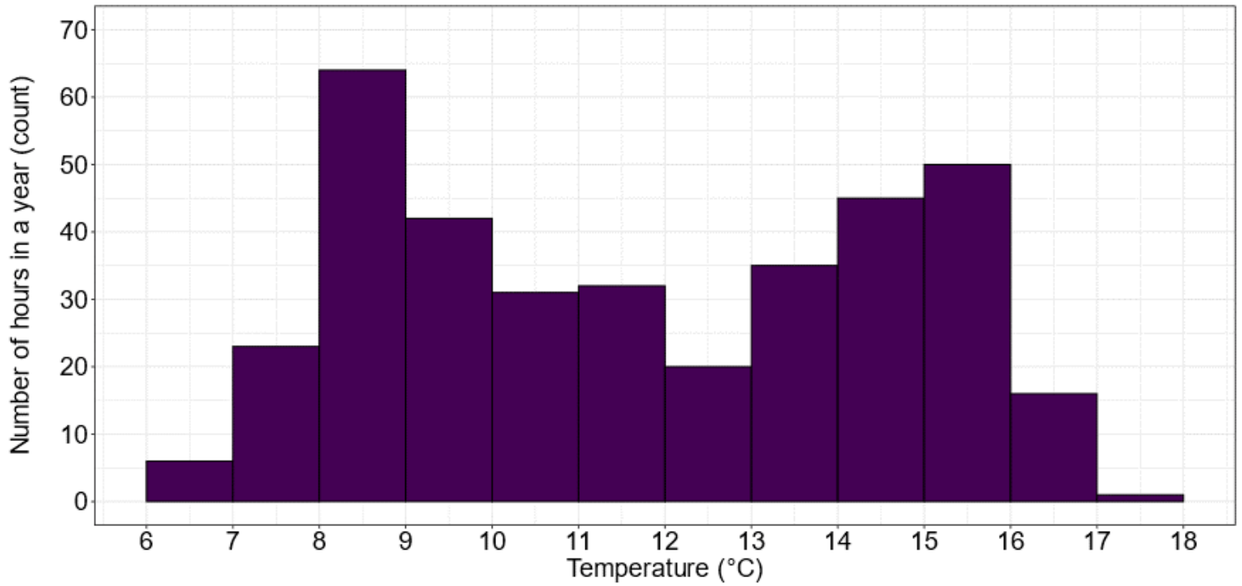

5GDHC
Heating Commercial
Cooling Commercial
Heating Residential
WWTP
BHP
BHP
BHP
BHP
BU
Heating
Cooling
4GDH&AC
Heating Commercial
Cooling Residential
Heating Residential
AC units
Heat Interface Units
WWTP
4GDH Energy Centre
Substation
Substation
SWSHP
ASHP
Heating Commercial
Cooling Commercial
Heating Residential
ASHP
ASHP
Network Lines Legend
Ambient Network Hot Line (Bidirectional Flow)
Ambient Network Cold Line (Bidirectional Flow)
Low Temperature Hot Water Hot Line (Flow)
Low Temperature Hot Water Cold Line (Return)
Chilled Water Cold Line (Flow)
Chilled Water Hot Line (Return)
5GDHC-1
Heating
Cooling
WWTP
BU
ASHP
P_{Heat}
P_{Coolth}
5GDHC-2
Heating
Cooling
WWTP
BU
P_{Heat}
SWSHP
P_{Coolth}

Waste heat utilisation

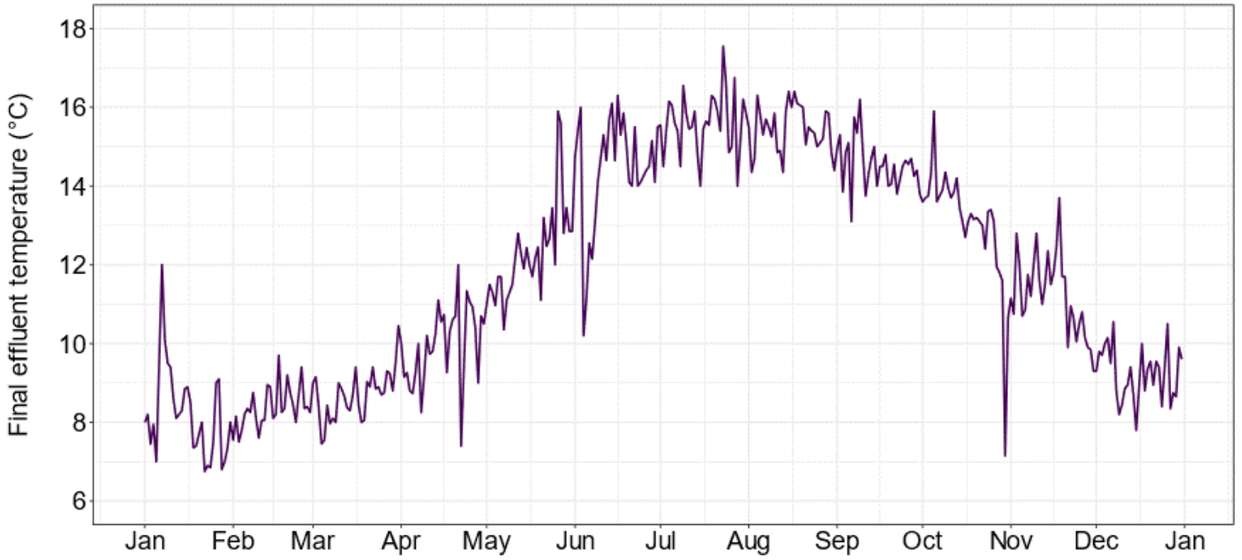


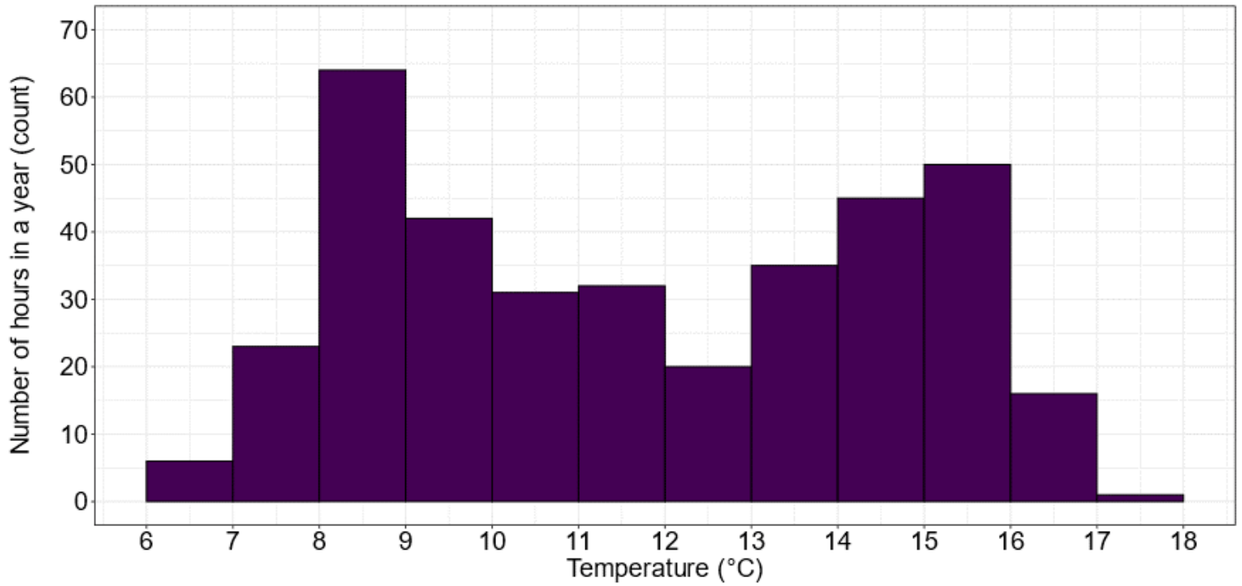
Waste heat utilisation

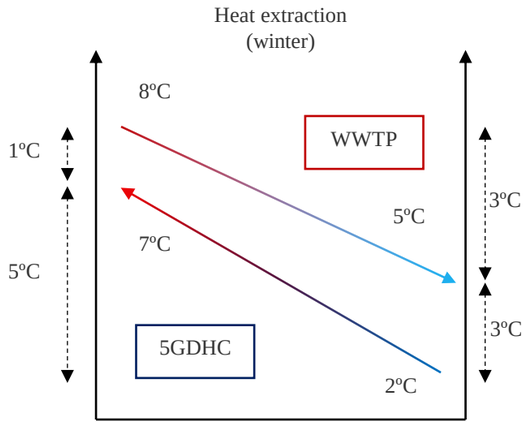


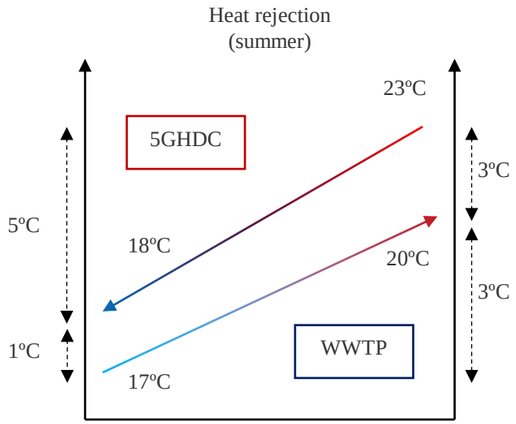


Waste heat utilisation

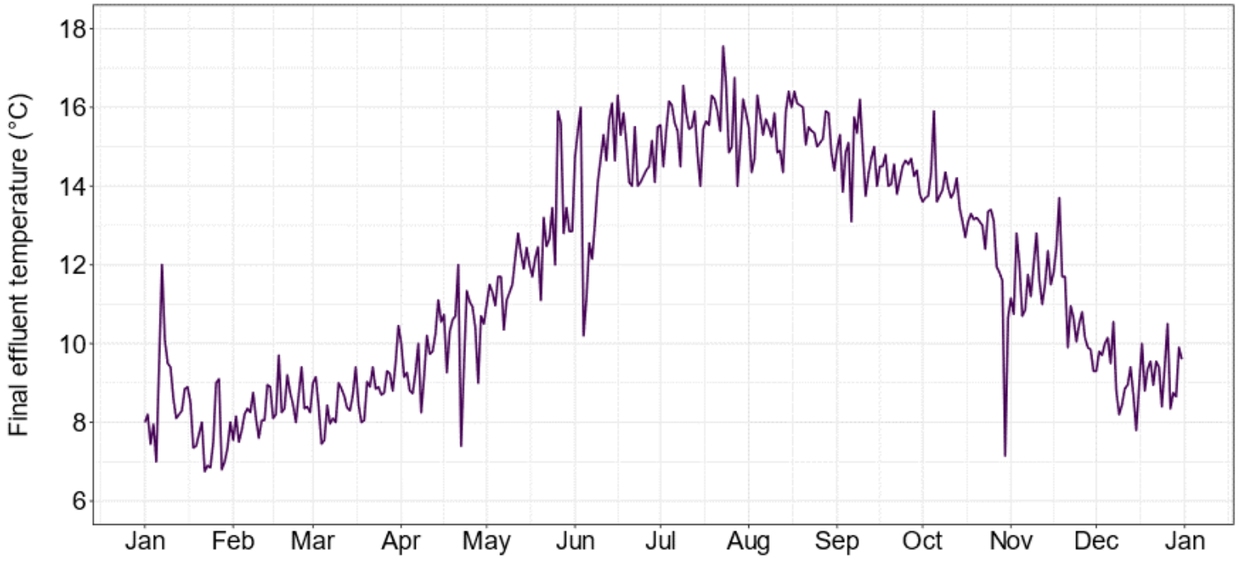


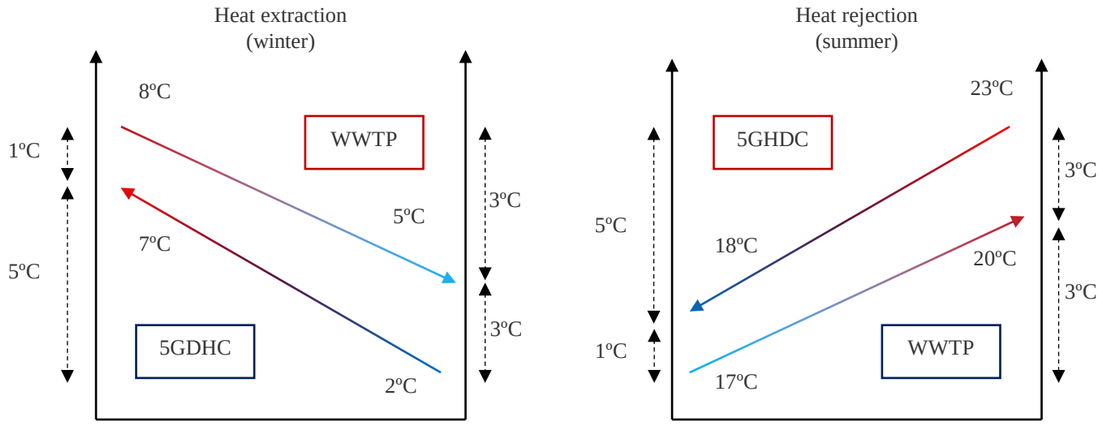


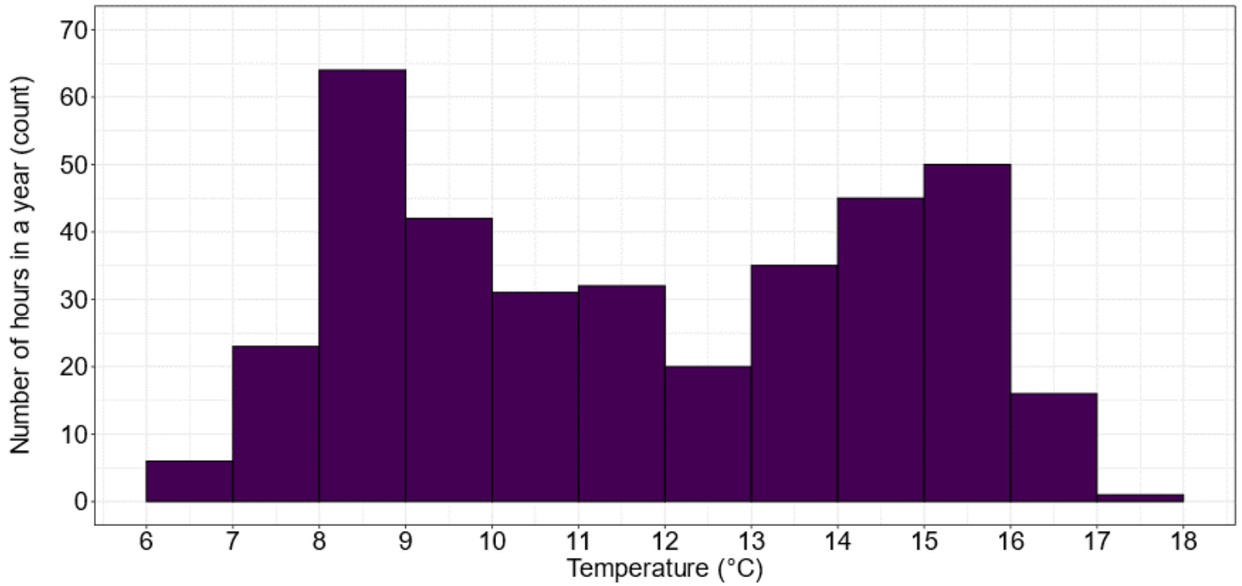


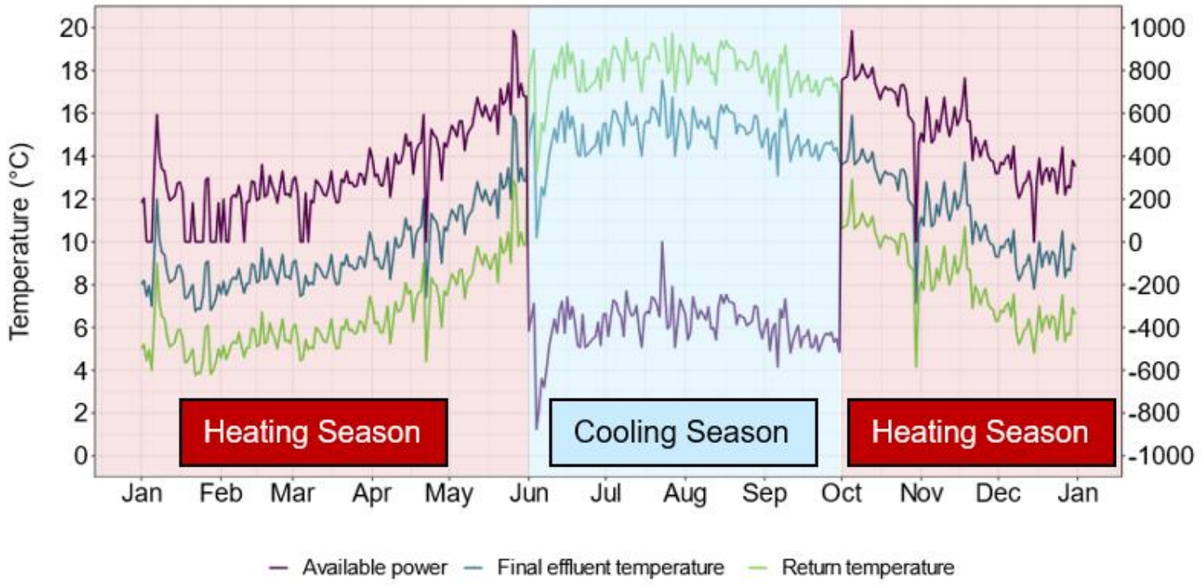


Waste heat utilisation









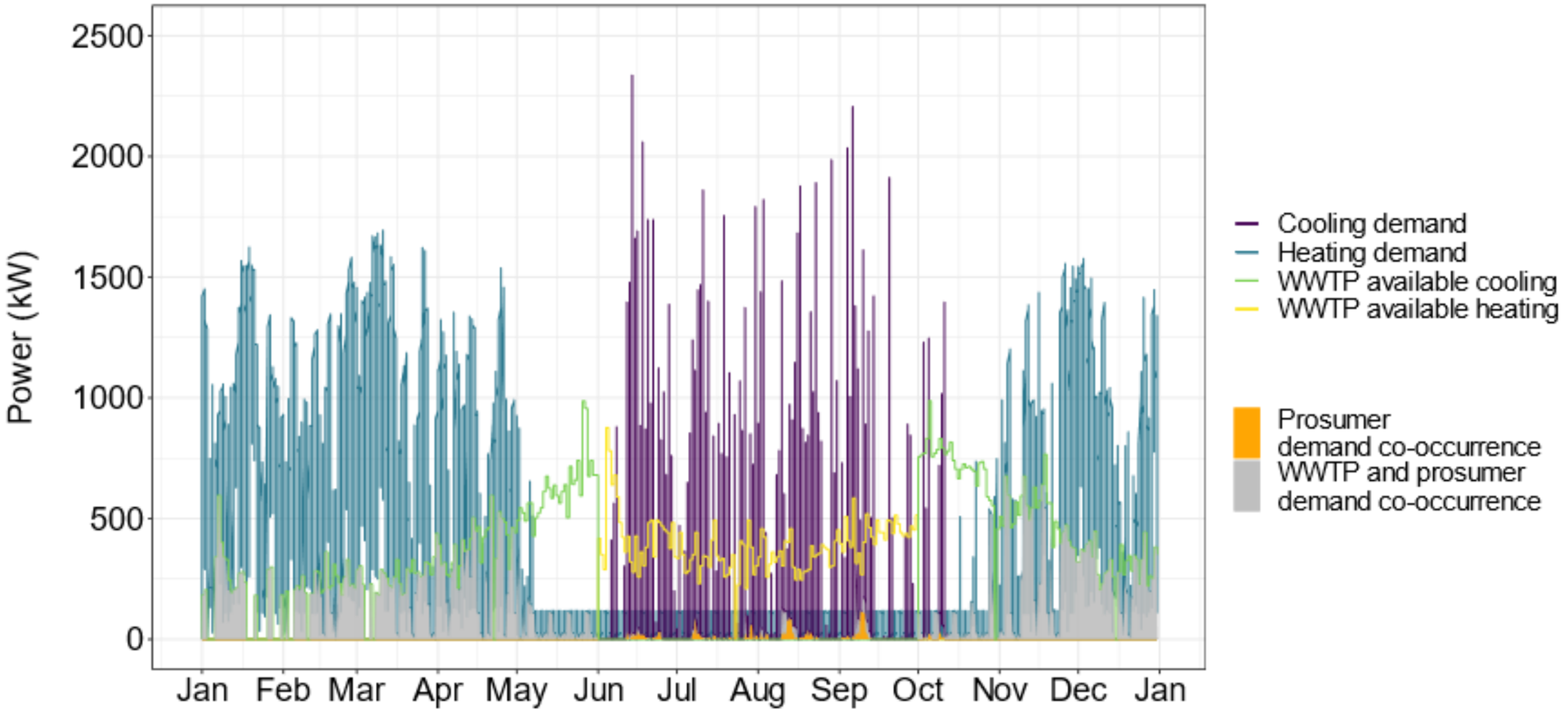
Analysis methodology

Stage	Action	Model / Software	Output
1. Demand Modelling	Demand assessment for individual buildings	Modelica ProHMo building models	Individual prosumer hourly power supply profile
2. Supply Analysis	Design for waste heat utilisation and other supply energy assets	Excel	5GDHC and 4GDH network characteristics
3. Network Simulation	Integrate prosumer profiles and fixed network controls	Modelica ProHMo prosumer/BU models	Hourly power flow profile for ambient network
4. Hydraulic Analysis	Network topology in GIS and hydraulic assessment	GIS and CATHeaPS	Pipe schedule and network characteristics for 5GDHC and 4GDH networks
5. Techno-Economic-Environmental Analysis	Calculate total system yearly electricity use	CATHeaPS	Complete Techno-Economic-Environmental Analysis

- A lot more details on each of these can be found on the paper which **is open access. → QR code**

https://www.sciencedirect.com/science/article/pii/S037877882600316 6?via%3Dihub

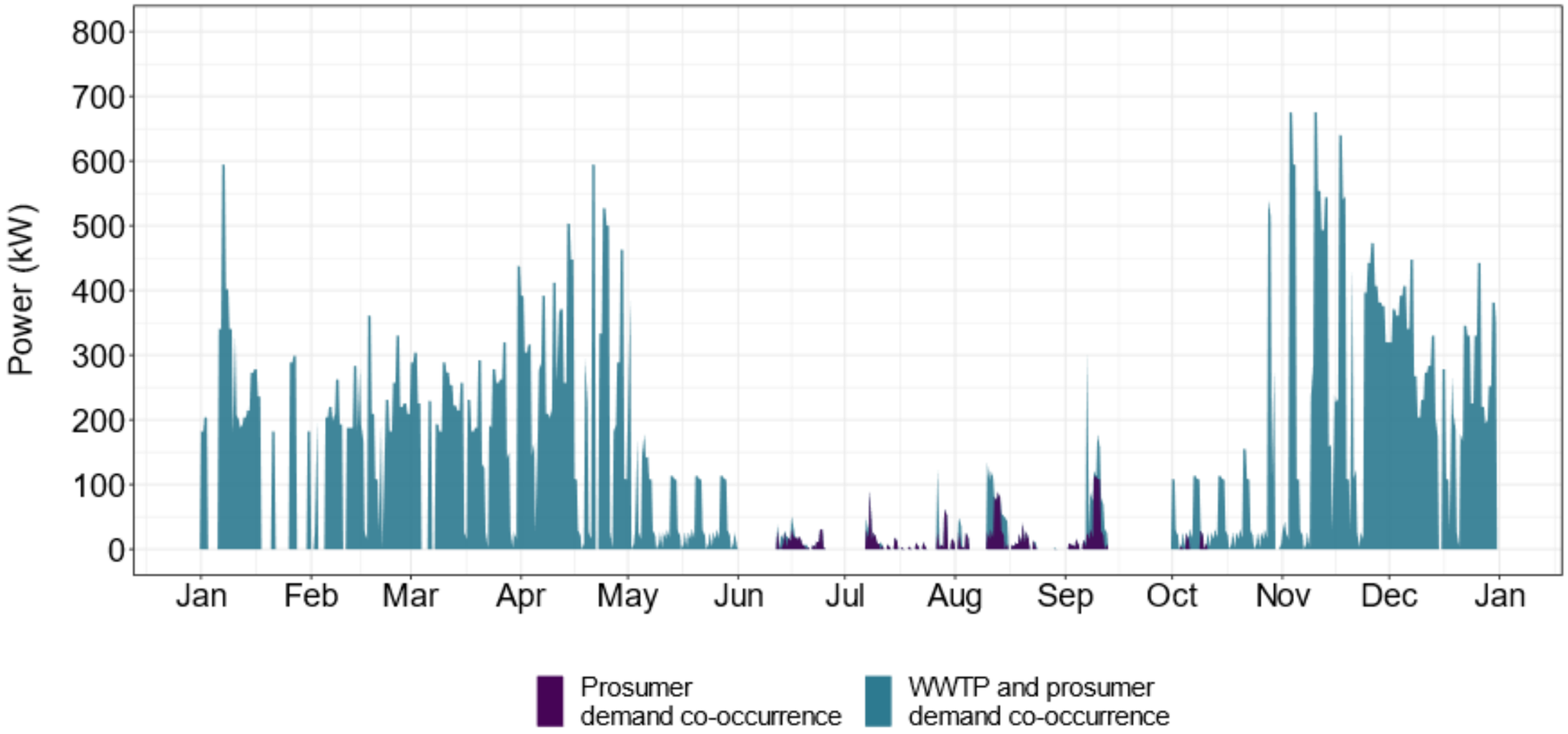
Results: The effect of low temperature waste heat



- Seasonal demand profile. Heating and cooling demand co-occurrence of **114MWh for full built out**, which represents **3.4%** of the total energy demand.

- The potential **energy share from the WWTP reaches 38.4%** with the additional 3.4% coming from demand overlap from buildings.

Results: The effect of low temperature waste heat

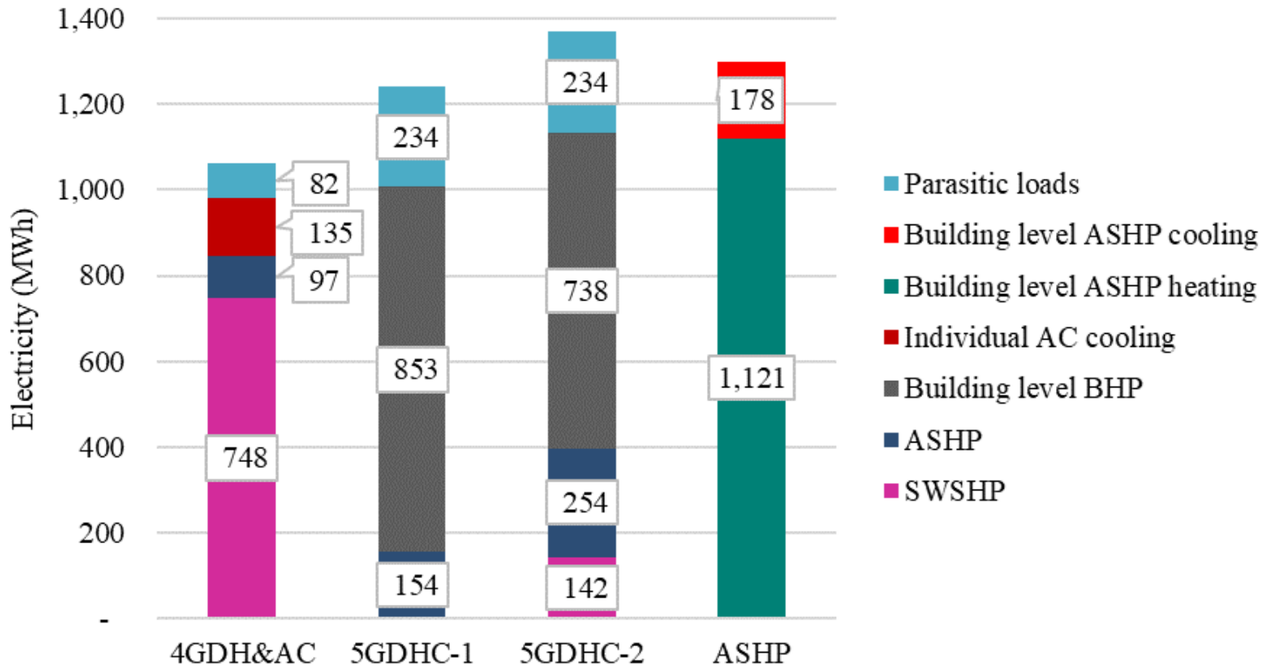


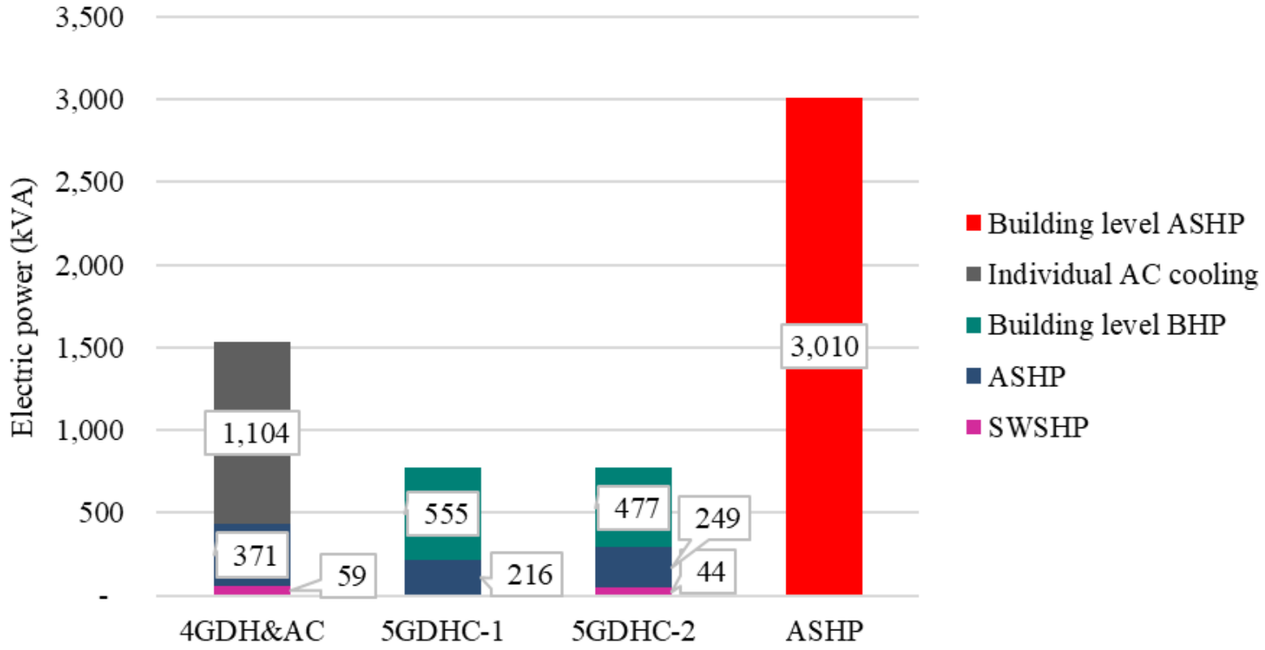
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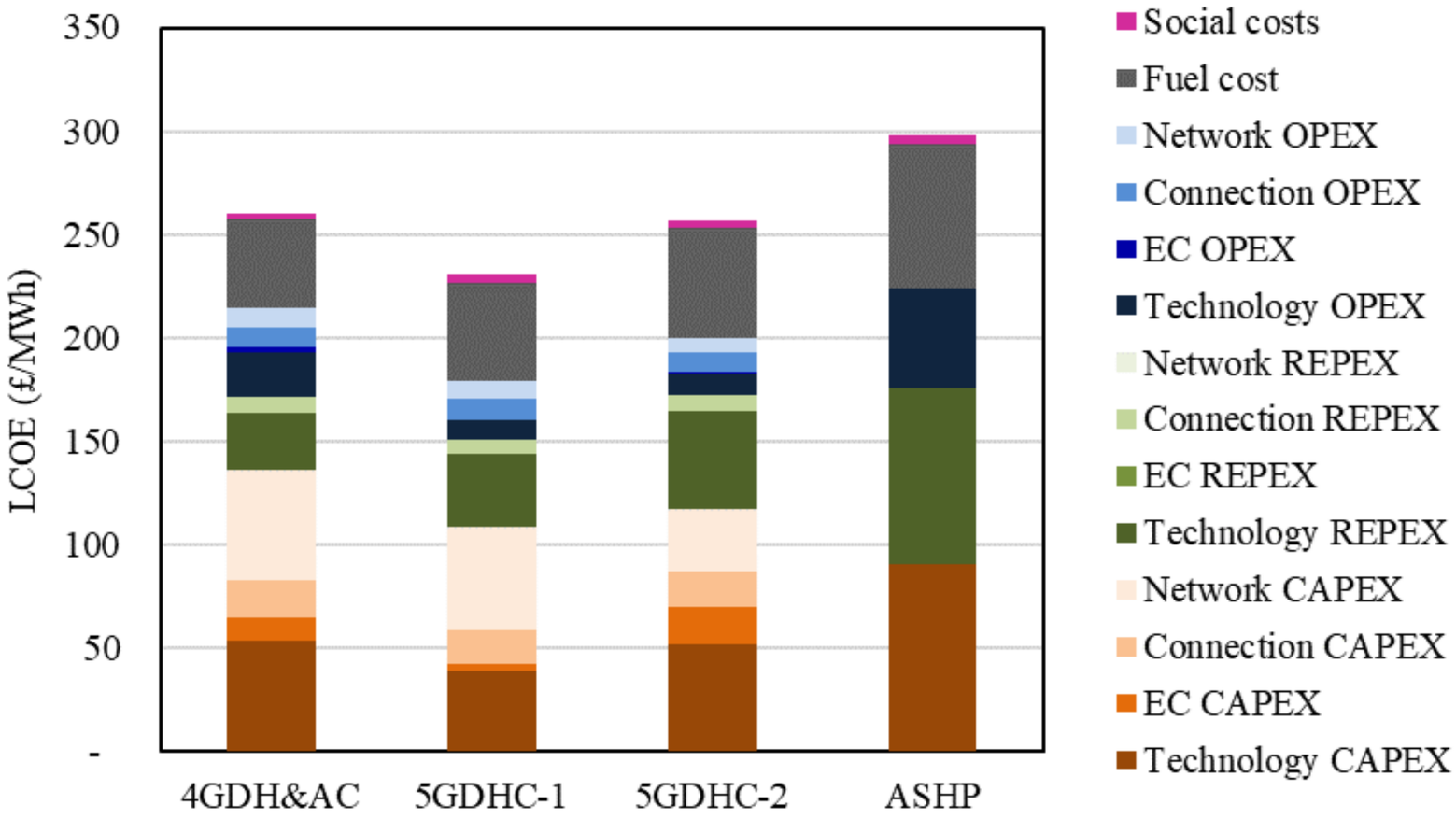
Results: Electricity use

- 5GDHC requires more electricity overall than DH&AC units.
- There are variations on the total electric power capacity requirements, ranging from 1.5MVA for 4GDH&AC and 3.0MVA for ASHP to 0.8MVA for 5GDHC-1 and 5GDHC-2.
- Overall, the solutions with decentralised, individual units have a large electrical capacity requirement, even though their individual impact is small.



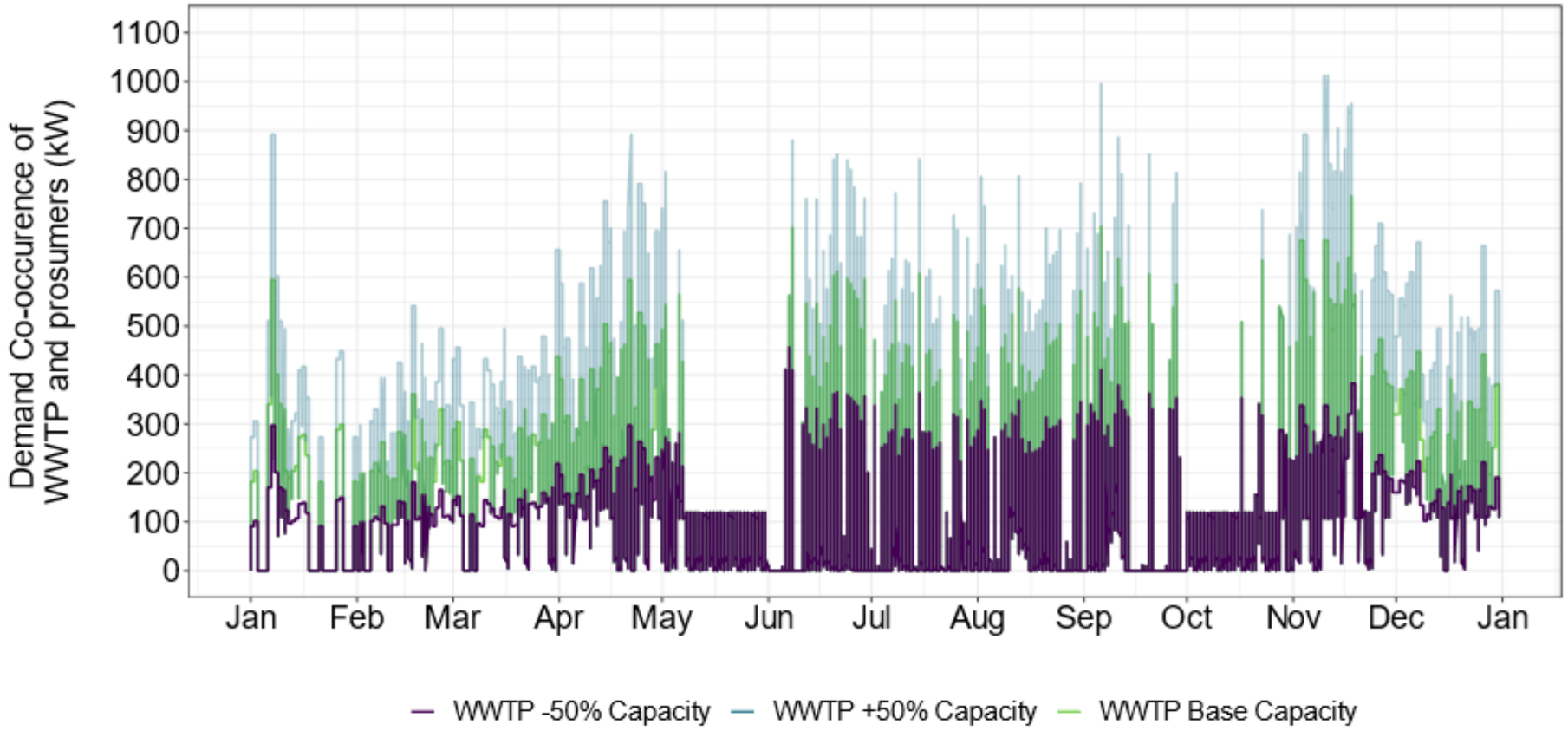


Results: The effect of low temperature waste heat



- The best performing scenario is 5GDHC-1 with a LCOE of 227£/MWh. 5GDHC-2 has the second lowest LCOE with 253£/MWh. The 4GDH&AC scheme is the next best performing option with an LCOE of 257£/MWh and lastly the ASHP option has a LCOE of 294£/MWh.

Results: Sensitivity analysis of WWTP capacity



- For 5GDHC-2, the only difference will be the SWSHP's share of supply but for 5GDHC-1, the effect on the BU demand needs to be studied.

- When the WWTP available capacity increases by 50% and the DOC reaches 41.8%, the electricity use drops by 76%. Adversely, when there is 50% less available WWTP capacity and the DOC is at 28.1%, the electricity use increases by 40%.

Discussions

- High LCOE in new buildings due to low demands.
- Seasonality of heating and cooling demands.
- 5GDHC could provide flexibility in phasing the CAPEX by utilising reversible units.
- Low demand co-occurrence can be tackled by utilising low temperature waste heat sources.
- Several limitations include:
  - Hydraulic component behaviour.
  - Impact of more complex control regimes for the prosumer BHPs.
  - Incorporation of an equipment free BU.
  - Investigation of a wider technology mix.

Conclusions

- Proposal of a detailed 5GDHC feasibility study including design and operation for a real case study with waste heat utilisation.
- More electricity use for 5GDHC due to lower SPF than DH&AC but lower capacity requirement due to reversible units.
- Best economic performance for 5GDHC.
- More complicated controls for the 5GDHC network.
- Quantified benefits and shortfalls of 5GDHC against counterfactuals. Proposed 5GDHC as best option for 5GDHC when waste heat is available.

Thank you for your time

A lot more details on each of these can be found on the paper which **is open access. → QR code**

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