Lund University | LTH Faculty of Engineering

The role of UTES systems in 5th generation technologies and DHC grids

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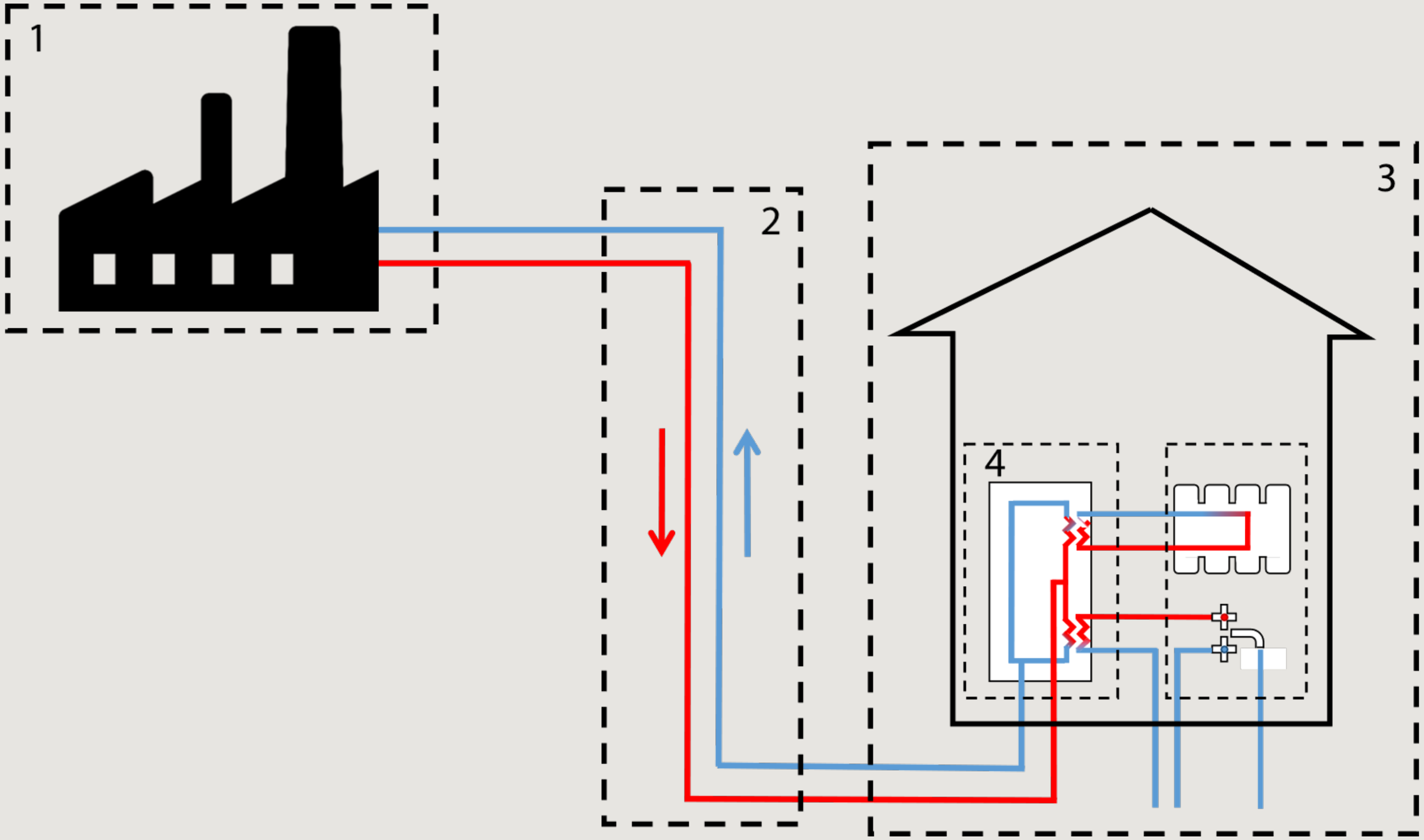
Towards Decarbonized Heating and Cooling!

Background – The idea of district heating and cooling



1. Heat supply plant
2. Pipe distribution network
3. Customer demands
4. Substation for transferring heat

Simple illustration of district heating components. The figure was reproduced from: Månsson (2021). PhD Thesis.
https://portal.research.lu.se/portal/files/98293188/Sara_M_nsson_final_210517.pdf

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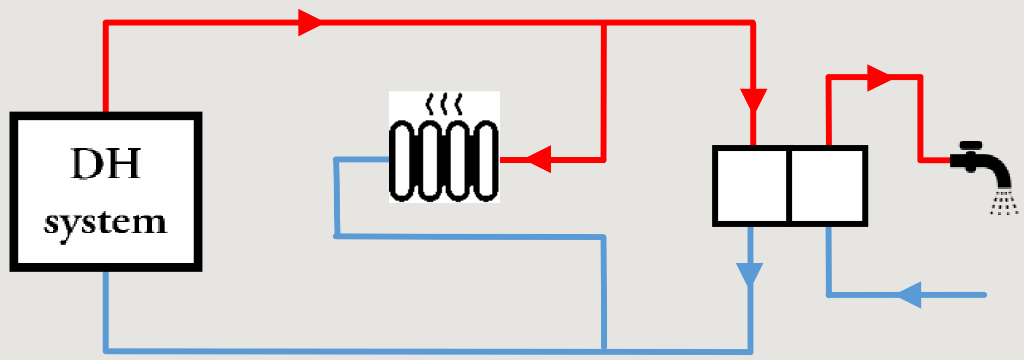
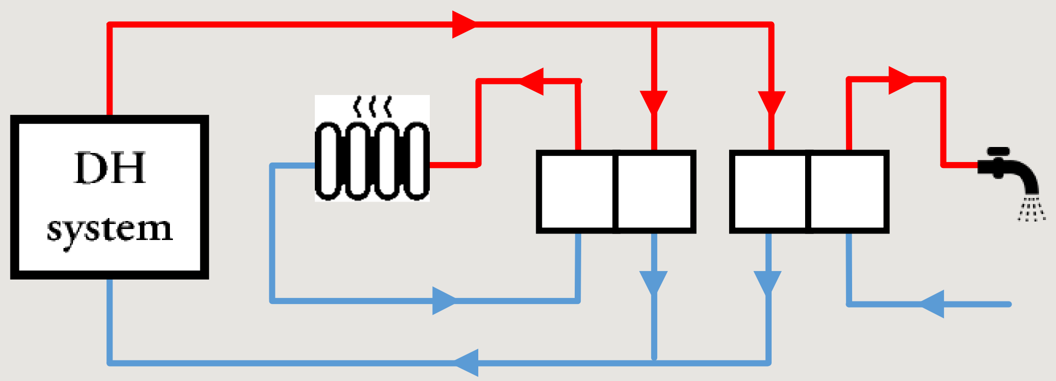
Background – The idea of district heating and cooling

Substation connections



Direct connection



Indirect connection

Types of connections in customer substations. The figure was reproduced from: Månsson (2021). PhD Thesis.
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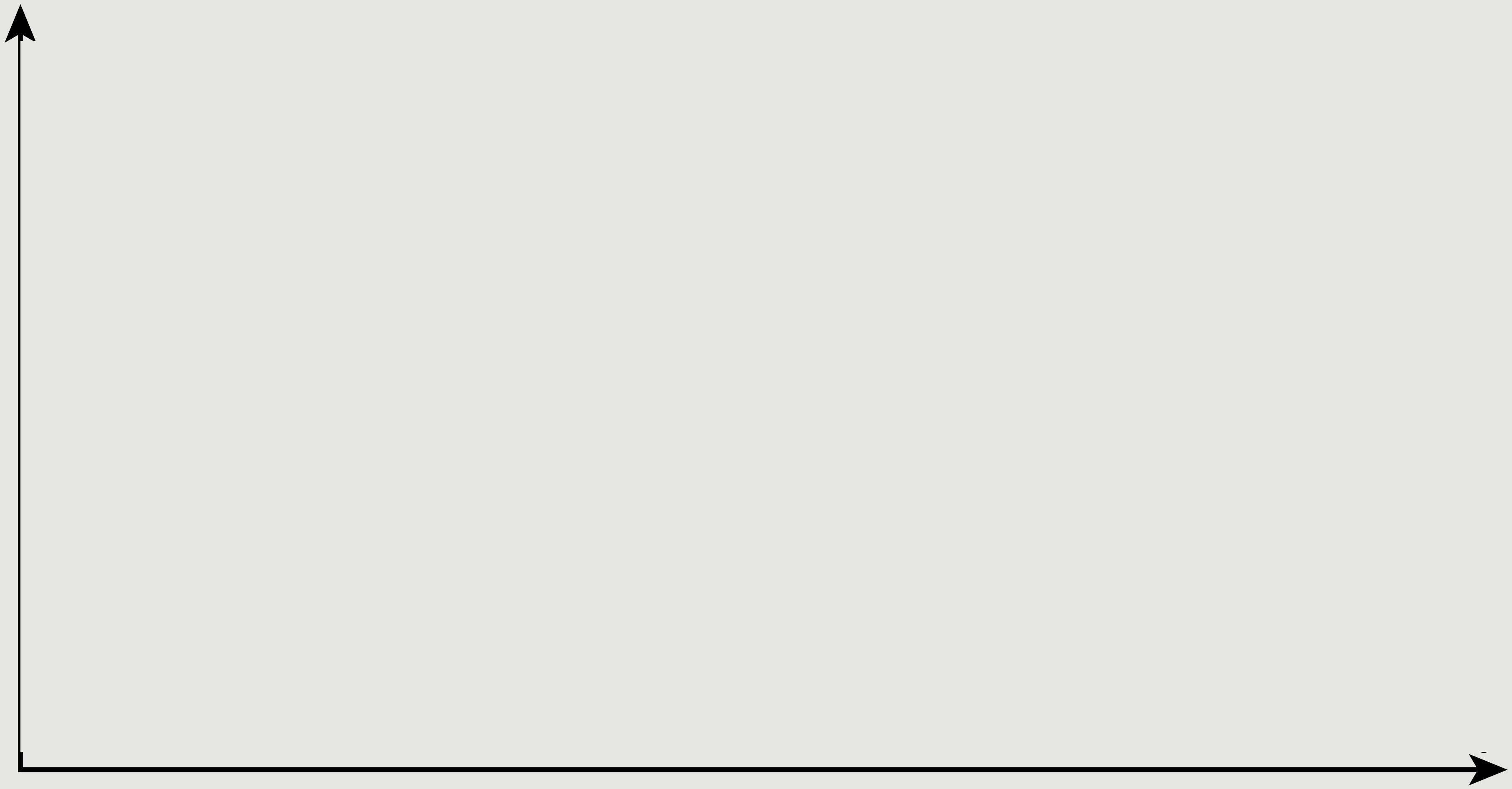
Background – Generations of district heating and cooling



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Background – Generations of district heating and cooling

- Low efficiency
- High risk of explosions

Evolution of district heating and cooling networks. Adopted from Lund et al. (2018) and Wirtz et al. (2020).
https://doi.org/10.1016/j.energy.2018.08.206
https://doi.org/10.1016/j.enbuild.2020.110245

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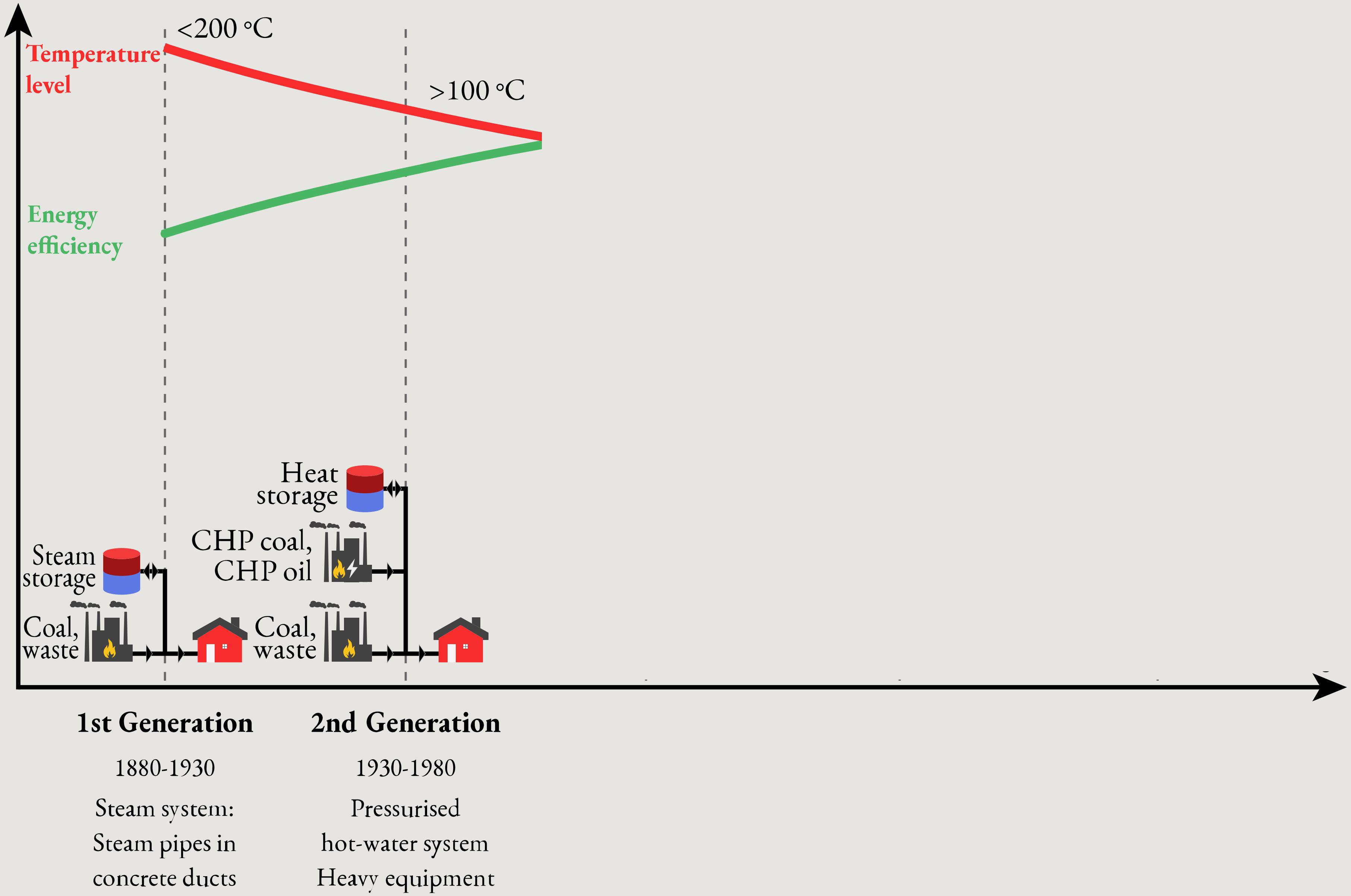

- High water temperature
- High distribution losses

Evolution of district heating and cooling networks. Adopted from Lund et al. (2018) and Wirtz et al. (2020).

https://doi.org/10.1016/j.energy.2018.08.206

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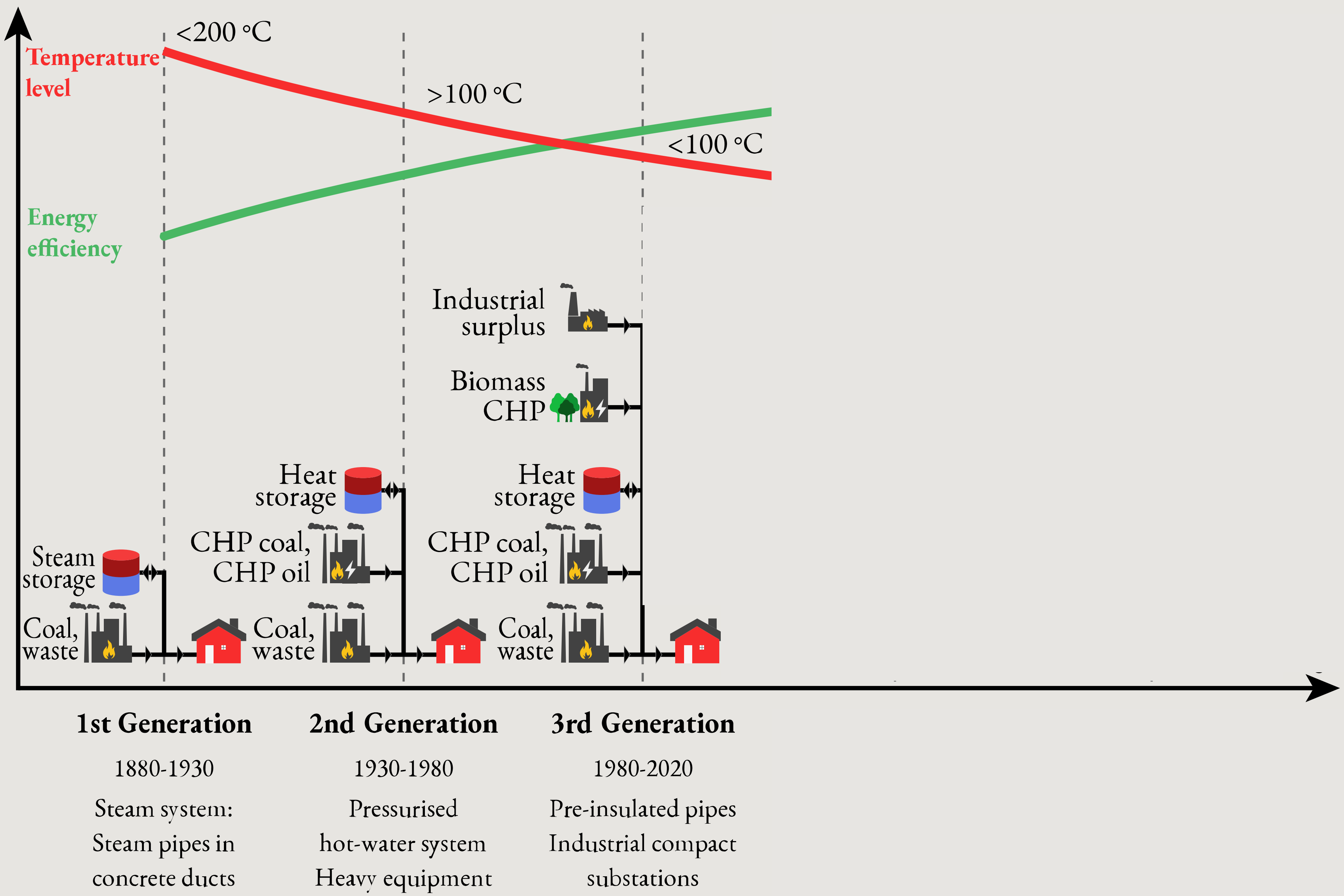

- Scandinavian DH
- Still widely used
- Low integration of RES

Evolution of district heating and cooling networks. Adopted from Lund et al. (2018) and Wirtz et al. (2020).

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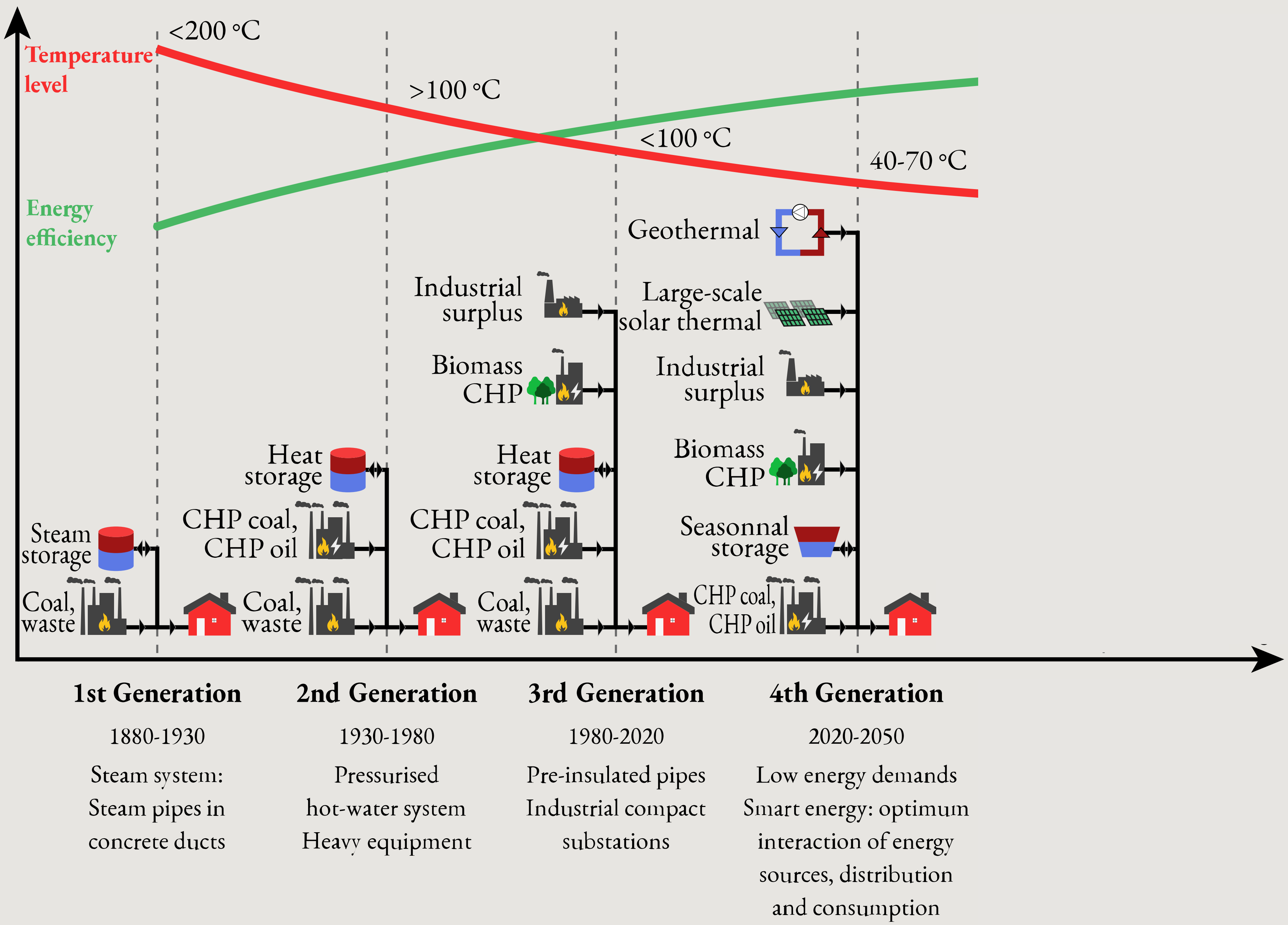

- Centralized heat production
- Separate pipes required to supply cooling

Evolution of district heating and cooling networks. Adopted from Lund et al. (2018) and Wirtz et al. (2020).

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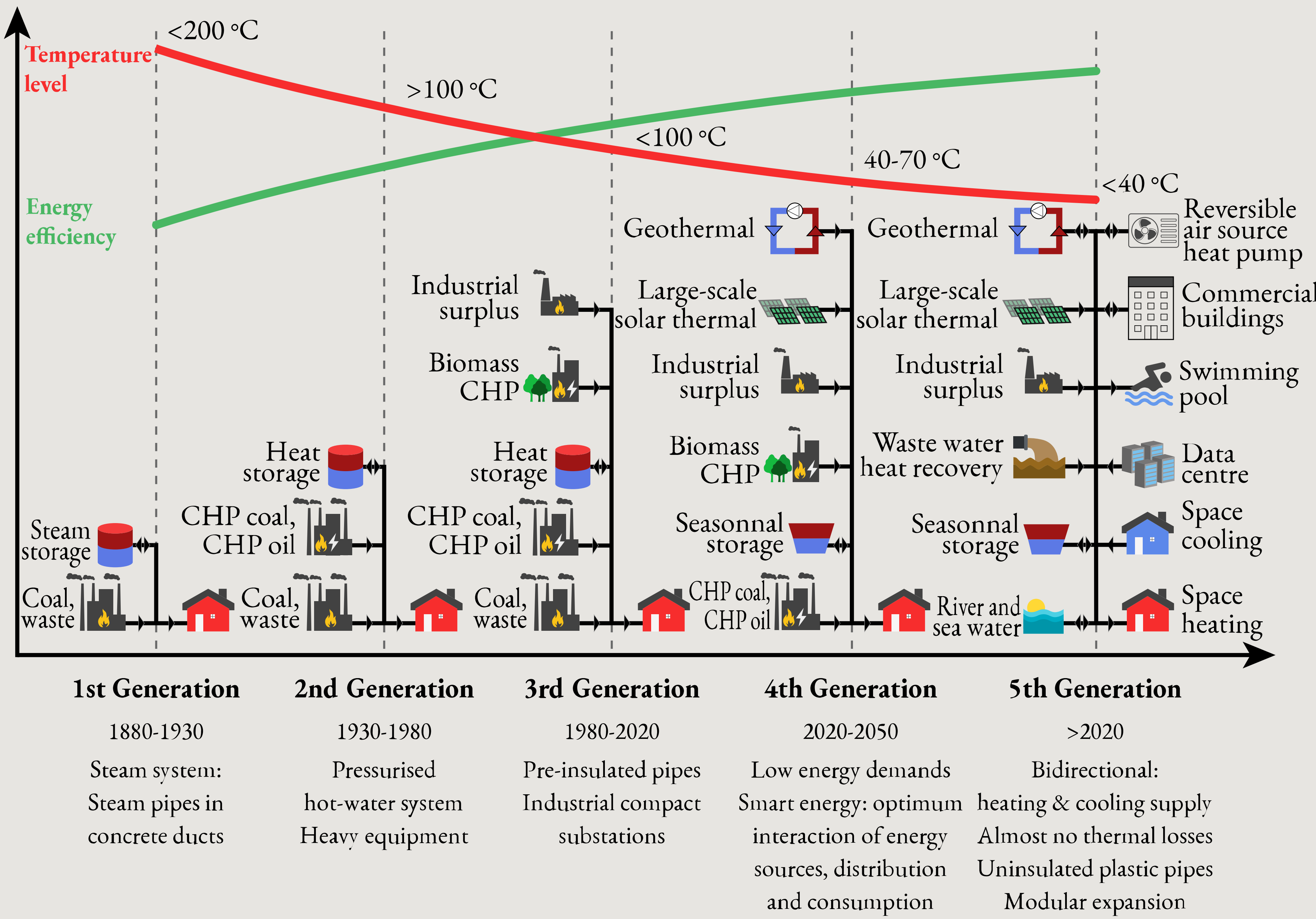

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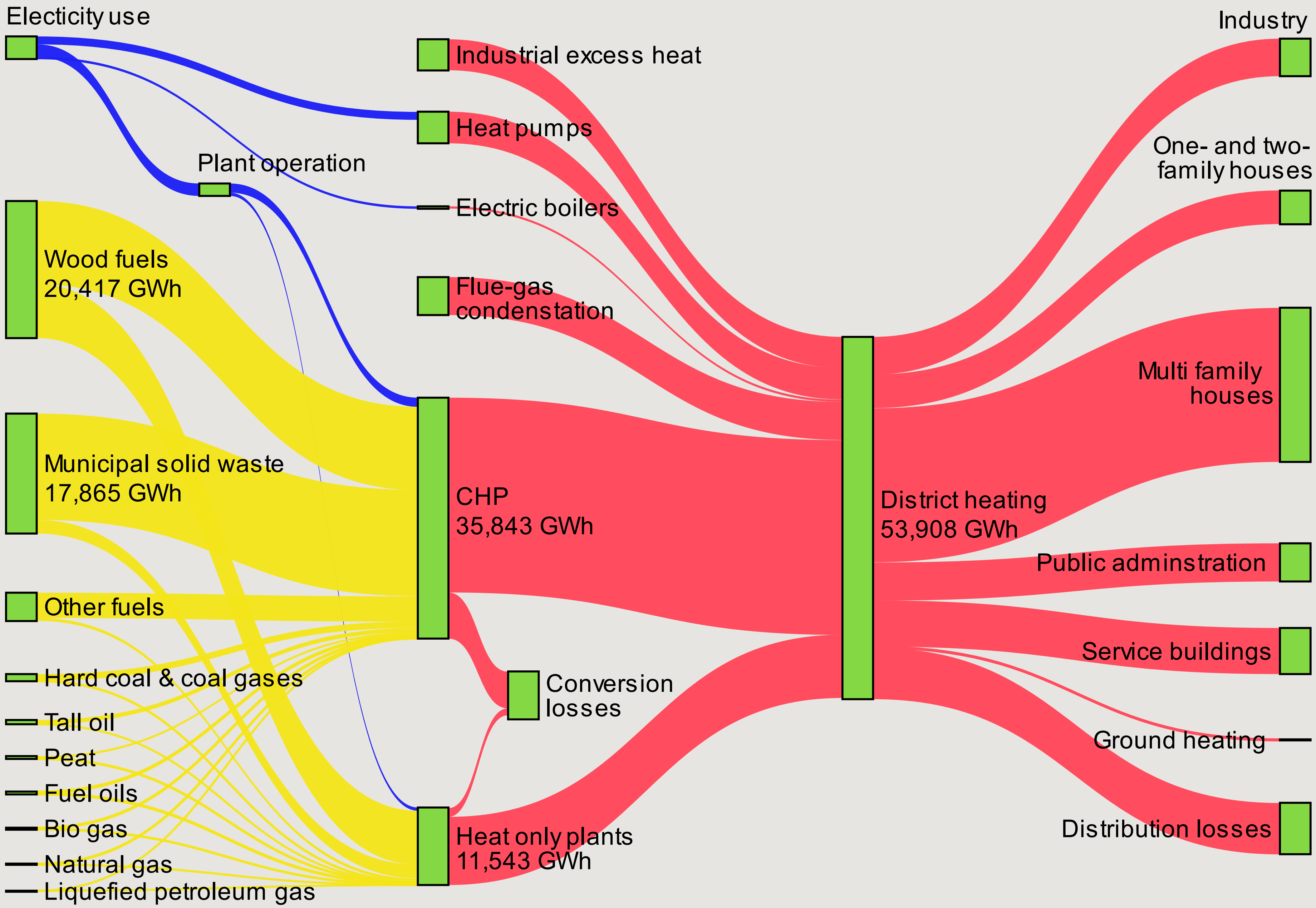
Background – Swedish district heating and cooling



- Market share of 60 % of all heat supply to buildings
- Supply temperature ≈ 80 °C
- Distribution losses ≈13 %
- The debate about biomass!
- District cooling ≈ 1 TWh (largest in Europe)

Sankey diagram for the Swedish district heating energy balance in 2020. The width of connecting bars is proportional to the quantity of heat flow measured in GWh. Reproduced from: Abugabbara et al. (2023). [*https://doi.org/10.1016/j.egyr.2023.04.048*](https://doi.org/10.1016/j.egyr.2023.04.048)

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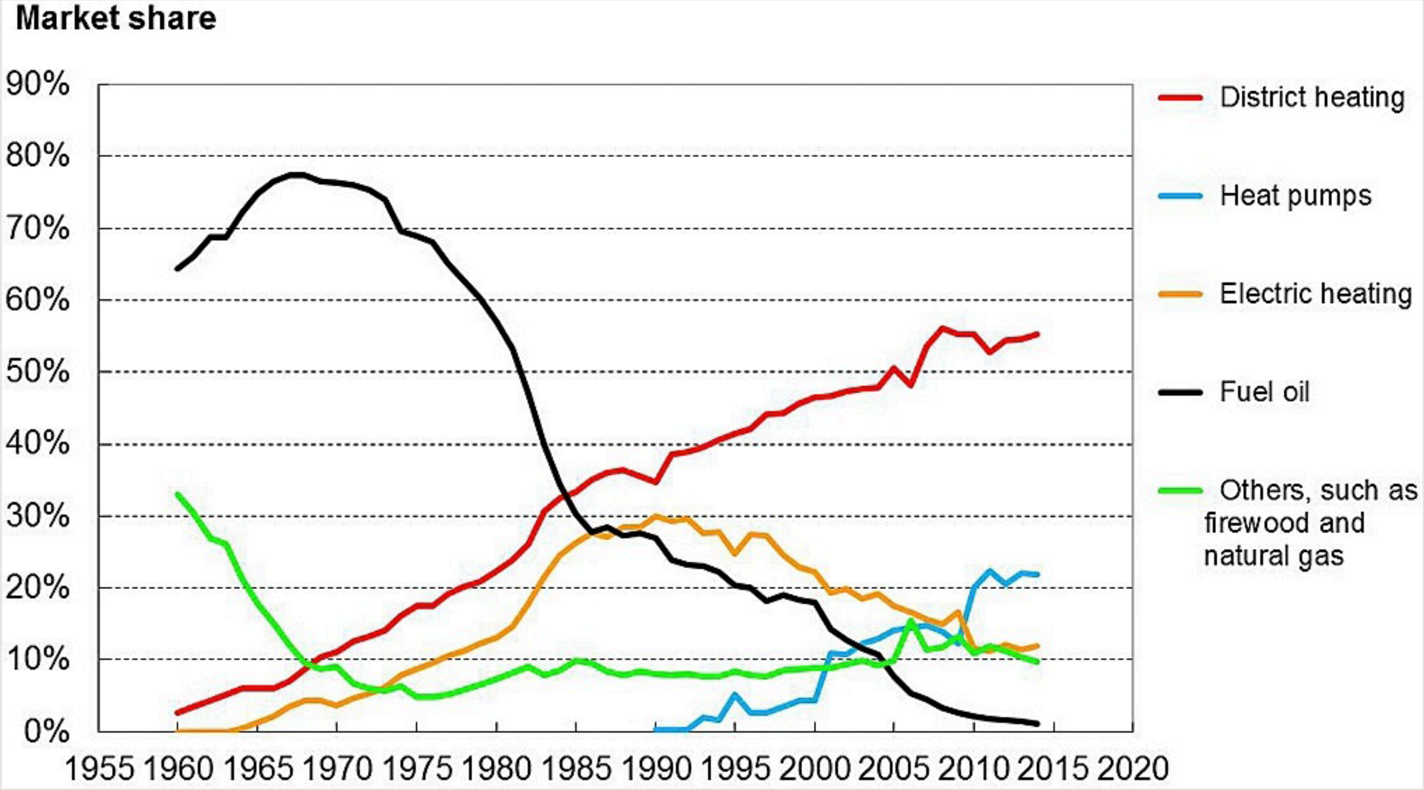
Towards Decarbonized Heating and Cooling!

Background – Swedish district heating and cooling

- Can district heating be combined with heat pumps?
- How future district heating would look like? (↓heating ↑cooling)
- What are the technologies that support decarbonization of the heating sector?

5GDHC networks are a possible solution.



Market shares for heat supply to Swedish residential and service sector with respect to heat delivered from various heat sources. Source: Werner (2017).
https://doi.org/10.1016/j.energy.2017.03.052

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Terminology of 5GDHC networks

- Low-temperature networks
- Ultra low temperature
- Bidirectional low-temperature
- Ambient temperature
- Cold networks
- Anergy grids
- …

Lund et al. (2021). Perspectives on fourth and fifth generation district heating. https://doi.org/10.1016/j.energy.2021.120520

Sulzer et al. (2021). Vocabulary for the fourth generation of district heating and cooling. https://doi.org/10.1016/j.segy.2021.100003

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Technology behind 5GDHC networks

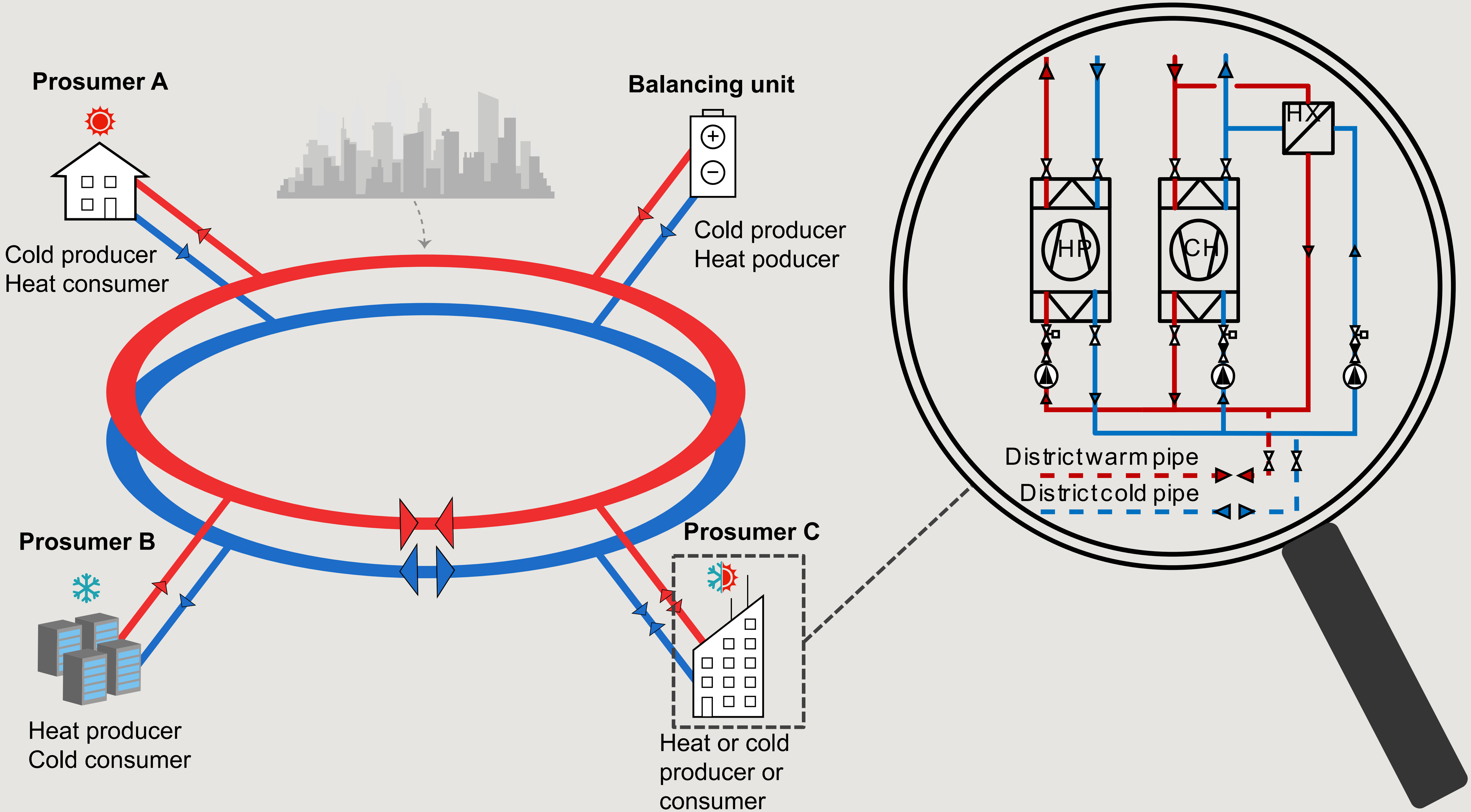

Illustration of a 5GDHC network with decentralized heat pumps and a balancing unit. Adapted from Abugabbara et al. (2022). https://doi.org/10.1016/j.energy.2022.125245

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Technology behind 5GDHC networks

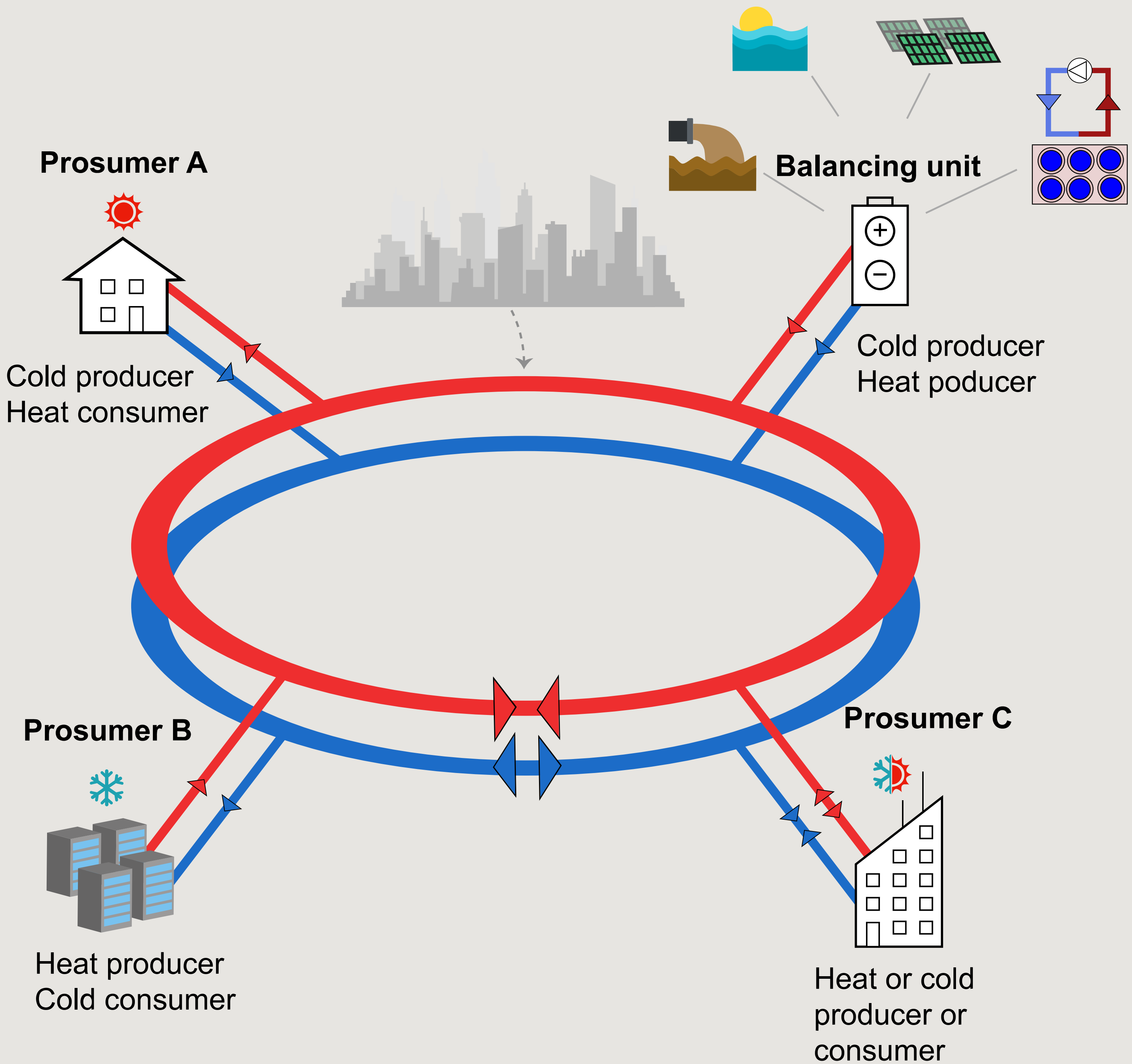

Illustration of a 5GDHC network with decentralized heat pumps and a balancing unit. Adapted from Abugabbara et al. (2022). https://doi.org/10.1016/j.energy.2022.125245

Features of 5GDHC networks:

- Simultaneous heat and cold supply
- Bidirectional energy flows
- Waste heat recovery (reduce urban heat island)
- Low network temperature (5-20 °C)
- Low distribution losses
- Flexible network expansion
- High integration of Renewable Energy Sources (RES)
- Low-enthalpy heat sources

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The role of shallow geothermal energy

- Renewable heat source
- Flexible source for providing heating and/or cooling
- Ability to use the ground as a thermal battery (seasonal thermal storage)
- Sector coupling with power grids (a possible solution for the problem of excess electricity)

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Towards Decarbonized Heating and Cooling!

The role of shallow geothermal energy

The problem in the power sector

- Power grids must be balanced (supply = demand)

  → Crucial for frequency stability

- Intermittent generation from Renewable Energy Sources (RES)

  ↑ RES ↓ Conventional power plants

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- Cycling cost increase

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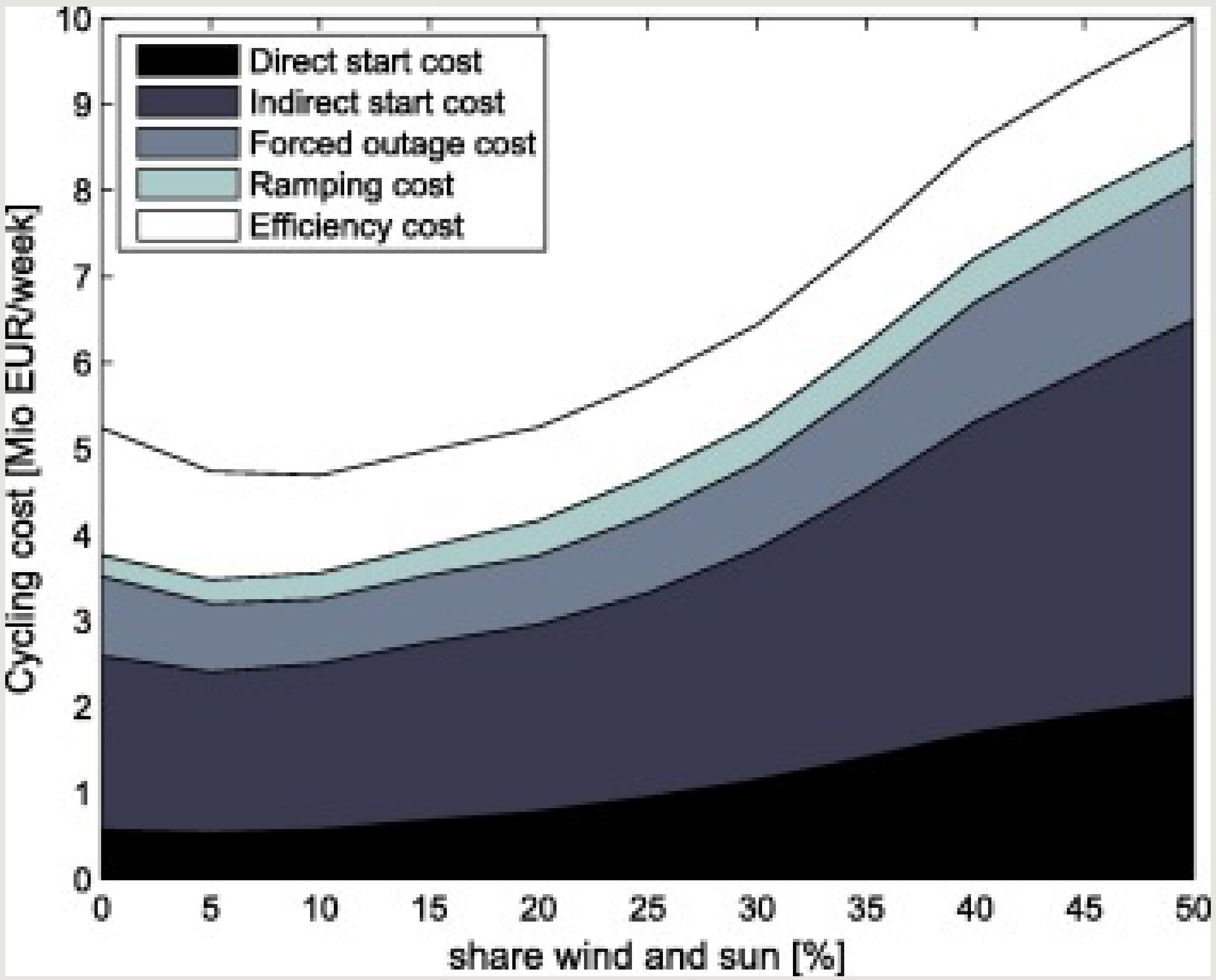
Towards Decarbonized Heating and Cooling!

The role of shallow geothermal energy

The problem in the power sector



Cycling cost is doubled when the share of wind and sun increases from 10 % to 50 %

Source: Van den Bergh and Delarue (2015).
https://doi.org/10.1016/j.enconman.2015.03.026

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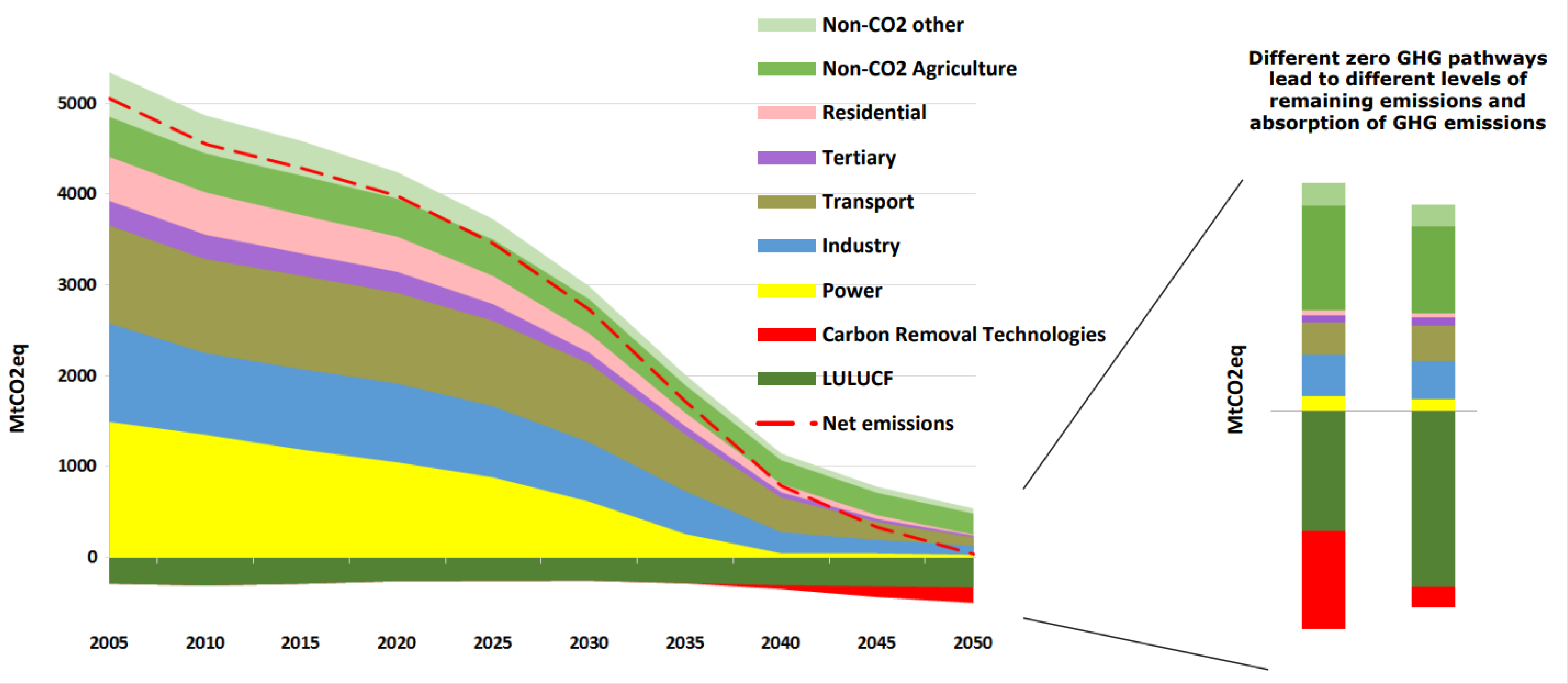
The role of shallow geothermal energy

The problem in the power sector

- The European strategic long-term vision



Source: EU Commission (2018). COM(2018) 773 final
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

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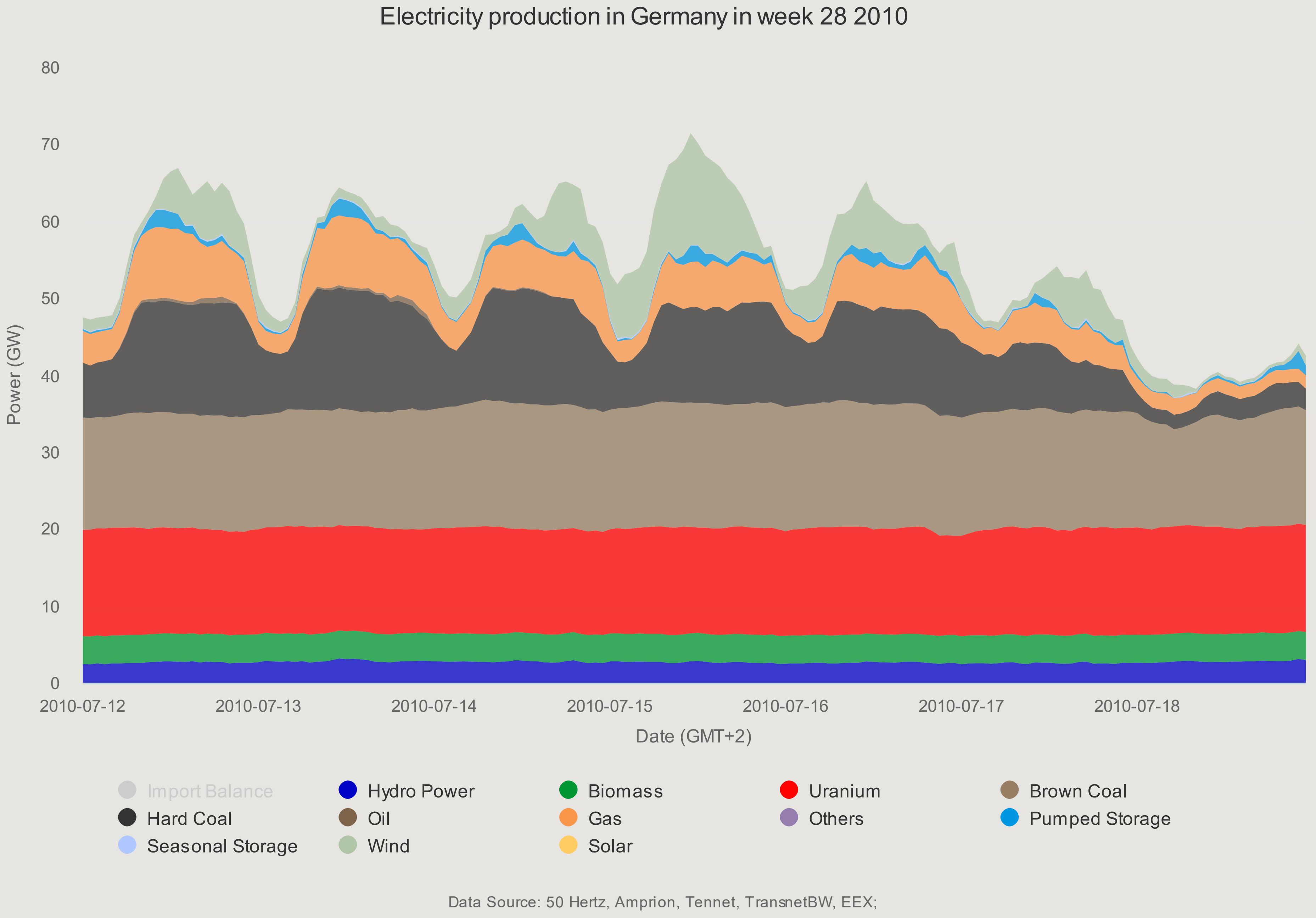
The role of shallow geothermal energy

The problem in the power sector

- Energy-mix for electricity production in Germany



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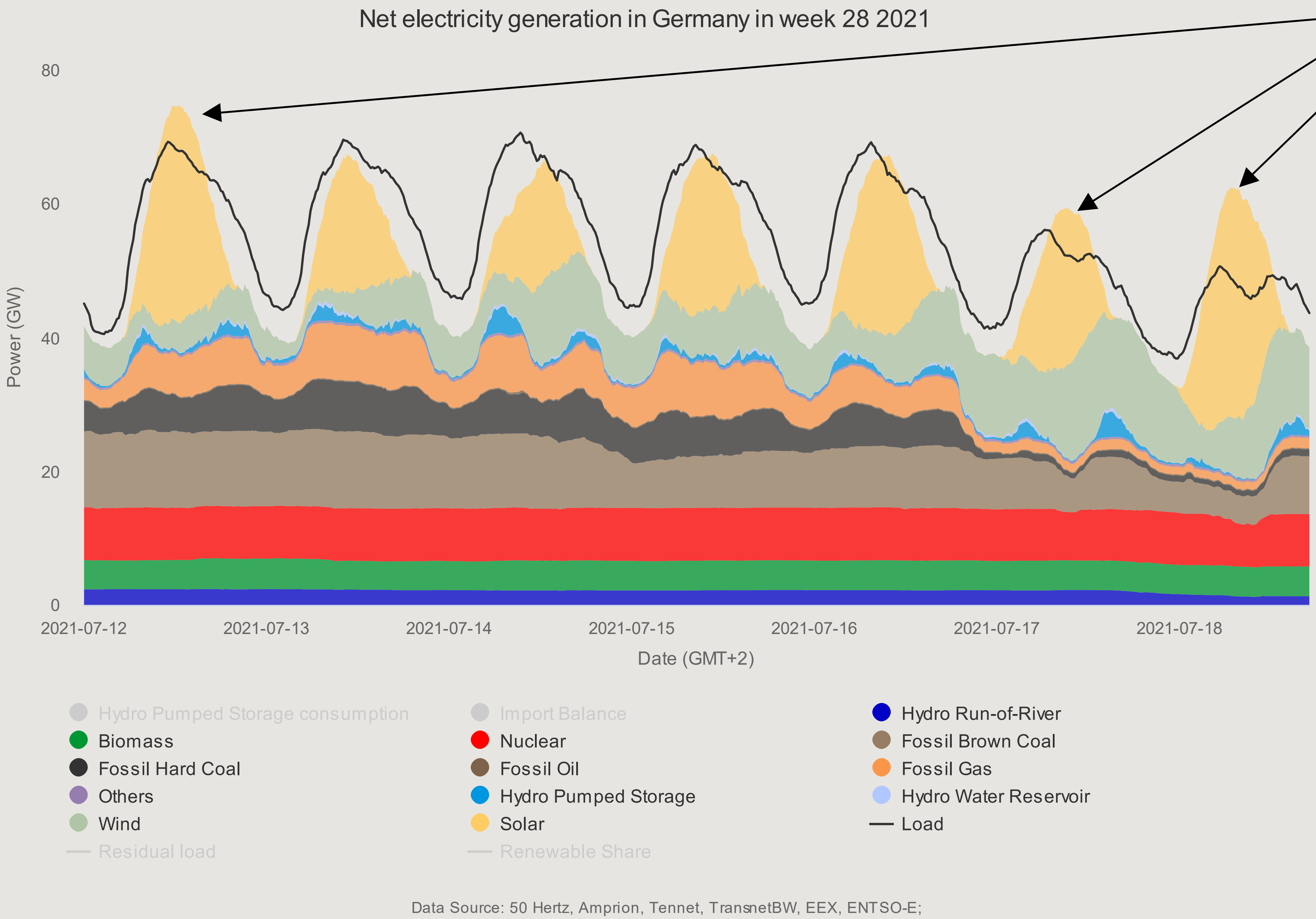
The role of shallow geothermal energy

The problem in the power sector

- Energy-mix for electricity production in Germany



The problem appears as the share of intermittent renewables increases.

More electricity storage and transformation will be needed in the future.

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The role of shallow geothermal energy

Storage and transformation of excess electricity

- Batteries
- Reversible hydro power plants (pumping mode)
- Desalination via electrical field (P2W)
- H_2 production via electrolysis (P2H2)
- Power to heat (P2H)

But what about efficiency and cost?

→ Ground storage is an economically feasible option (≈130 times cheaper than batteries[1])

[1]Lund (2018). https://doi.org/10.1016/J.ENERGY.2018.03.010

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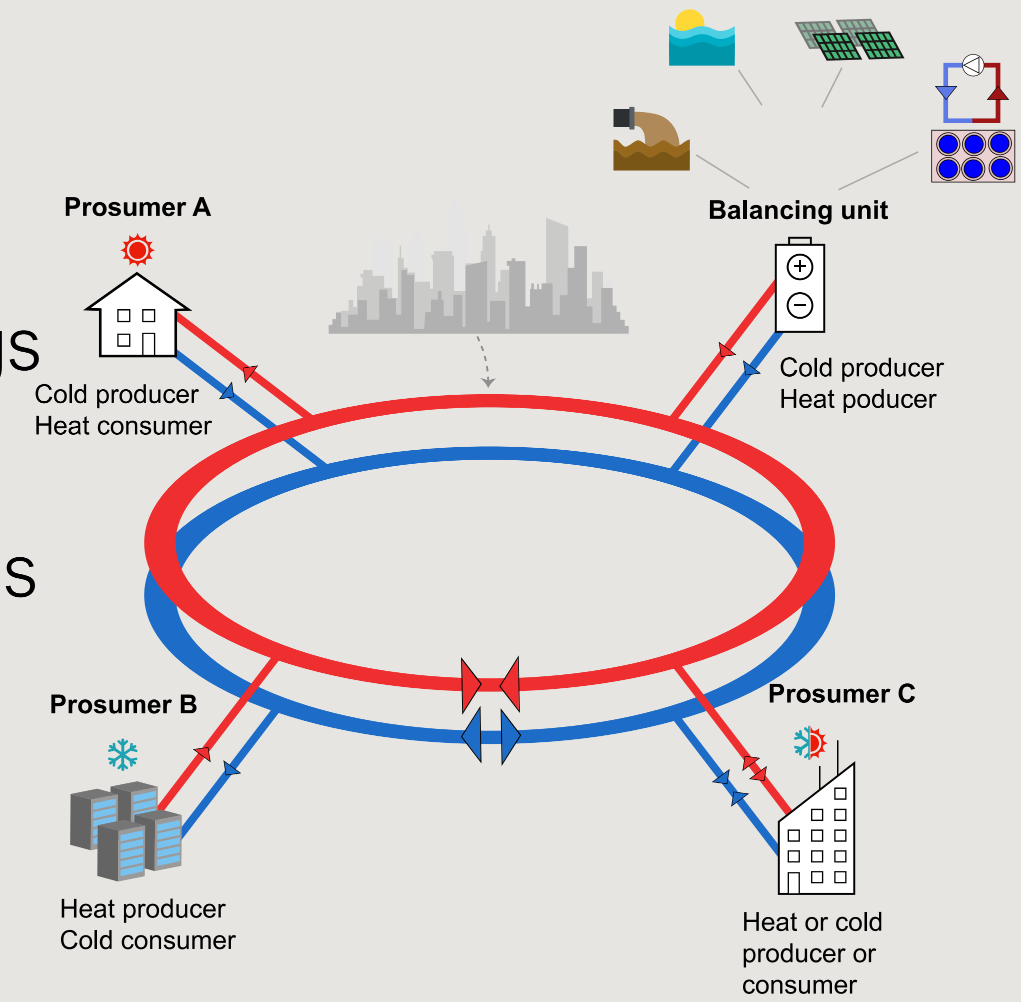
The added value

- Geothermal energy coupled with 5GDHC networks offers high flexibility in planning 100 % renewable urban energy systems

Current challenges – System design

1. Building heating and cooling demands
2. Heat exchange between connected buildings
3. Heat losses/gains, pressure drops, and mass flow rates in the distribution pipes
4. Network loads → sizing of GSHP and BHE
5. Temperature and pressure controls



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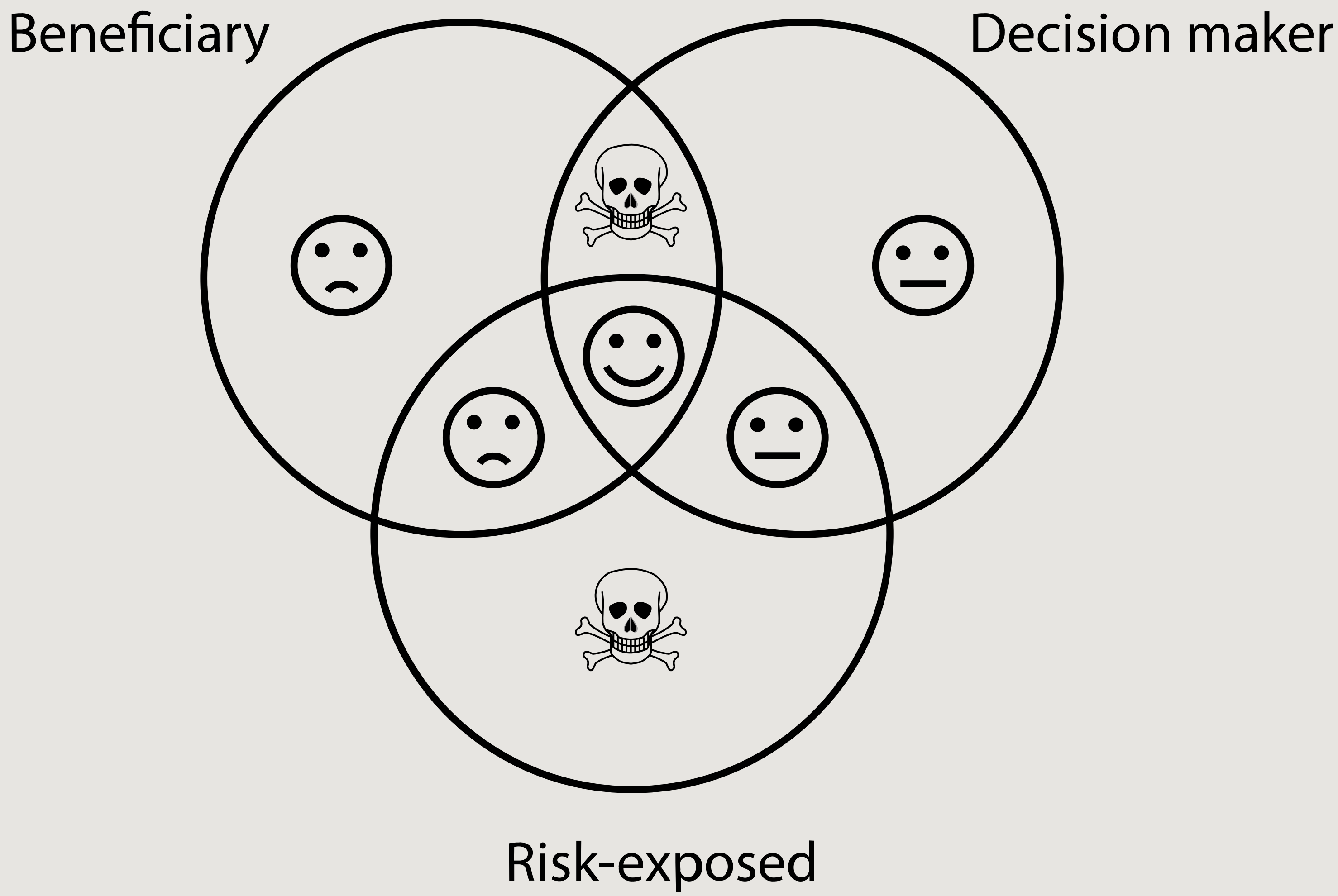
Current challenges – System ownership



- Multiple actors' conflict!
- Liability when failures occur!
- Should the geothermal energy system be owned independently or collectively (on-bill financing)?
- How different societies perceive this technology?
- Financing[1]:
  - Grants and subsidies
  - Private or public loans
  - Leasing
  - Crowdfunding

Source: Hansson (2018). How to perform an ethical risk analysis (eRA). https://doi.org/10.1111/risa.12978

[1]Leoni et al. (2020). Developing innovative business models for reducing return temperatures in district heating systems: Approach and first results. https://doi.org/10.1016/j.energy.2020.116963

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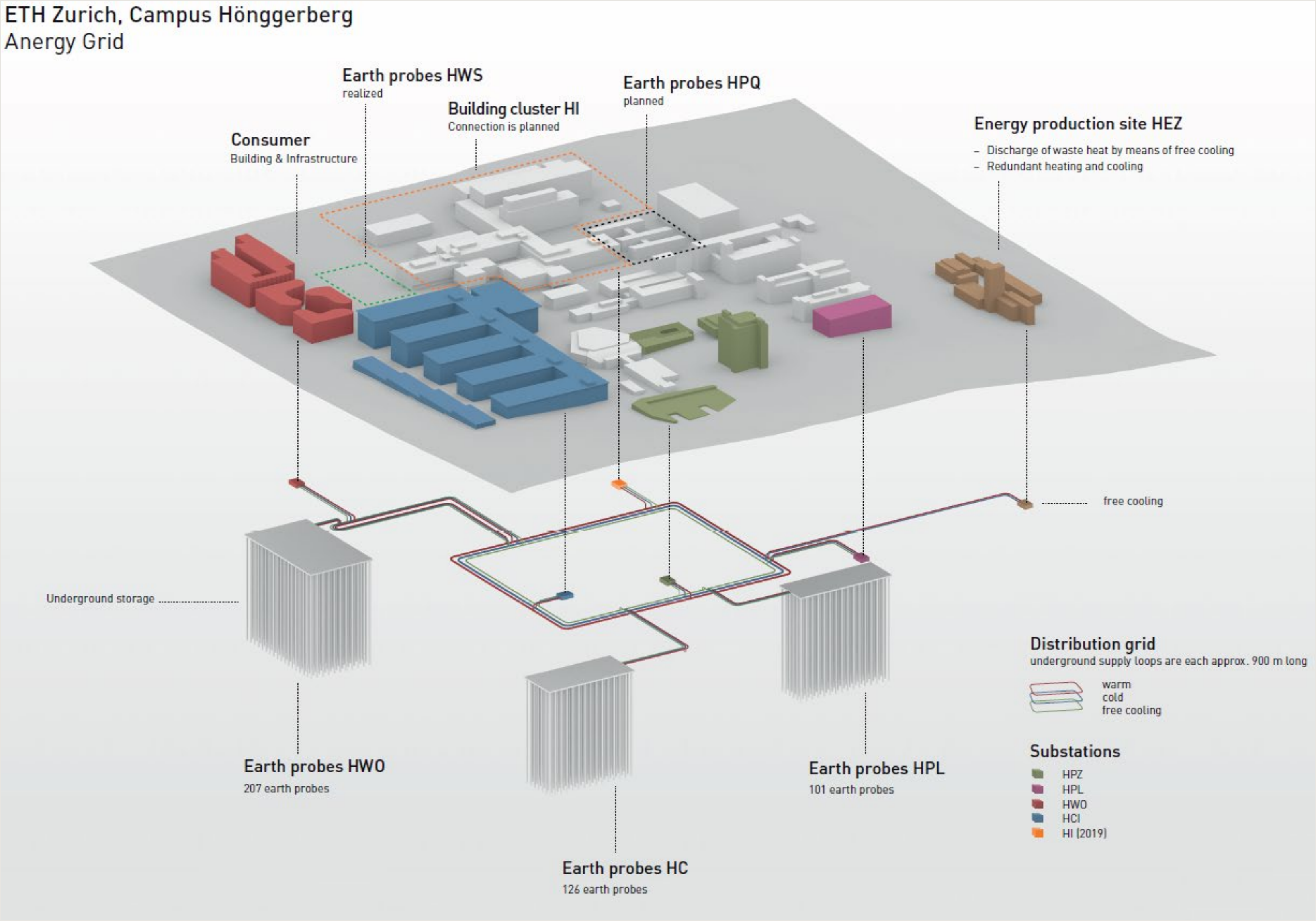
Anergy grid in Zurich, Switzerland



- 400,000 m² of total heated floor area
- The project was launched in 2012 and is expected to finish in 2025.
- Three-pipe network
- Network temperature range:
  4/8 °C (winter)
  18/22 °C (summer)
- 431 boreholes, each 200 m deep
  Total length ≈ 86,200 m

Image source: ETH website.
https://ethz.ch/en/the-eth-zurich/sustainability/campus/environment/energy/anergy-grid.html

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Anergy grid in Zurich, Switzerland

Key figures [1]

	COP [2] Coefficient of Performance	JAZ [3] Annual COP
Heating (per substation)		
HPZ	7.1	5.8
HPL	8.2	6.3
HWN	7.2	5.2
	EER [4] Energy efficiency ratio	**JAZ [3] Annual COP**
Cooling (per substation)		
HPZ	32.9 *	6.7 ** (incl. HEZ)
HPL	27.1 *	7.8 ** (incl. HEZ)
HWN	18.0 * (only air conditioning AC)	–

Source: https://ethz.ch/content/dam/ethz/main/eth-zurich/nachhaltigkeit/Dokumente/Anergienetz/200129_Anergienetz_A4_6s_Einzel_EN_RZ.pdf

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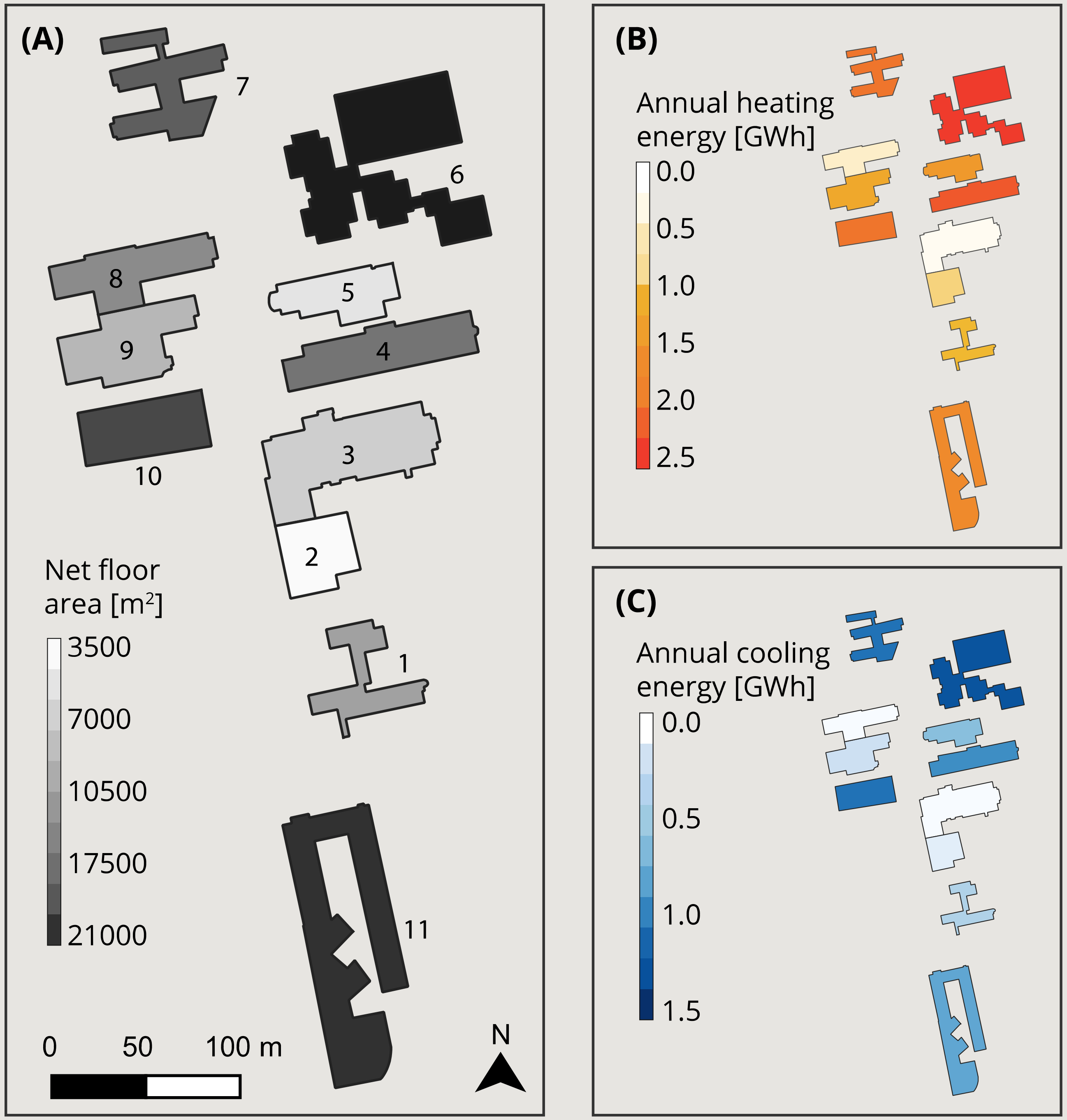
Ectogrid in Lund, Sweden



- 11 buildings with simultaneous heating and cooling demands
- Total floor area ≈110 000 m²
- Annual heating energy ≈11 GWh
- Annual cooling energy ≈ 4 GWh
- Patent title: District Energy Distribution System
- Patent description: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2018202519&tab=PCTBIBLIO&_cid=P11-KUCPTE-68691-1
- The patent explicitly mentions a geothermal heat source in the system components

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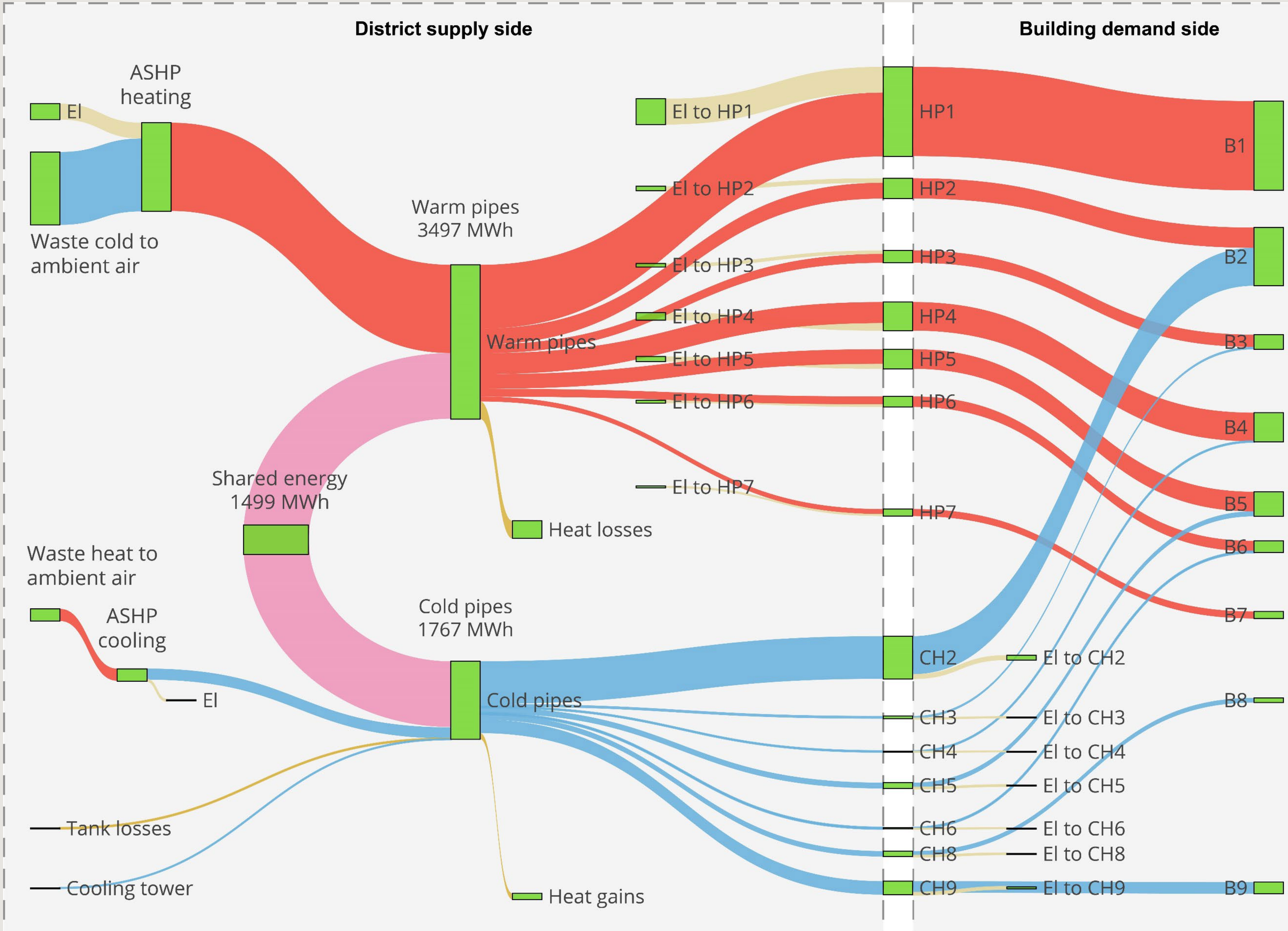
Ectogrid in Lund, Sweden



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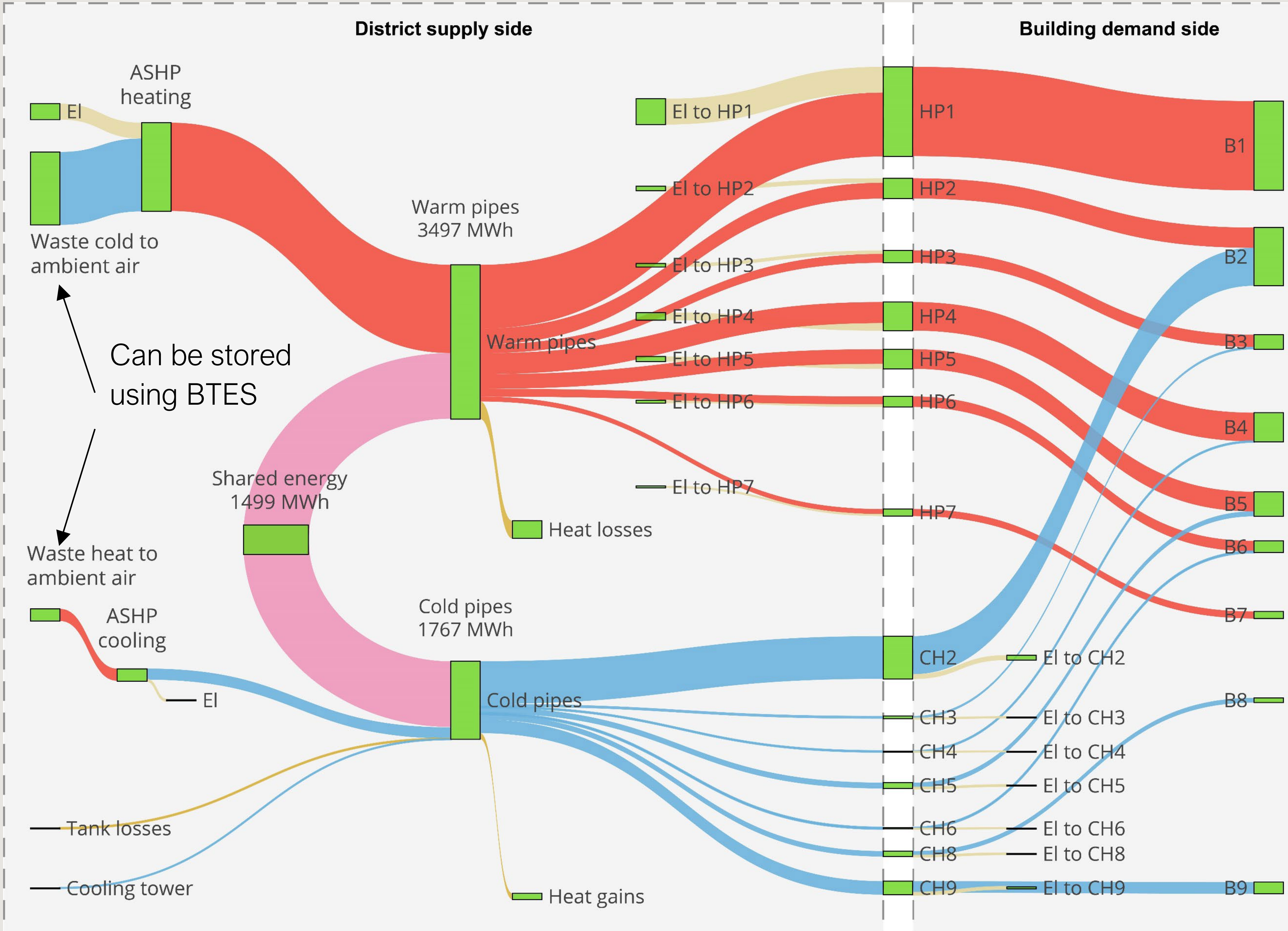
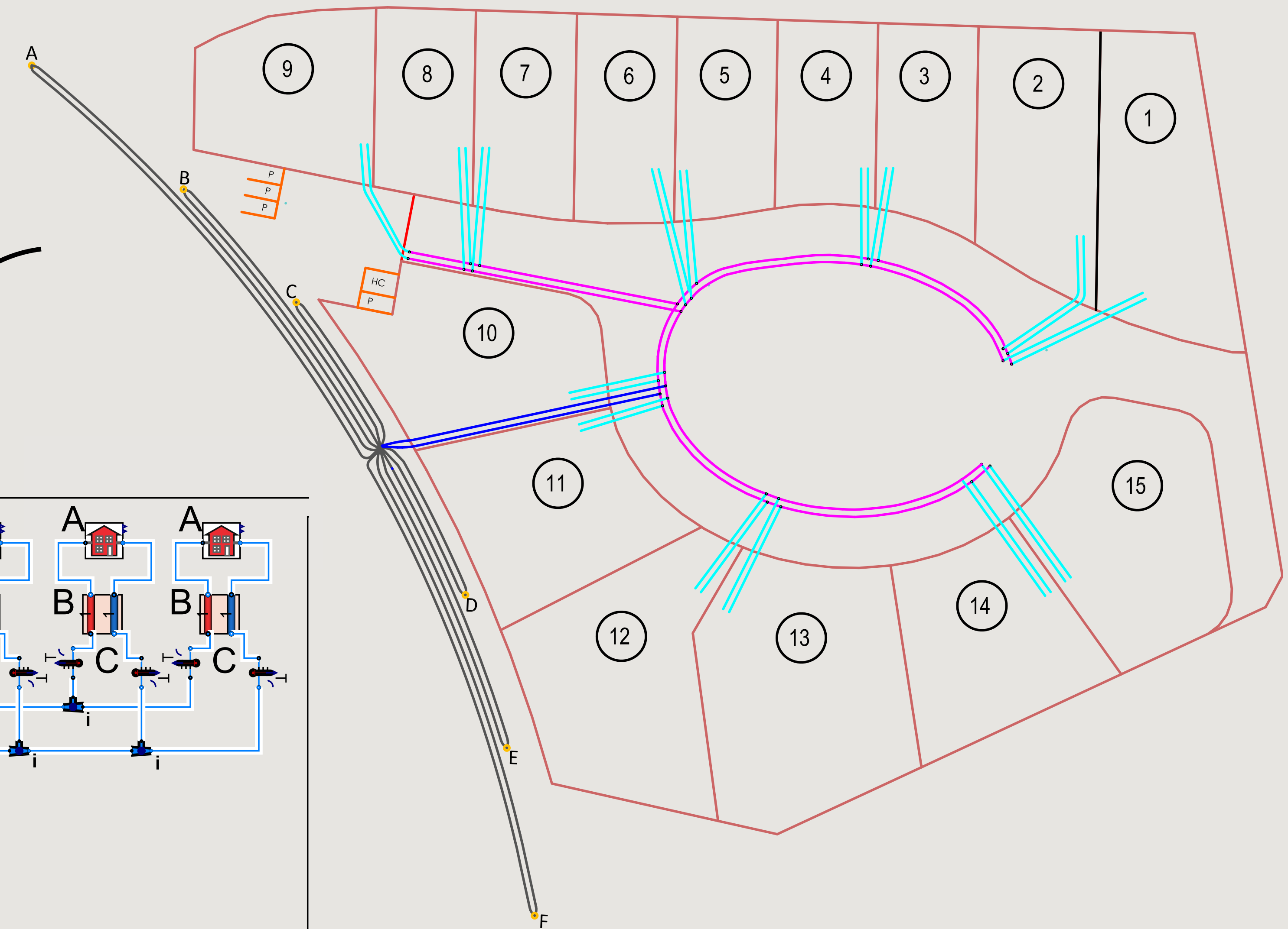
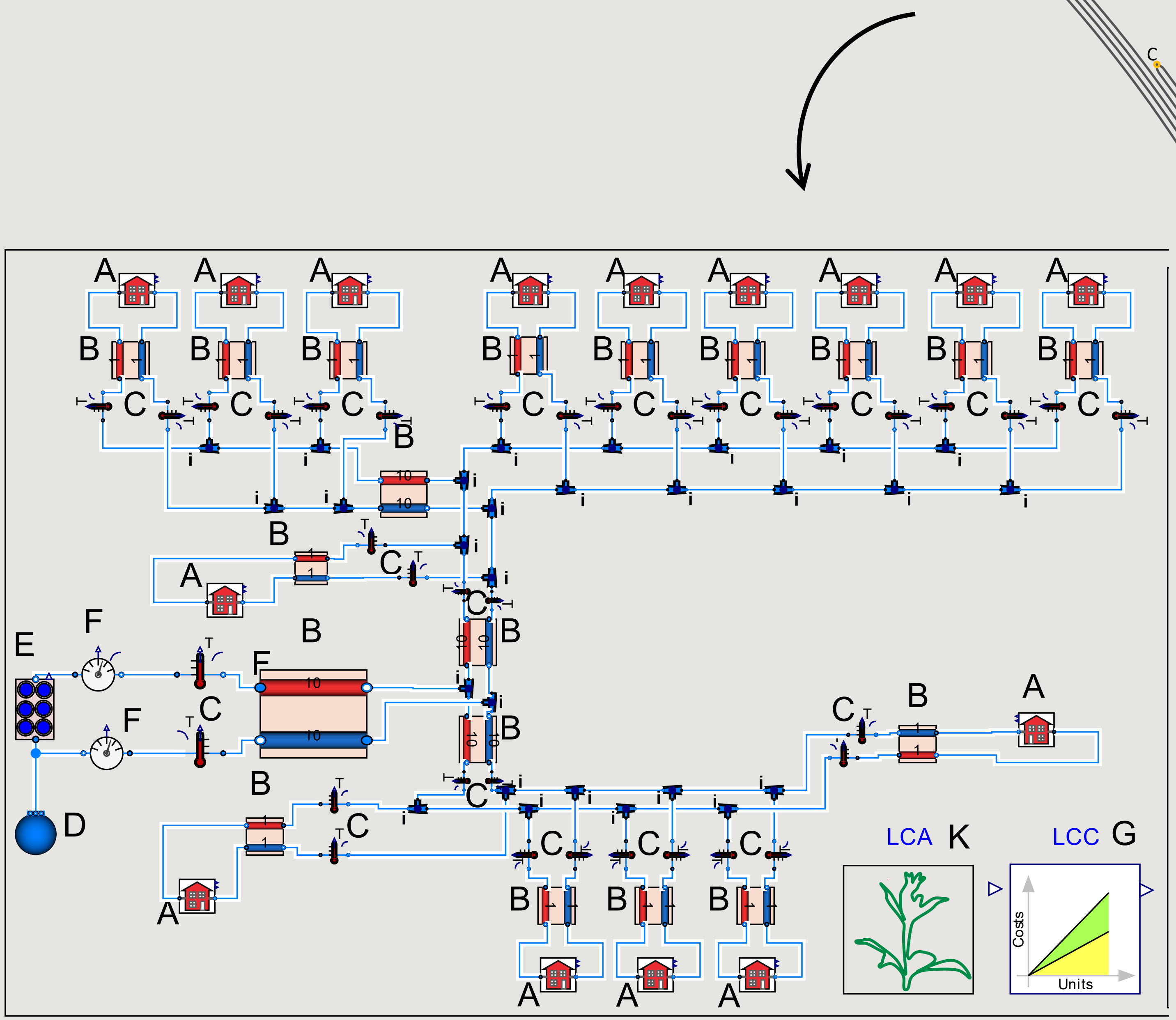


Termonet, Silkeborg, Denmark





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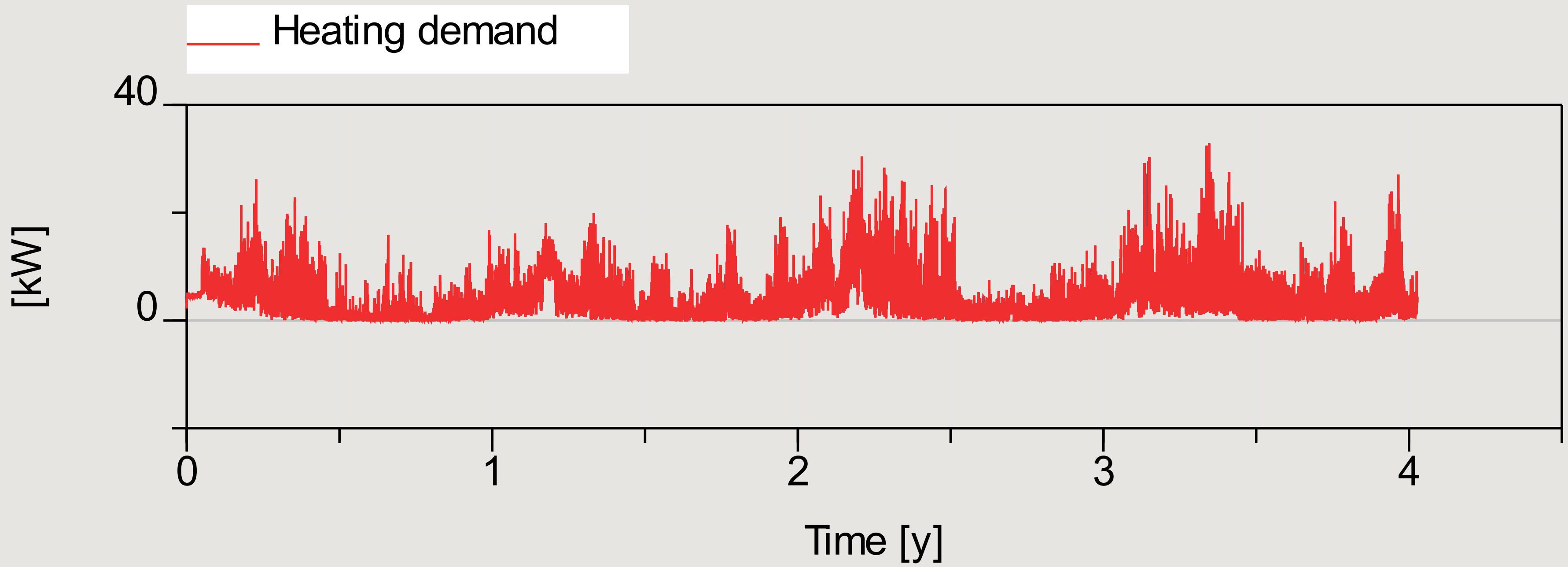

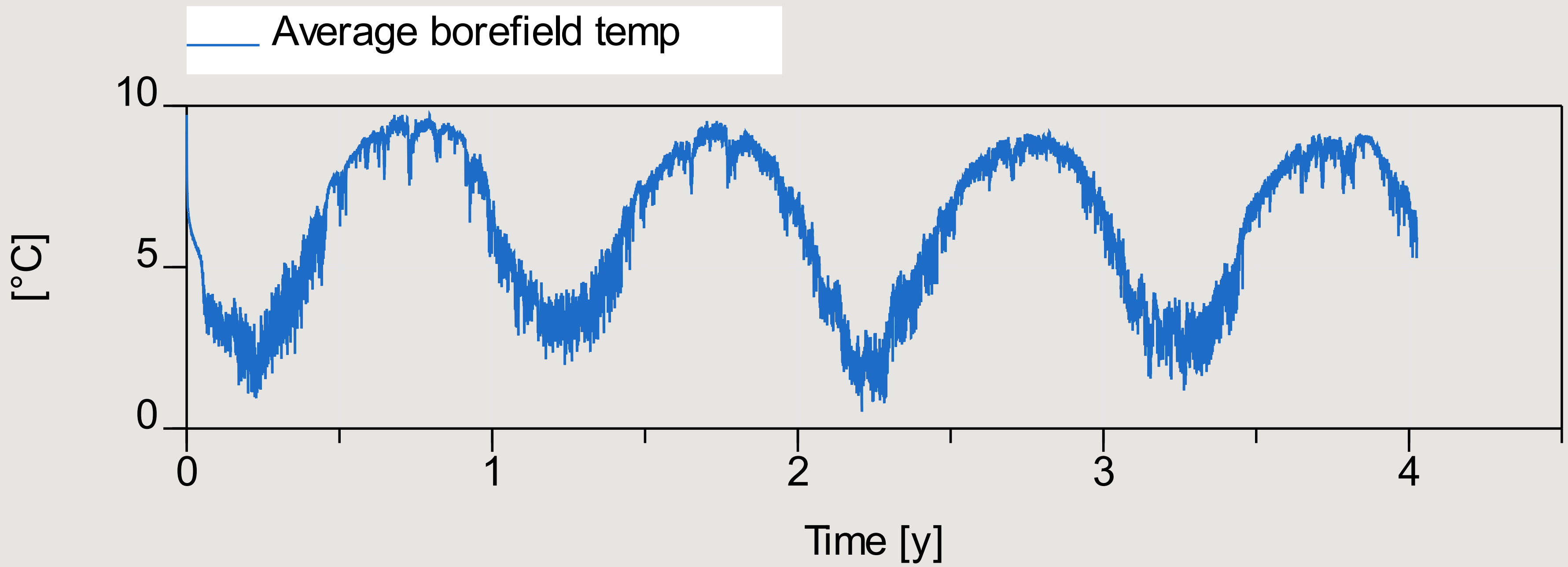

Measured heat demand and modelled borefield temperature

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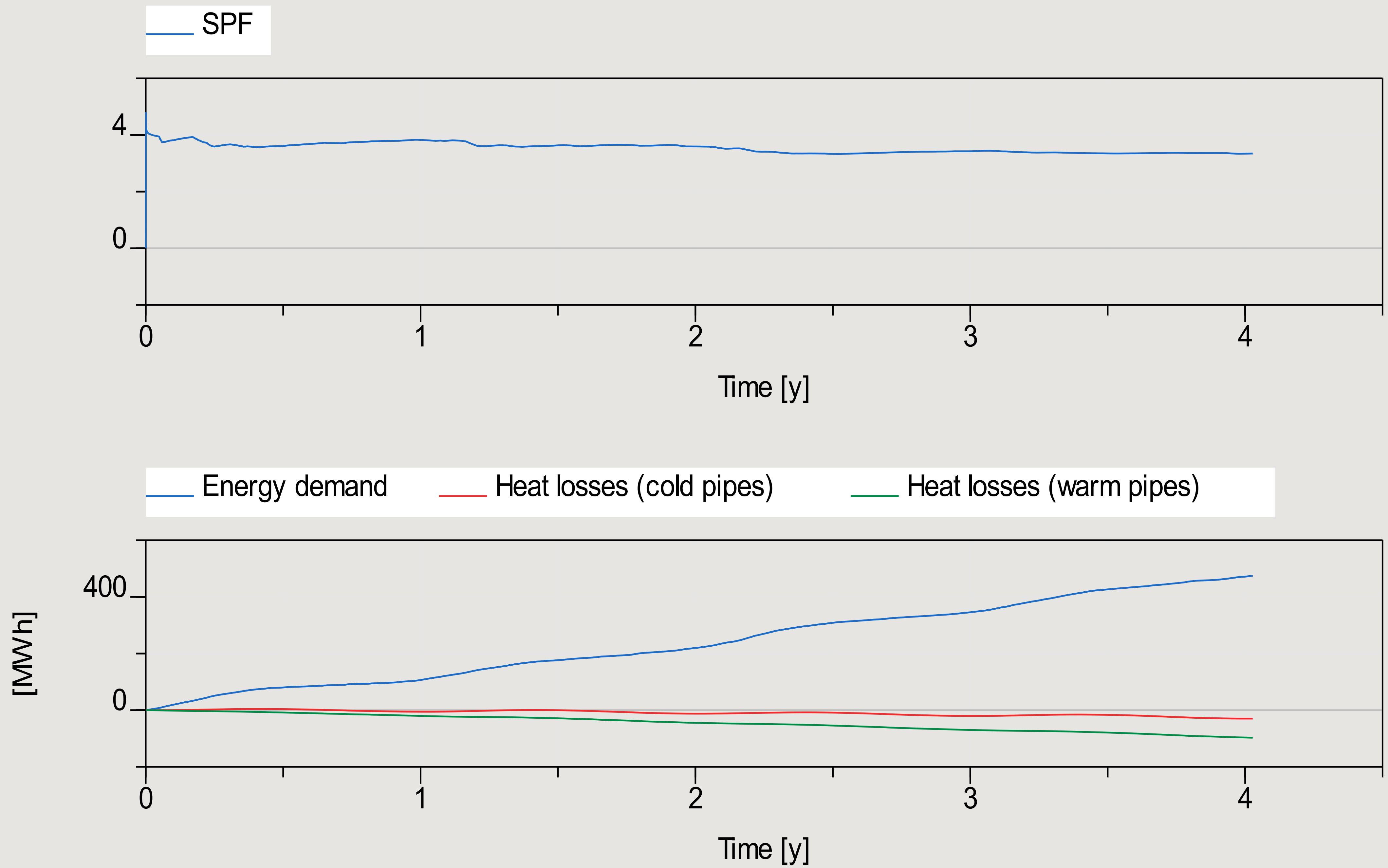
Termonet, Silkeborg, Denmark



Measured energy demand and modelled SPF

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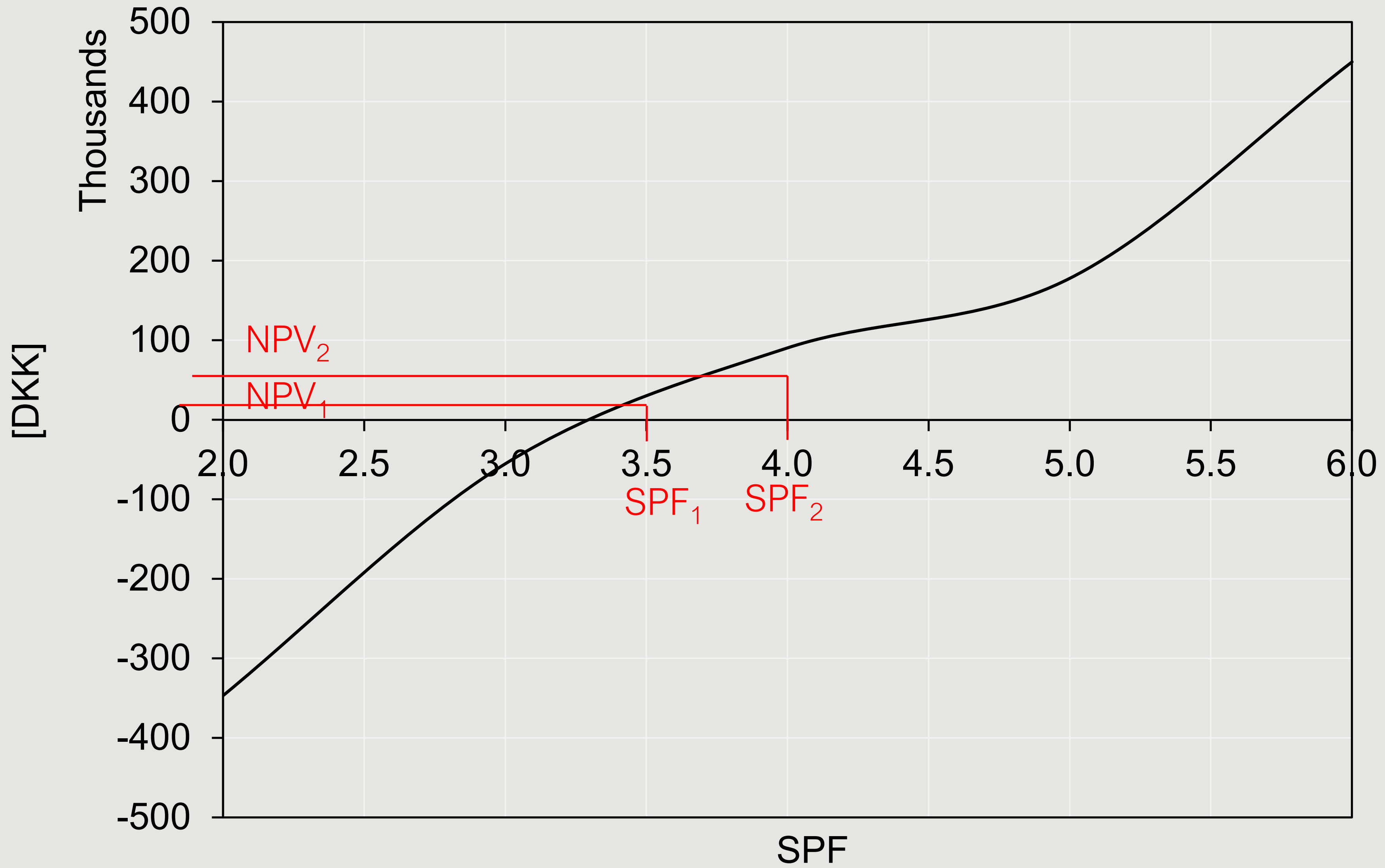

14 % of efficiency improvement ≈ 200 % increase in profitability over the life cycle

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Summary and future planning

- Development of off-the-shelf heat pumps with low temperature lifts.
- Control of energy exchange between connected buildings.
- Training courses for certified installers.
- Provision of standardized purchased packages.
- Promotion of joint ownership with business models for energy communities

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Thank you.


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