Integration Impacts of Low Temperature Districts on Existing District Heating Networks

A Swedish Case Study

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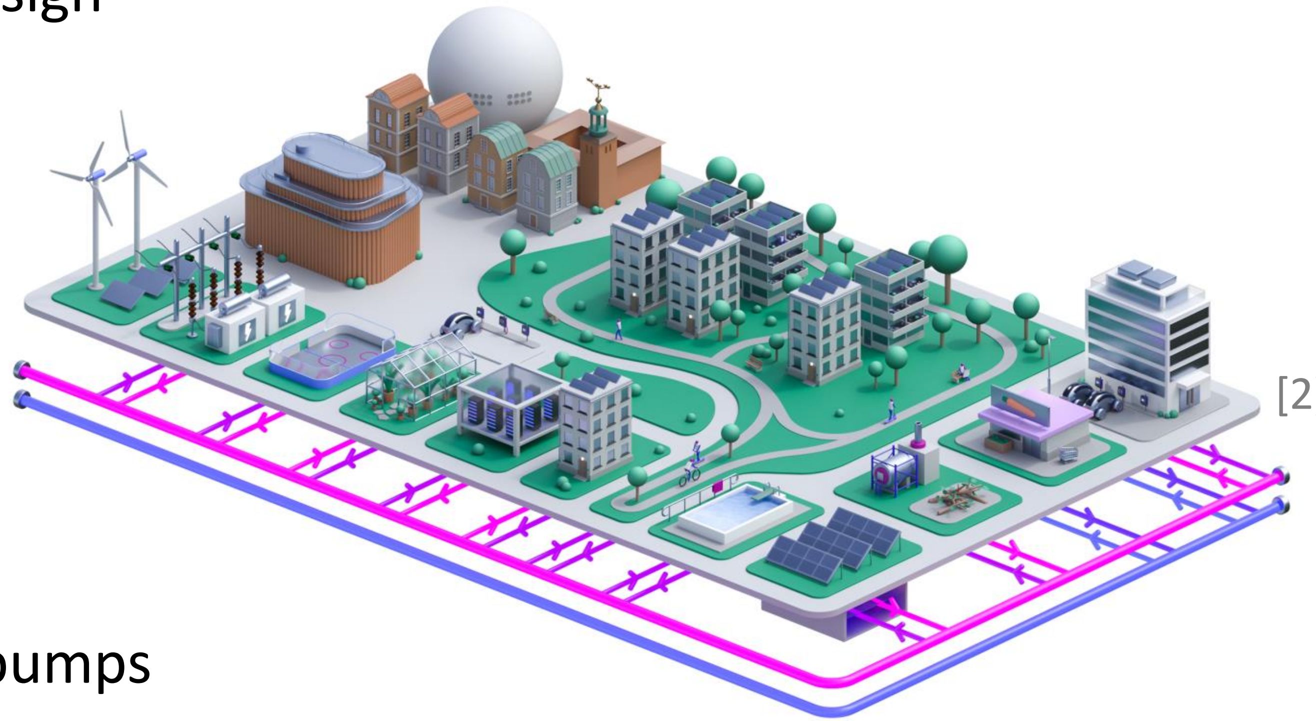
Nordic Master's of Innovative and Sustainable Energy Engineering

Energy System Modeling


[1]

Low Temperature District Heating

- Enabled by more efficient building design
  - Requires lower supply temperatures
  - Can return lower temperatures
- Interaction between customer and DHN more sensitive
  - Temperature utilisation important with lower supply temperatures
- Frequently used with electrical heat pumps
  - Shift heating load to electrical network
  - Can strain network capacity and increase social costs



[2]

Objectives

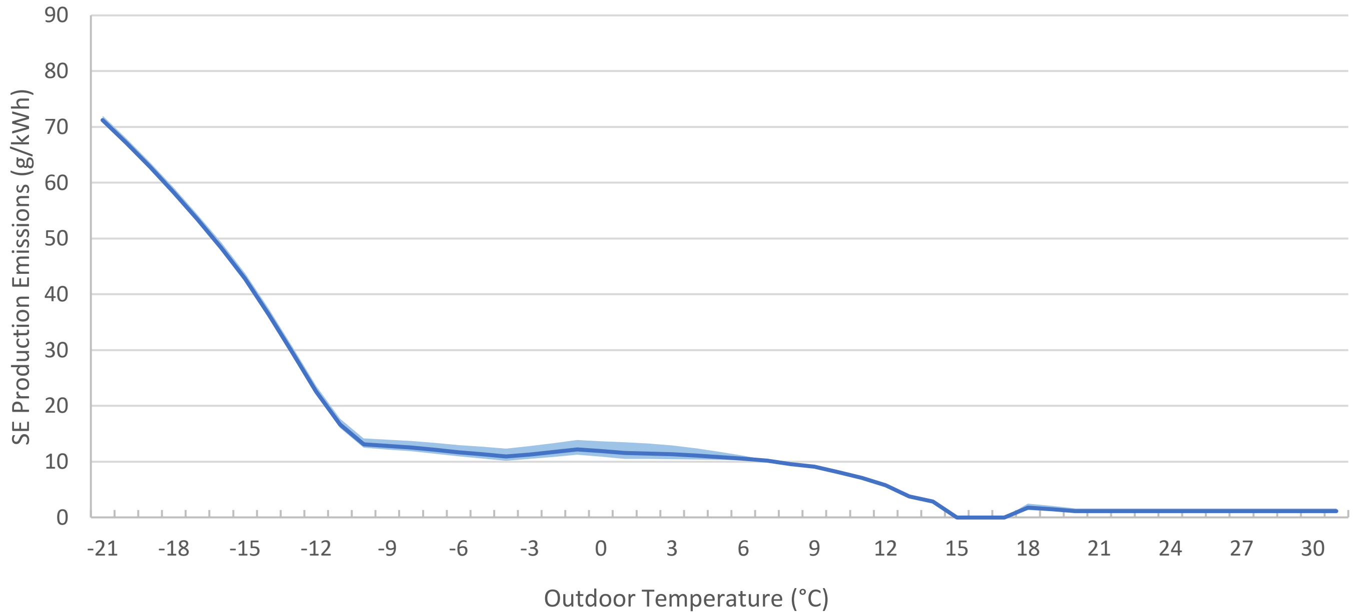
- For a new LTD connected to an extisting DHN evaluate:
    - The CO_2 emissions (inc. electrical) from heating
    - The new electrical energy and power requirements
    - The heat utilisation and recovery opportunities
    - Impact of substation v. network layout

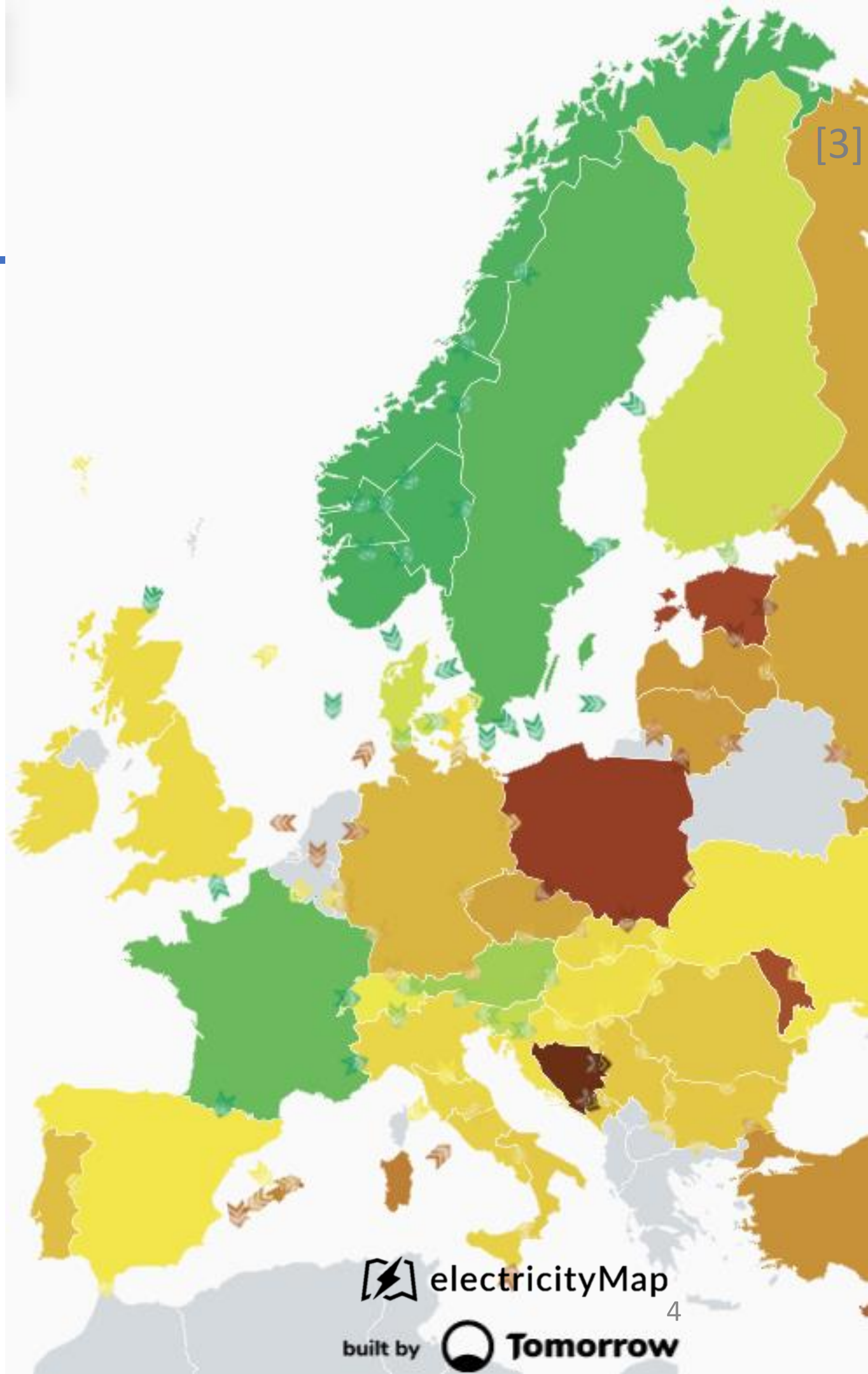
- Explored through through 5 heat supply scenarios in a case study

Heat and Electricity Emissions

- In decarbonised DHNs the emissions from electricity play a larger role – used Tomorrow hourly data
- Sweden's DHNs deliver heat with emissions near those of renewable electricity – SE below

Short Term Marginal Specific Emissions - Heat



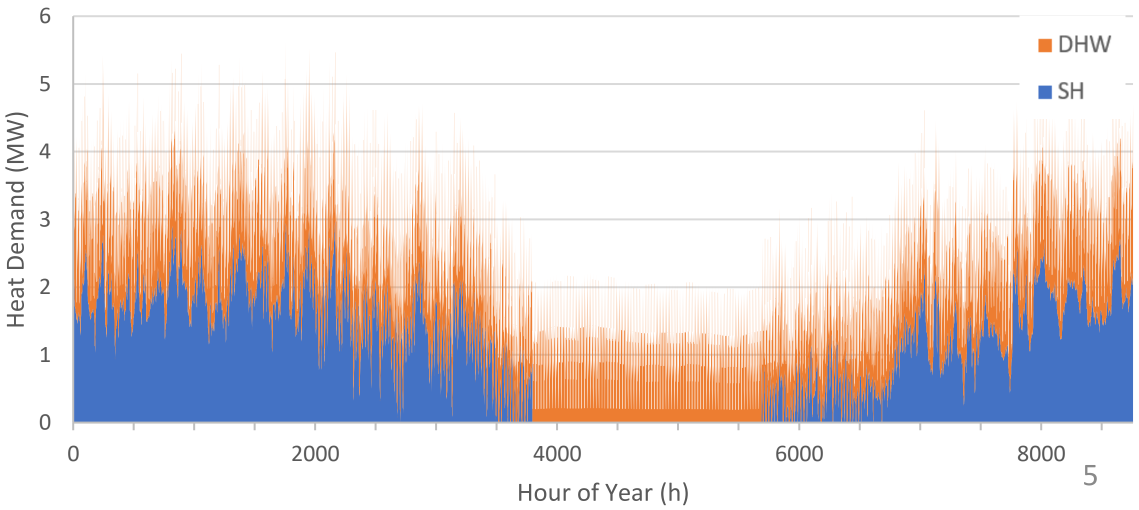


[3]

Case Study District - Loudden

- 4000 New Apartments in 570,000 m^2
  - 2 existing commercial buildings
  - 1 new sports facility
  - 31 new residential buildings, 5 stories, courtyard layout
- Heat and electrity target 50 kWh/m^2/yr
  - Low Energy Class 30 kWh/m^2/yr SH+DHW
- Supplied by a LTN at 65°C year-round
  - Tree structure
  - Russian 3-stage substations

Peak (MW)	Total (MWh/yr)	% SH
5.62	18,800	51%



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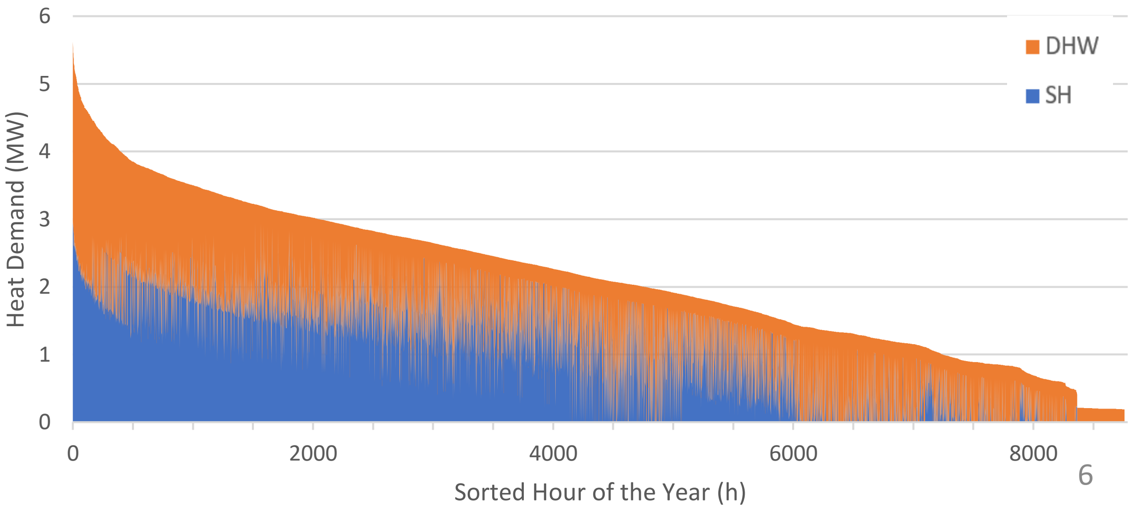
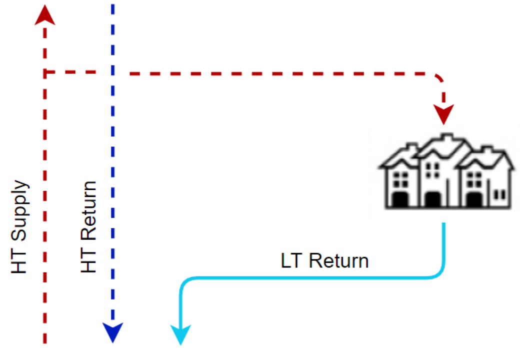
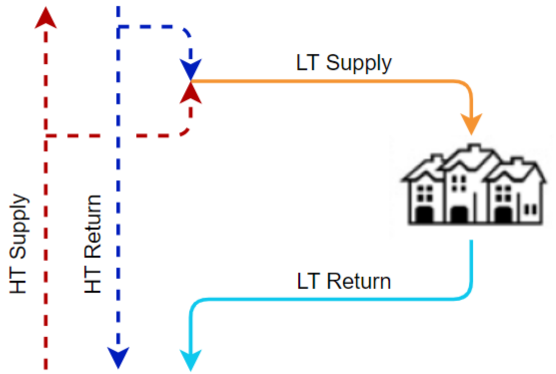


Scenario Descriptions

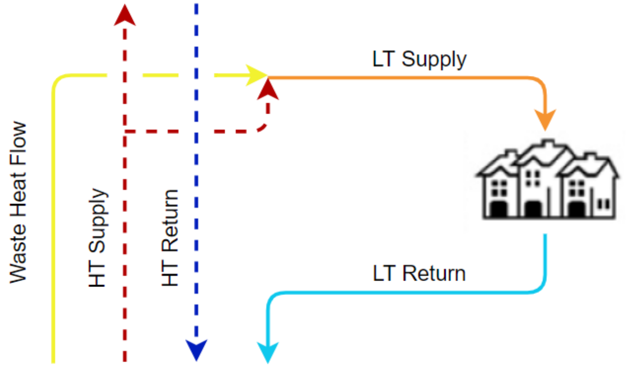
S0a: HT Supply



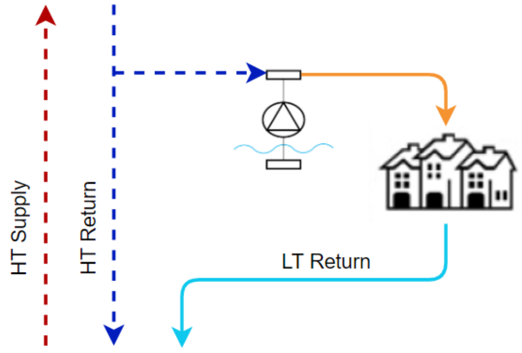
S1a: HT Shunt



S2a: Waste Heat Shunt



S3a: Using Sea-source HP



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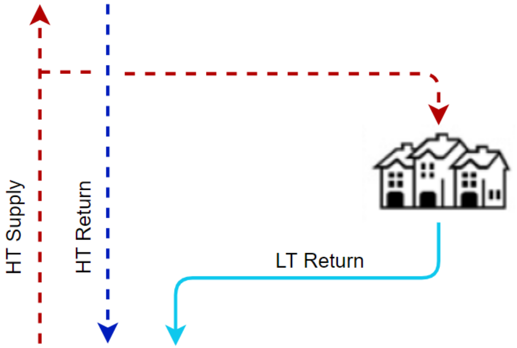

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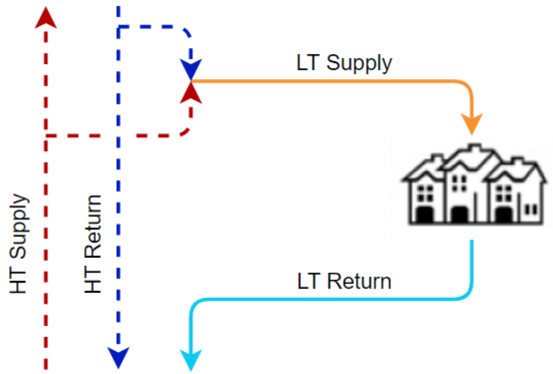

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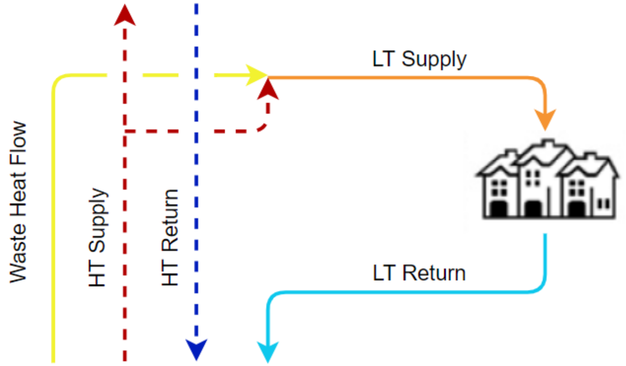

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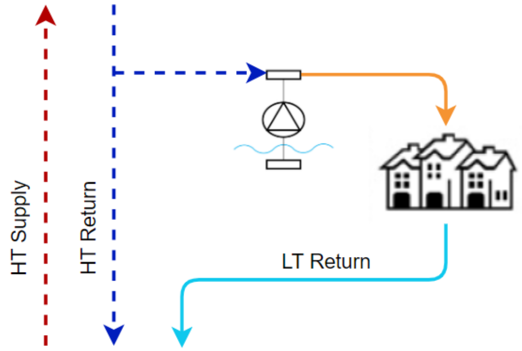
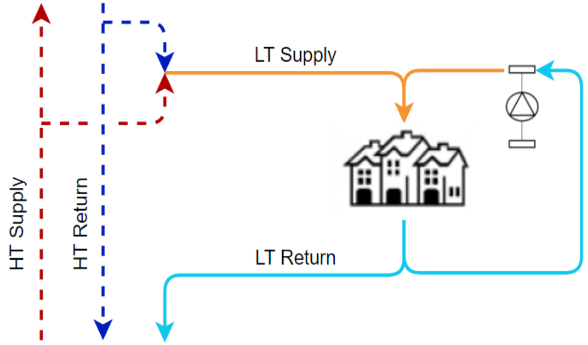
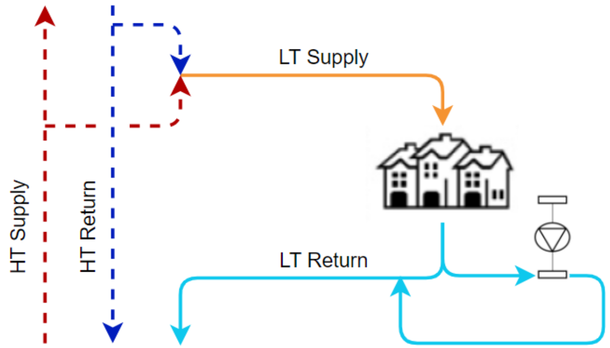


S4a: Prosumers to the LT Supply



S4b: Prosumers to the LT Return

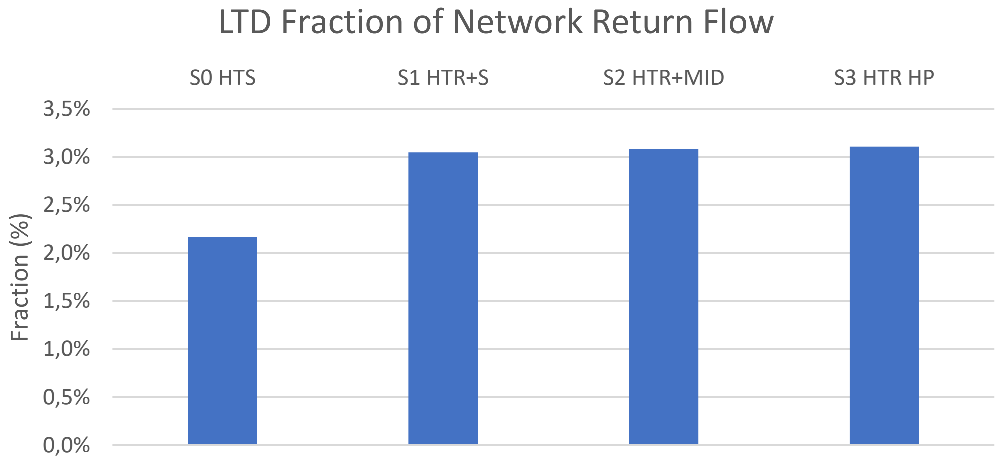


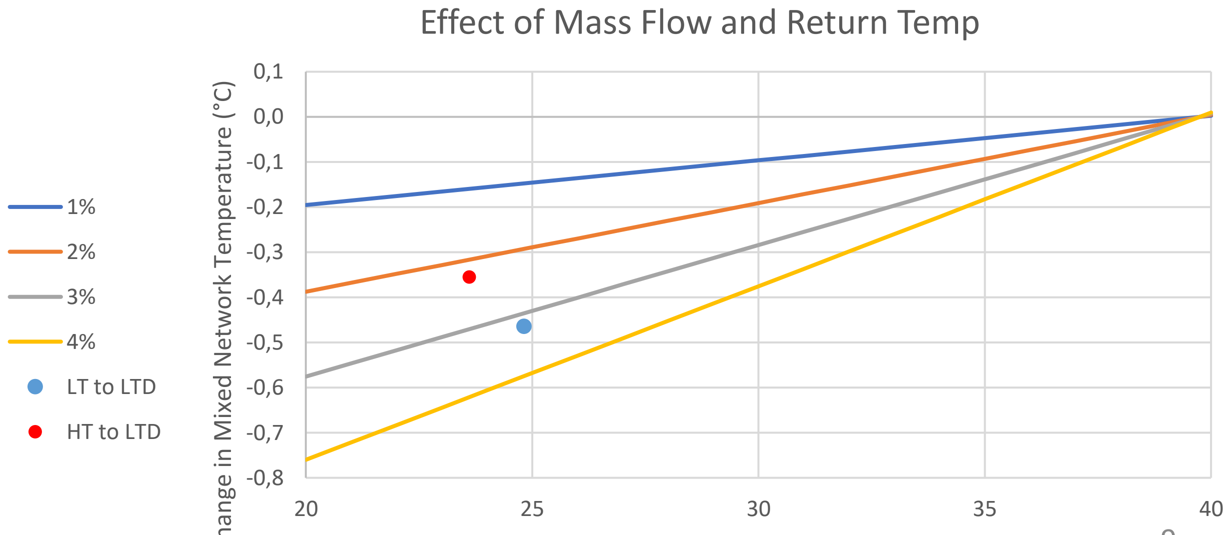
Network Return Temperatures

- HT Supply returned lower temperatures than LT Supply
  - Less temperature dilution when reheating DHW losses

- LTDH required 40-45% more flow than conventional 3GDH
- Results in higher impact for the LTD return temperatures than HTD

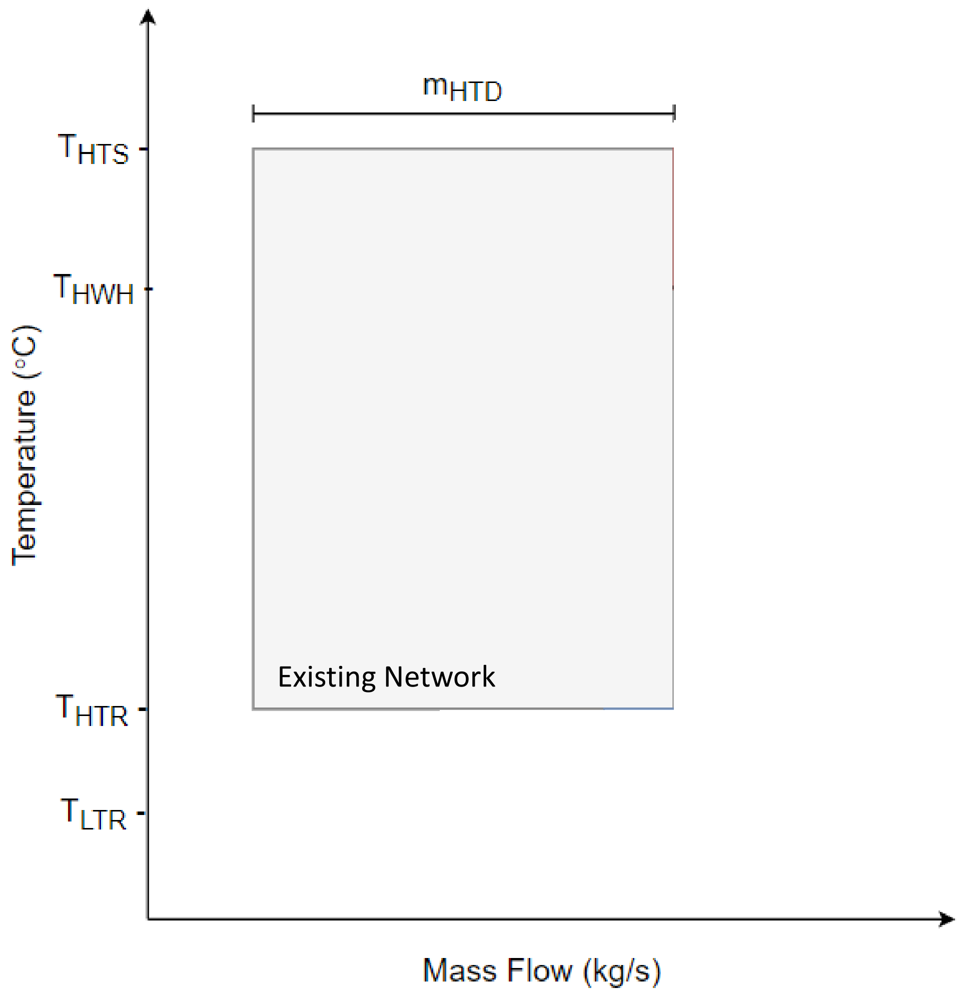
- Will have implications for faults in LTDs in future





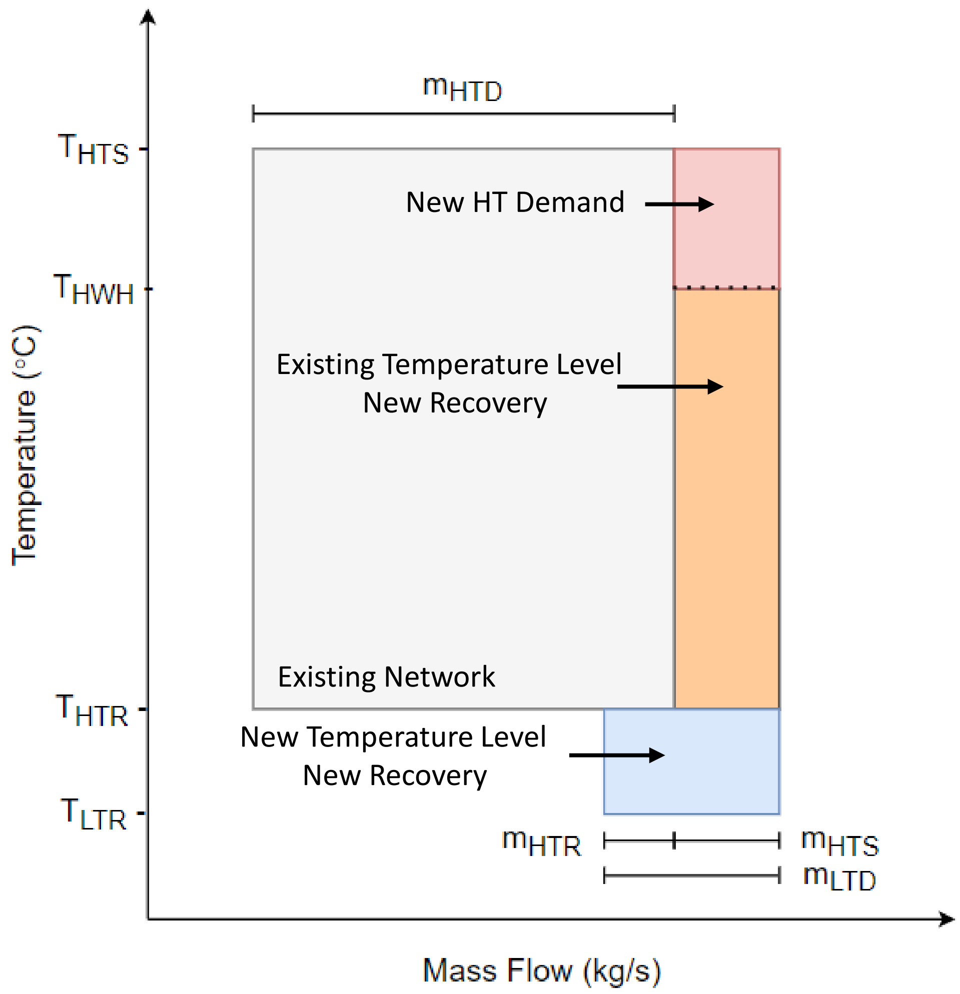
Heat Recovery

- Temperature levels are an important consideration for heat recovery



Heat Recovery

- LTDs create heat recovery oportunities by producing low return temperatures
- How much demand can be moved from high temperature to low with LTDH?



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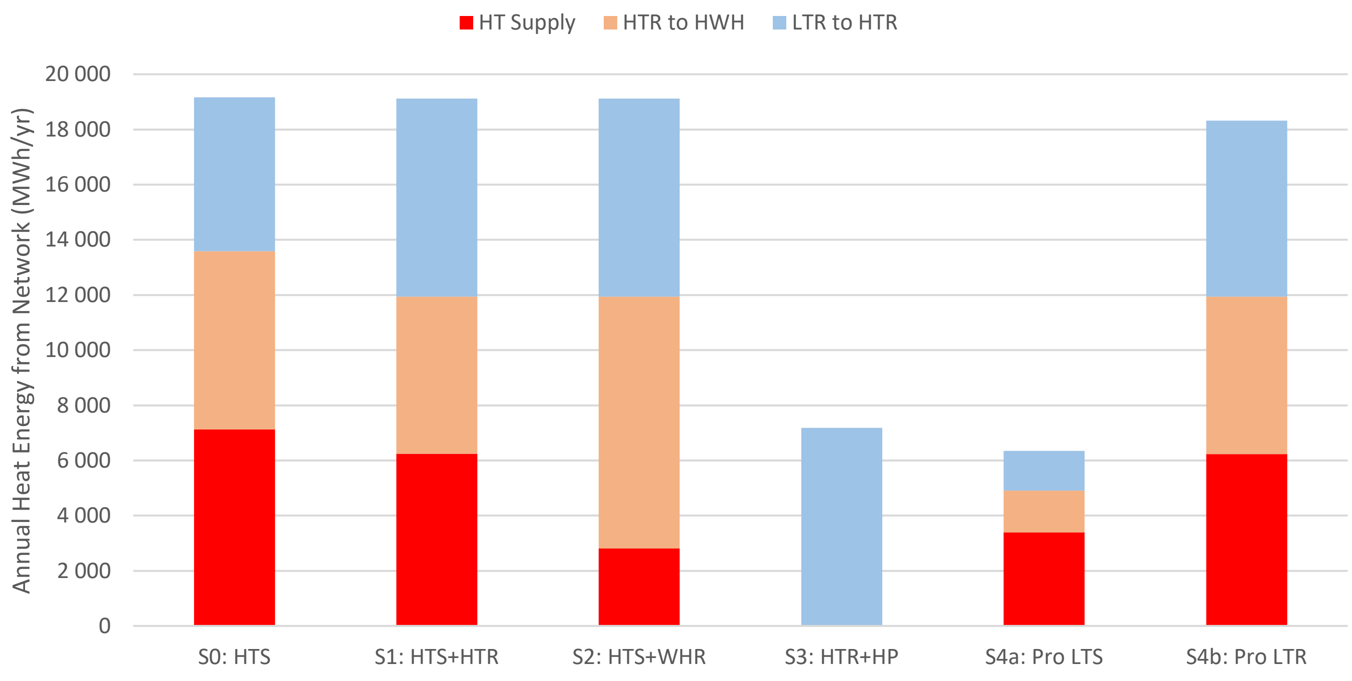
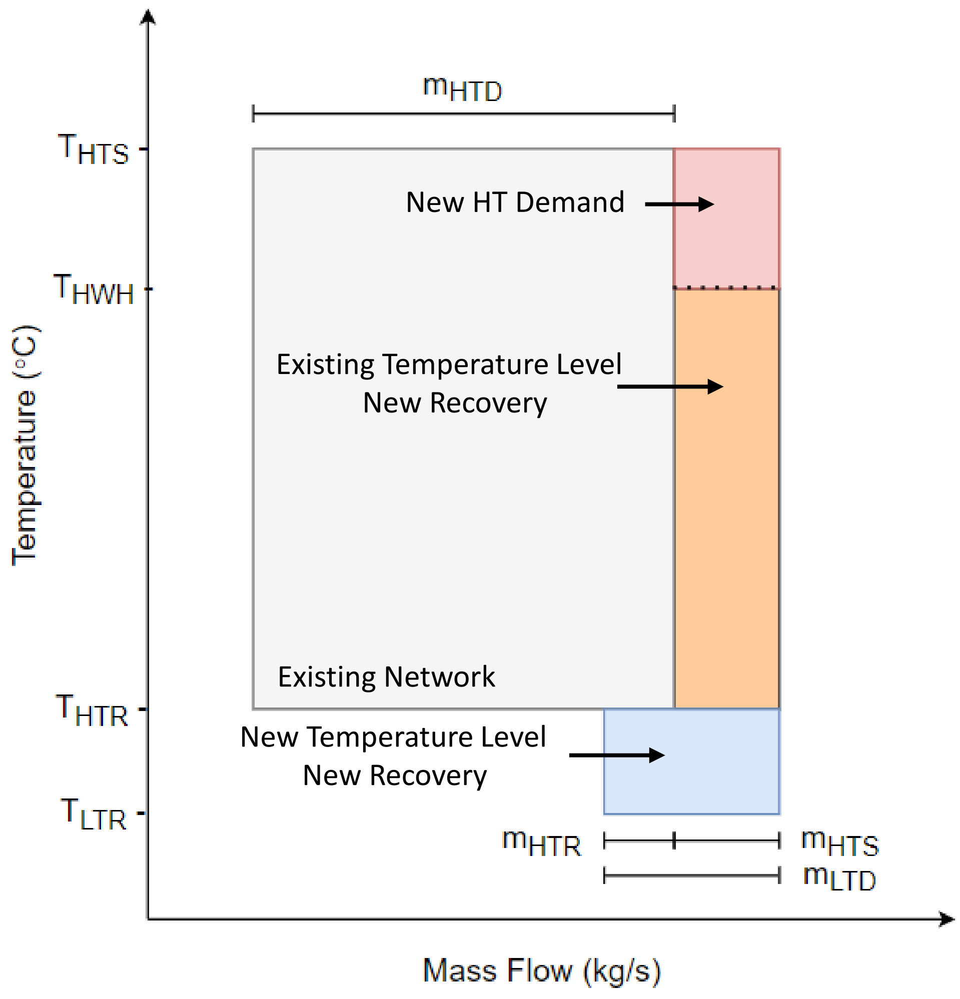
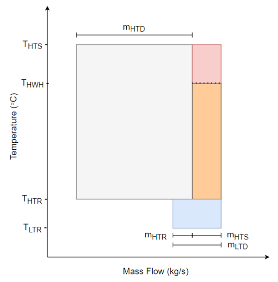
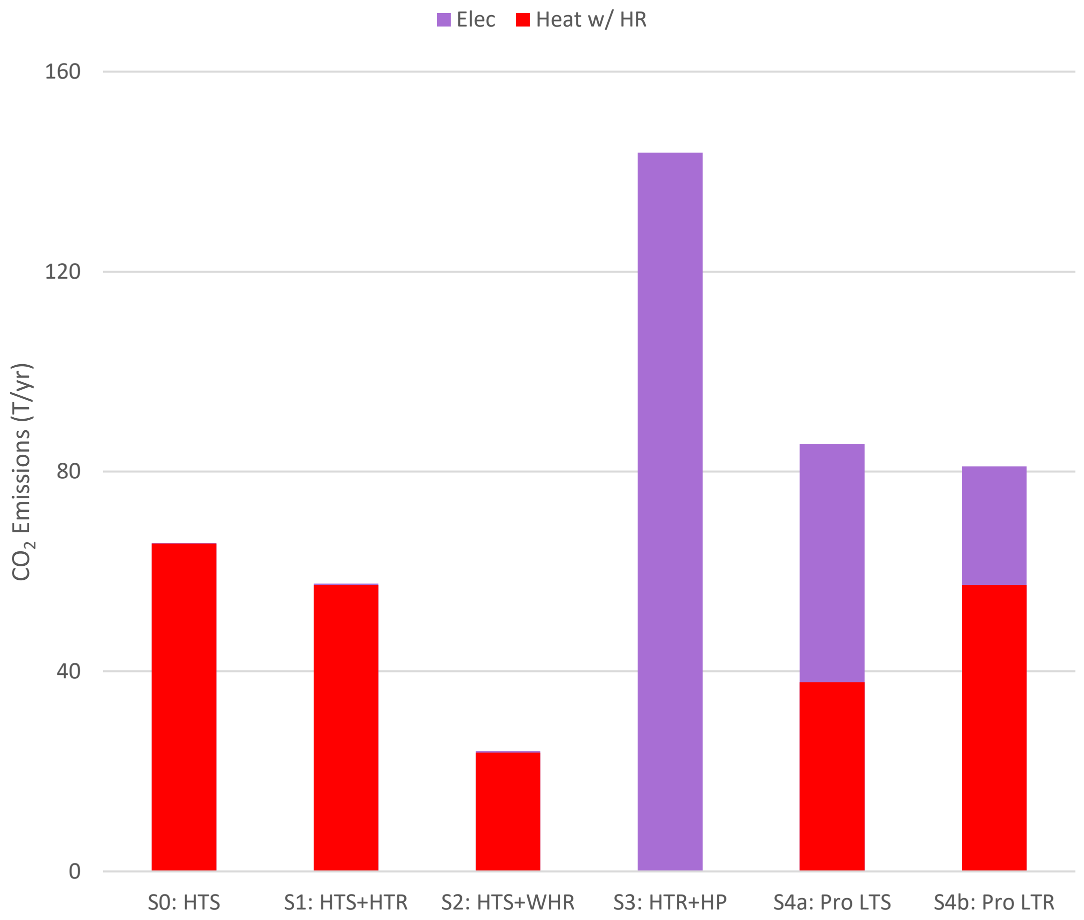




Emissions



- Electricity represents a significant fraction of total emissions in electrified scenarios – even in Sweden
- Increasing temperature of waste heat significantly reduces emissions



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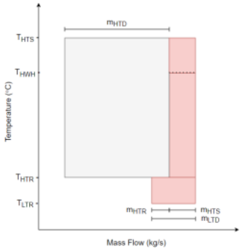

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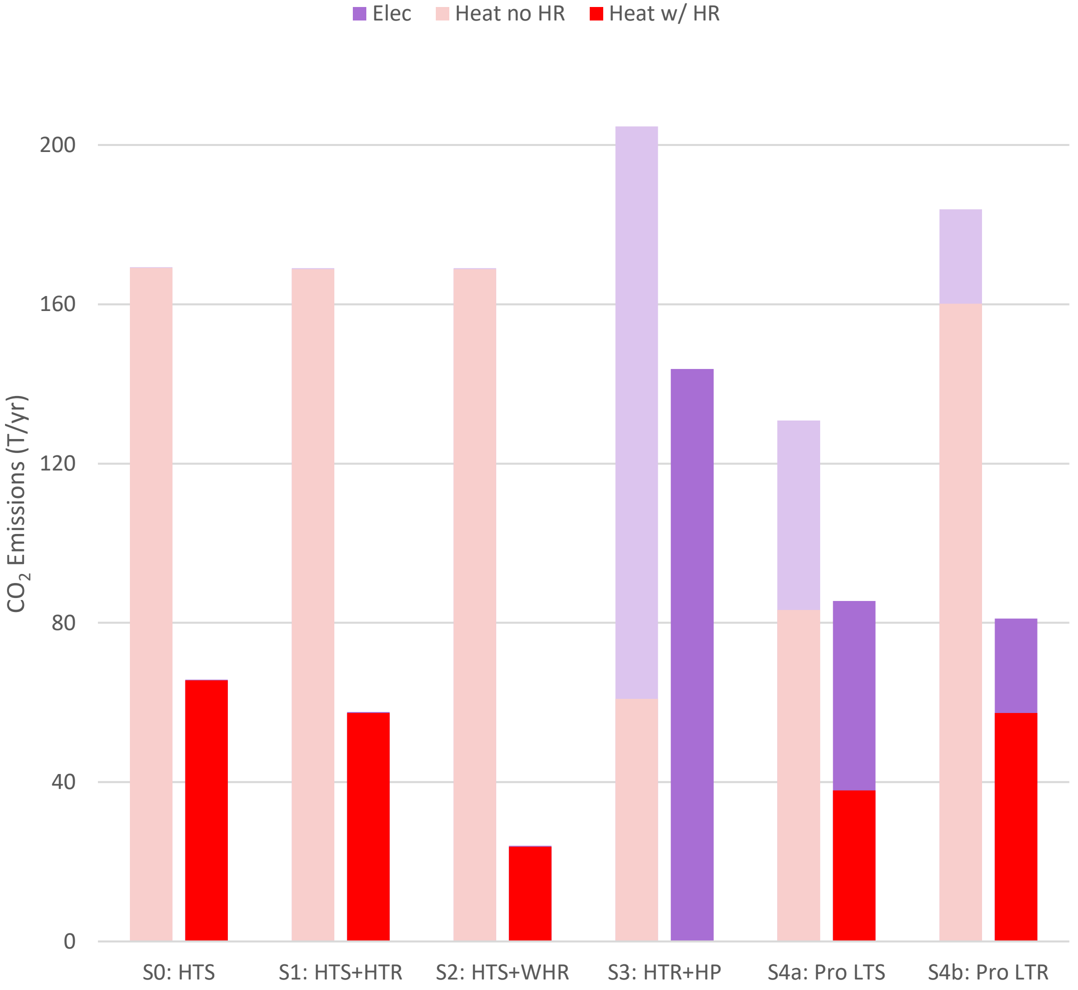
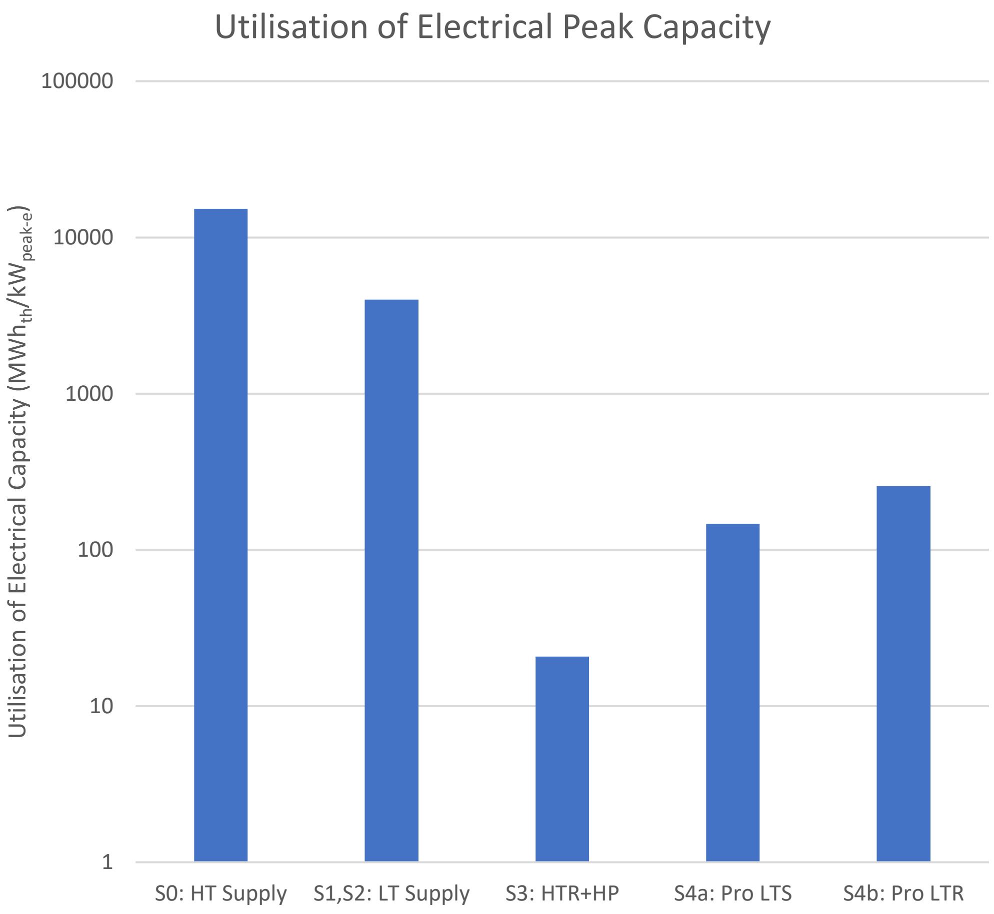
- Highest emissions both with and without heat recovery is the electric sea-source heat pump



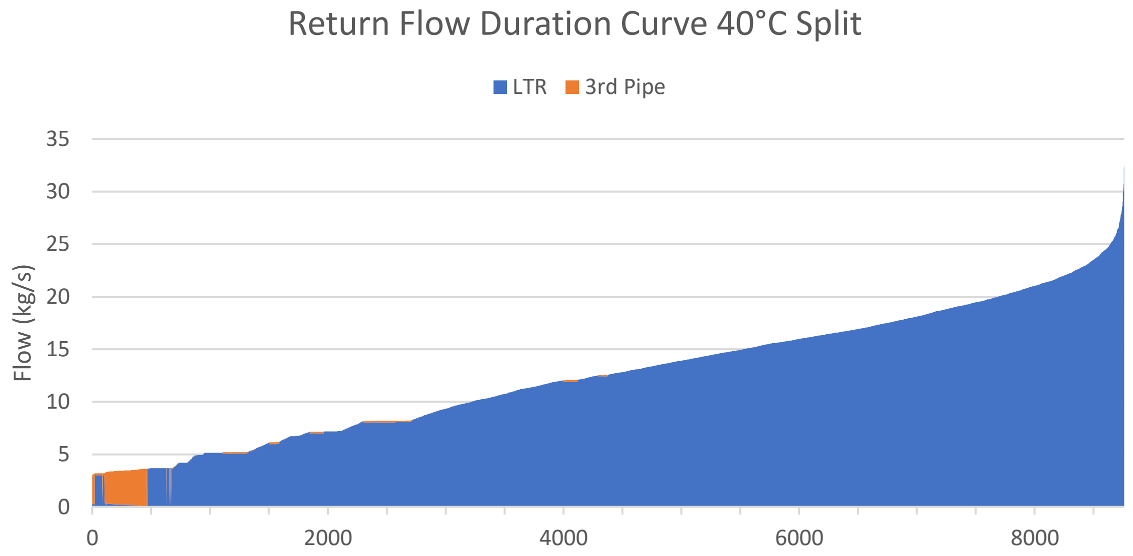
Electrical Utilisation

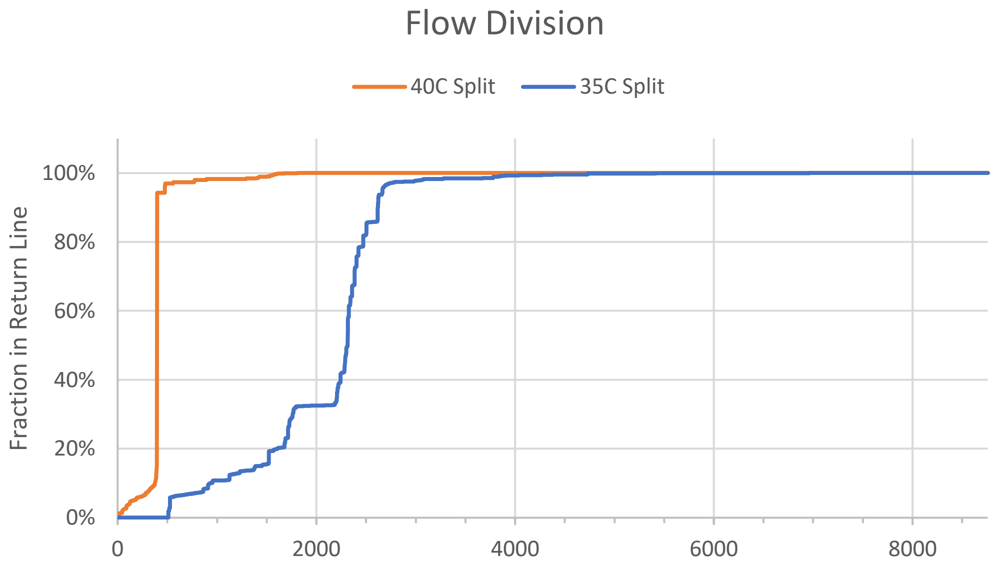
- Non-electrified scenarios deliver much more heat per connected electrical power ($MWh_{th}/kW_{peak\text{-}e}$)
  - District bounds only, not including electrical production in CHPs
- Significant implications for constrained electrical grids and the place of DHNs in the energy system

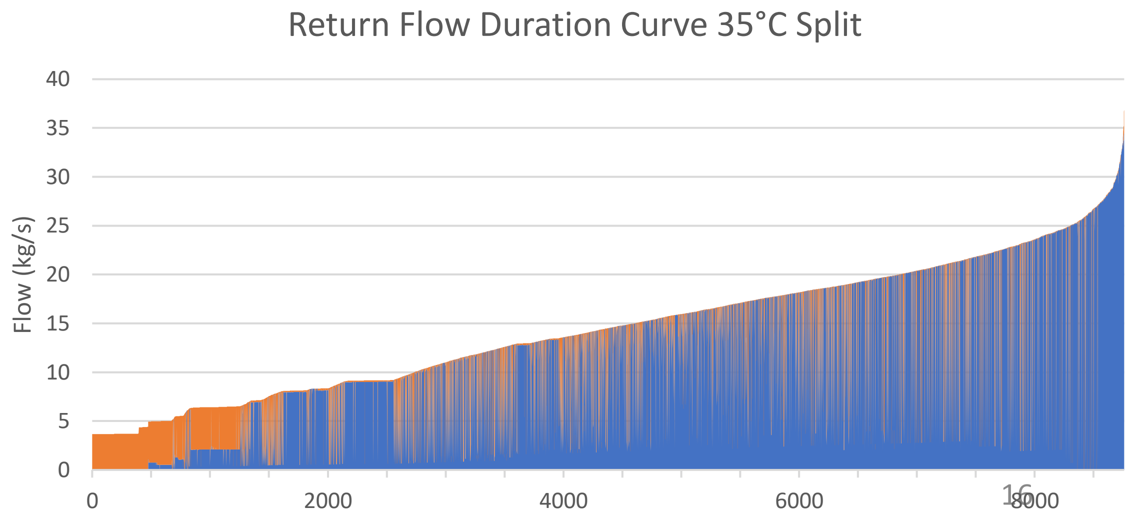


3rd Pipe (FRR)

- With fixed division temperature difficult to divide flow well
- 3rd Pipe has low utilisation with wide range of flow
- Lowering split temperature to 35°C impoves split, but does not recifiy situation







3-Stage vs. 3rd Pipe

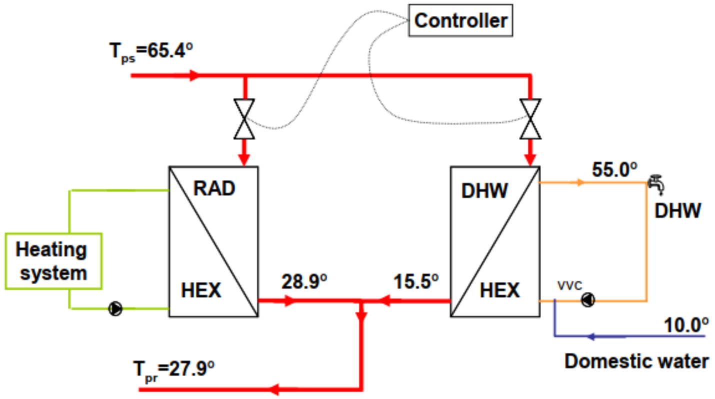
- 3rd Pipe not always feasible or cost effective
- When can a more temperature efficient substation provide similar benefits to 3rd pipe?
- When is a 3rd pipe justified to accept i.e. circulation flows or low temperature waste heat?

[4]

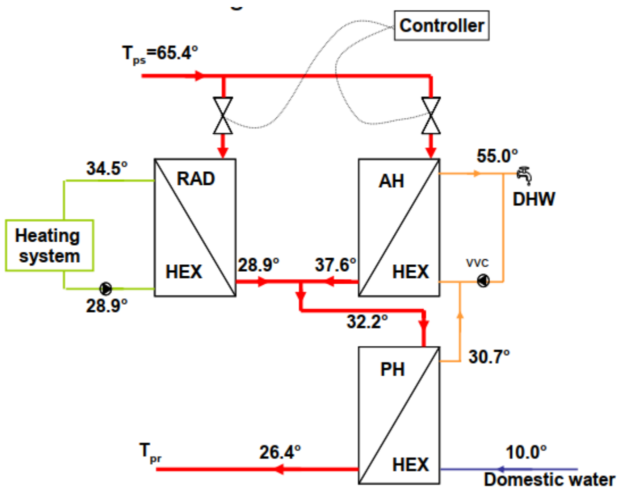
- Potentially more useful to bridge coincidence problems between different demands
- Exploring dynamic split temperatures
    - Assumes more direct communication and control with customer substations
    - i.e. relative to outdoor temperature, hottest XX kg/s, or depending on downstream needs

Substations in LTDs

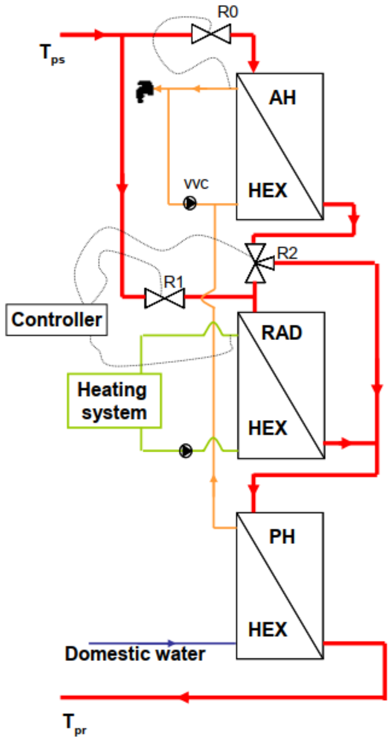
- Comparison of Parallel, 2-stage, and 3-stage in low demand, high efficiency buildings
- Higher fraction of DHW and lower SH temperature demand has implications for operation and selection



Simple Parallel



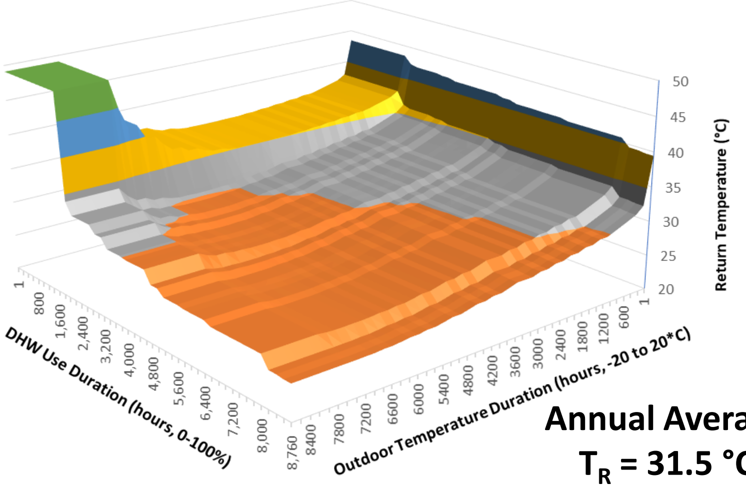
2-Stage



Russian 3-Stage

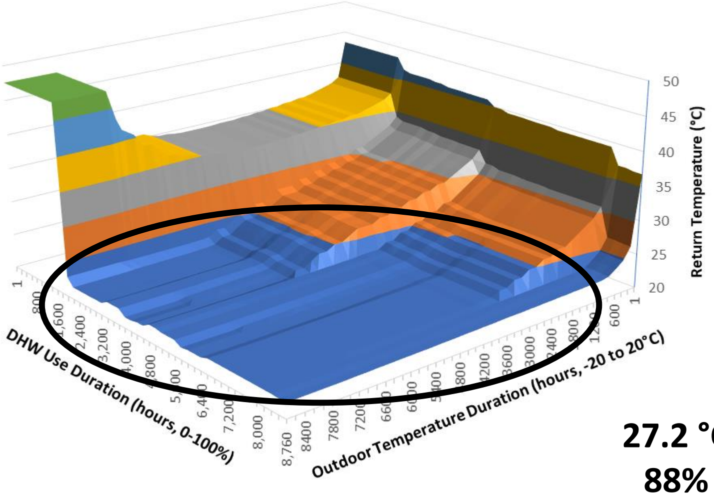
Substations in LTDs

- For 65°C 1ry, 60/40 2ry
- Significant reduction in T_R with multi-stage
- R3 able to utilise DHW re-heating at cost of more complexity



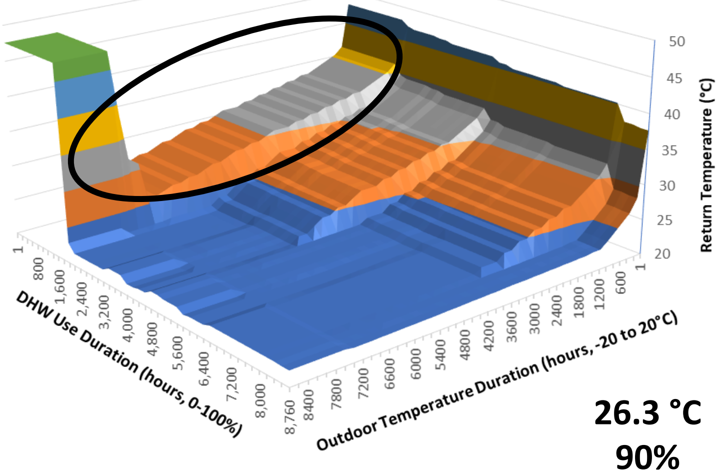
Annual Average
T_R = 31.5 °C
ε = 78%

Simple Parallel



27.2 °C
88%

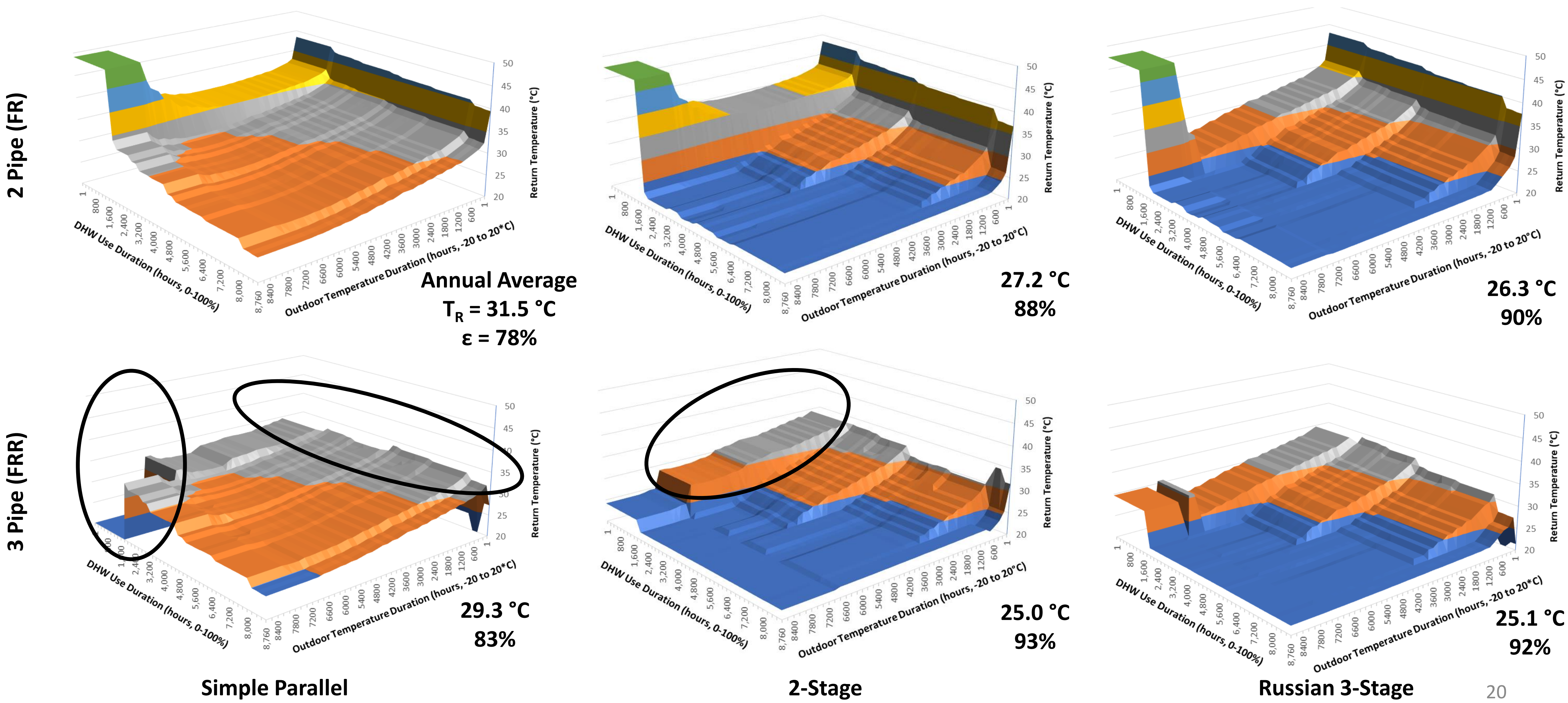
2-Stage



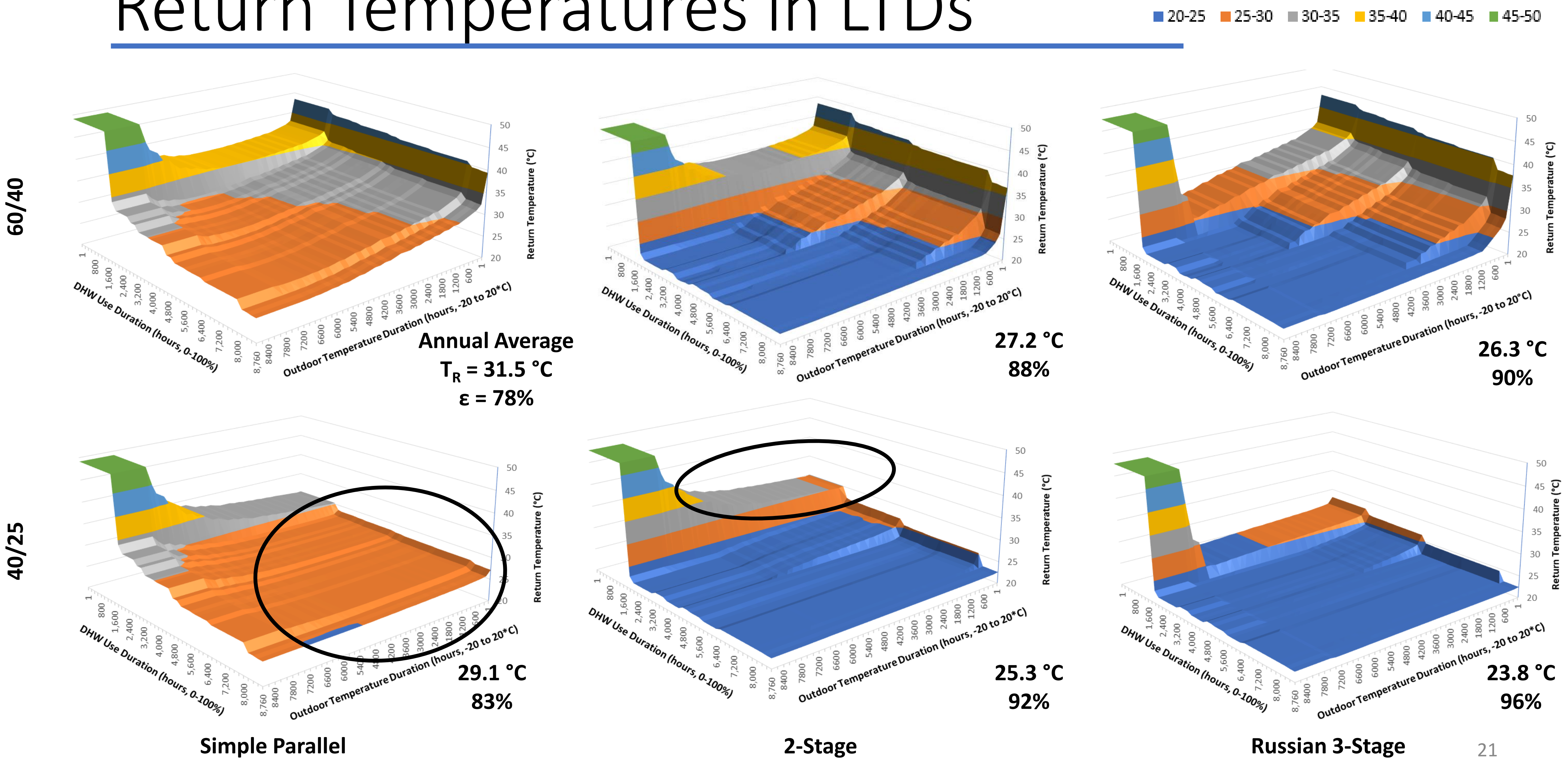
26.3 °C
90%

Russian 3-Stage

Return Temperatures in LTDs

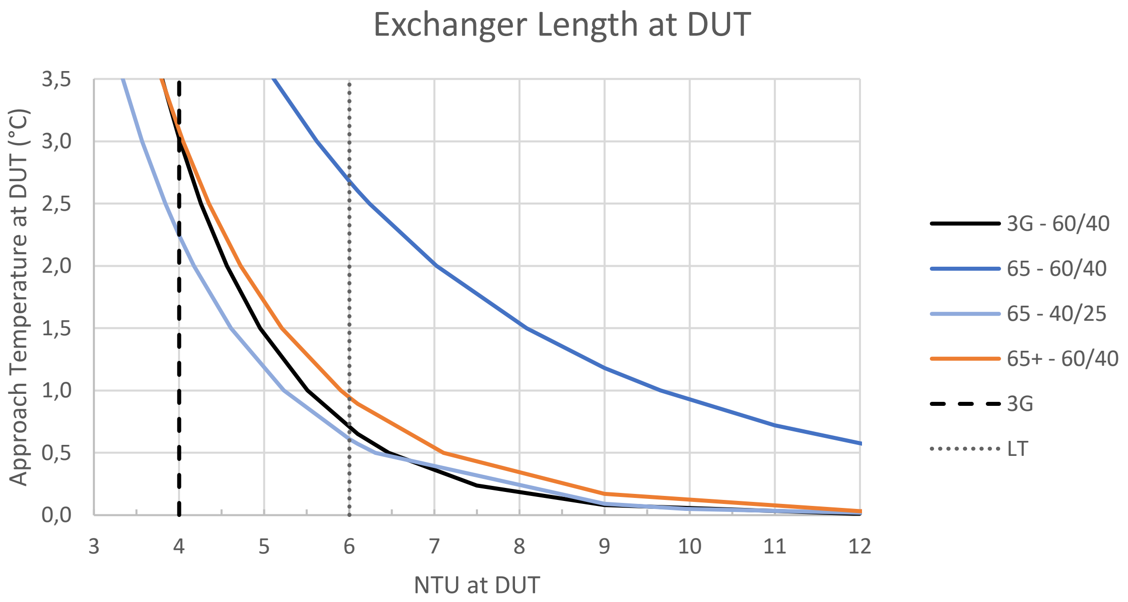


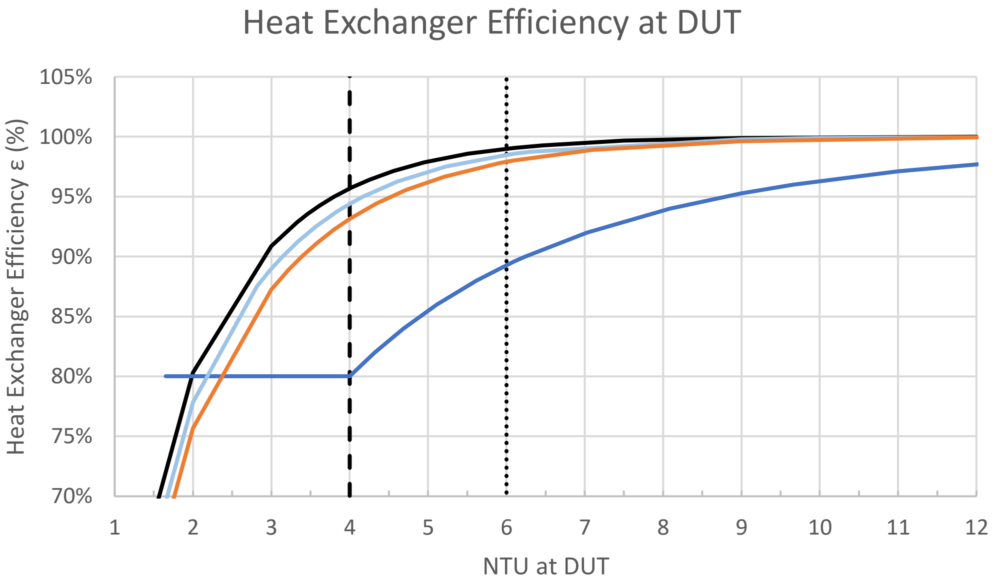
Return Temperatures in LTDs



Substations in LTDs

- 1ry/2ry program impact temperature efficiency in the substation – an important area of opportunity
- Increasing delta between 1ry supply and 2ry return can bring performance in line with conventional systems





*As T_{ute} rises, both the effective NTU and efficiency increase to ~12 NTU and ~100% at 17°C

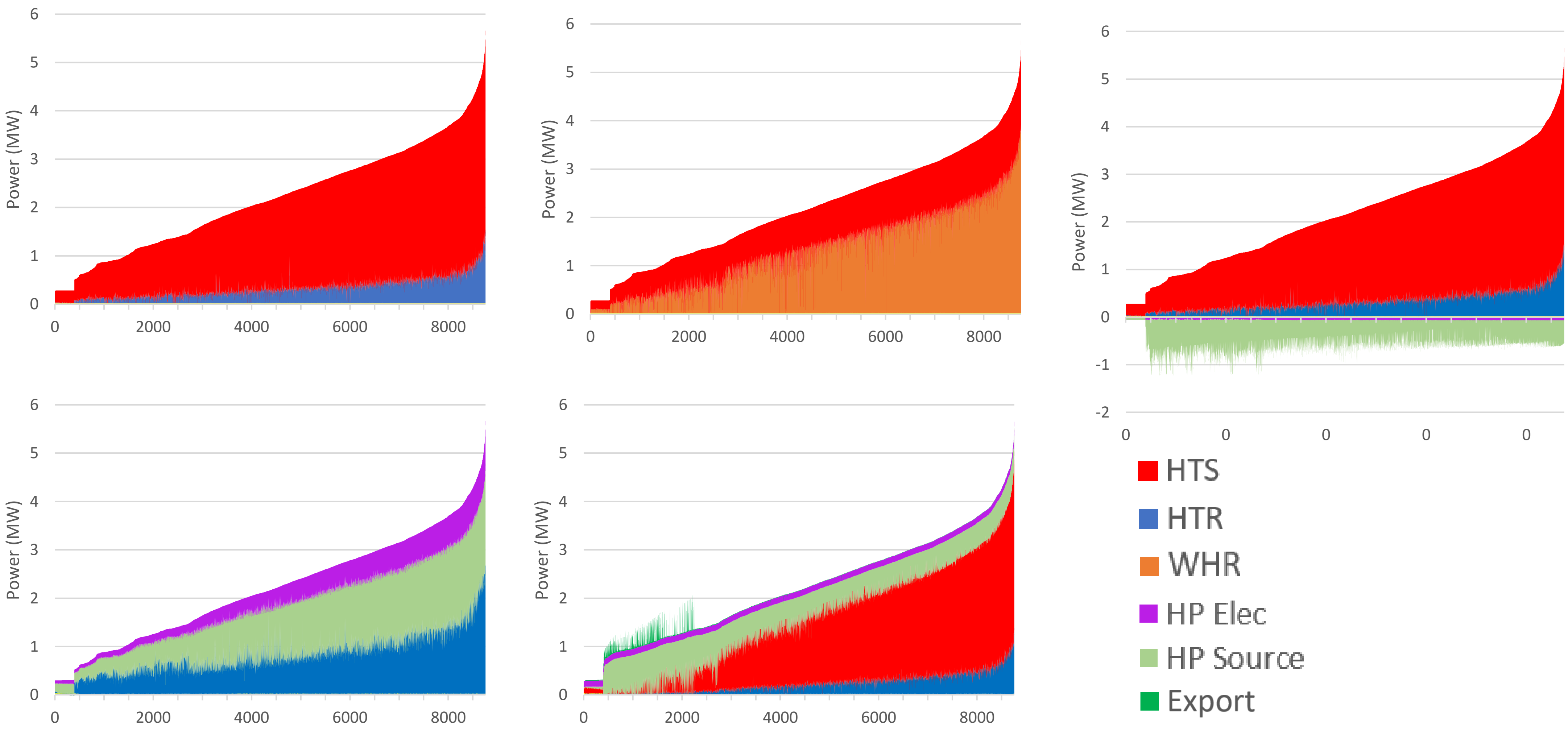
Conclusions

- In significantly decarbonised DHN, electrification can increase emissions
- Existing DHN deliver more heat per connected electrical capacity
- LTDs enable a significant amount of additional heat recovery in existing DHN, even with conventional HT supply
- Possibilities exist on both network and customer side to improve performance of LT substations

[4]

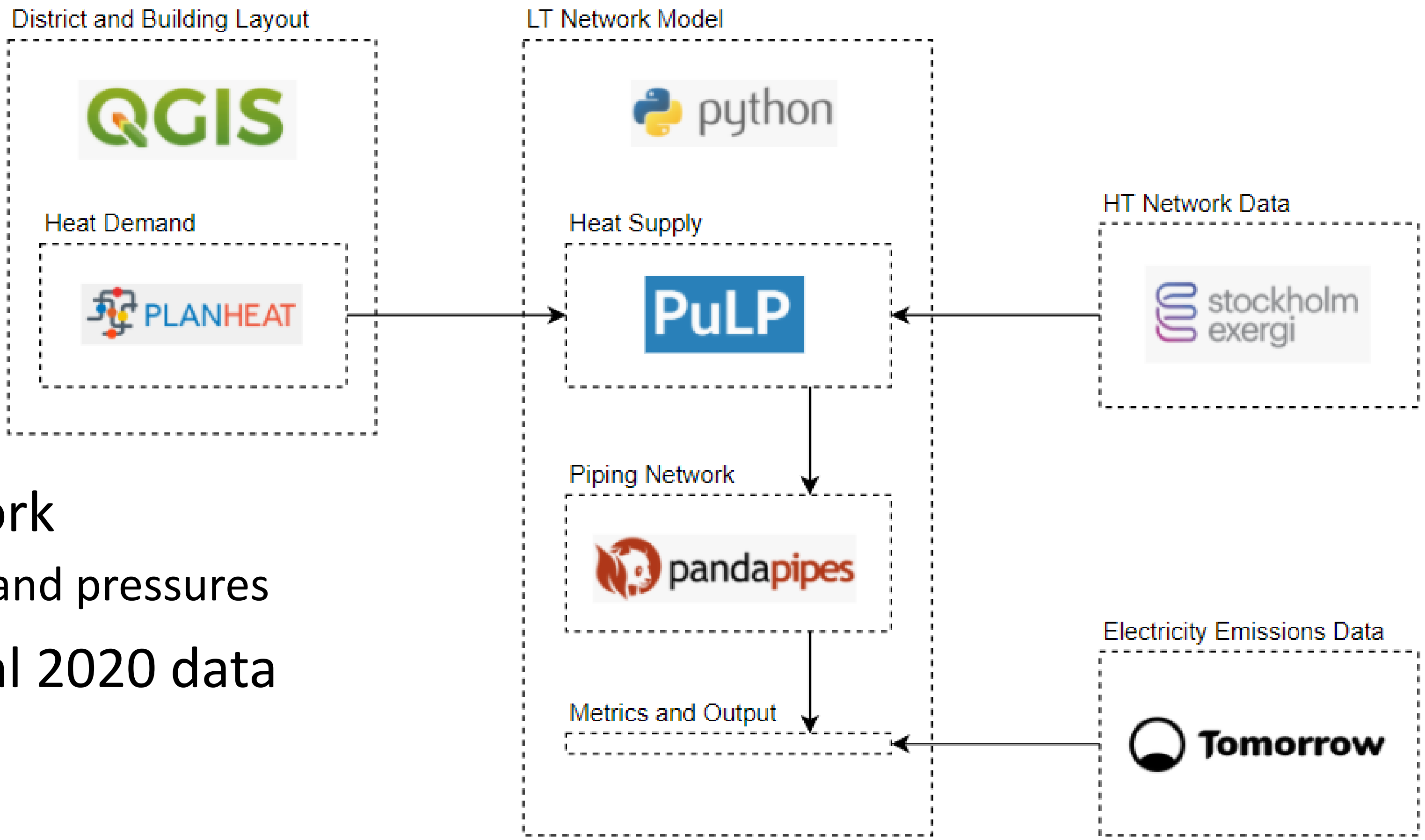
Thank You!

Scenario Heat Production



Modeling Approach

- Open Source Software
- District demands developed in PlanHeat
- Bottom-up quantitative approach



- Heat flow model of network
  - Mass flow, temperatures, and pressures
- Hourly resolution with real 2020 data

Sources

[1] Stockholms Stad, ‘Bostäder, förskolor och handel i Kolkajen’, *Stockholm växer*, May 2021. https://vaxer.stockholm/projekt/kolkajen/ (accessed Jun. 08, 2021).

[2] J. Börje, ‘Swedish TSO Svenska kraftnät deploys heat recovery at new power substation’, *Stockholm Data Parks*, Apr. 23, 2021. https://stockholmdataparks.com/2021/04/23/swedish-tso-svenska-kraftnat-deploys-heat-recovery-at-new-power-substation/ (accessed Jun. 11, 2021).

[3] Tomorrow, ‘Live CO_2 emissions of electricity consumption’, *Electricity Map*. http://electricitymap.tmrow.co (accessed Mar. 09, 2021).

[4] K. Gustafsson, ‘Negative emissions and policy requirements in the Stockholm multi-energy system’. Stcokholm Exergi & KTH, Jul. 2019. Accessed: Jun. 11, 2021. [Online]. Available: https://ercst.org/wp-content/uploads/2019/07/Gustafsson-Presentation-ERCST-Brussels.pdf