Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Materials Science & Technology

A study on the thermal performance of low temperature district heating networks with decentralized renewable energy feed-in

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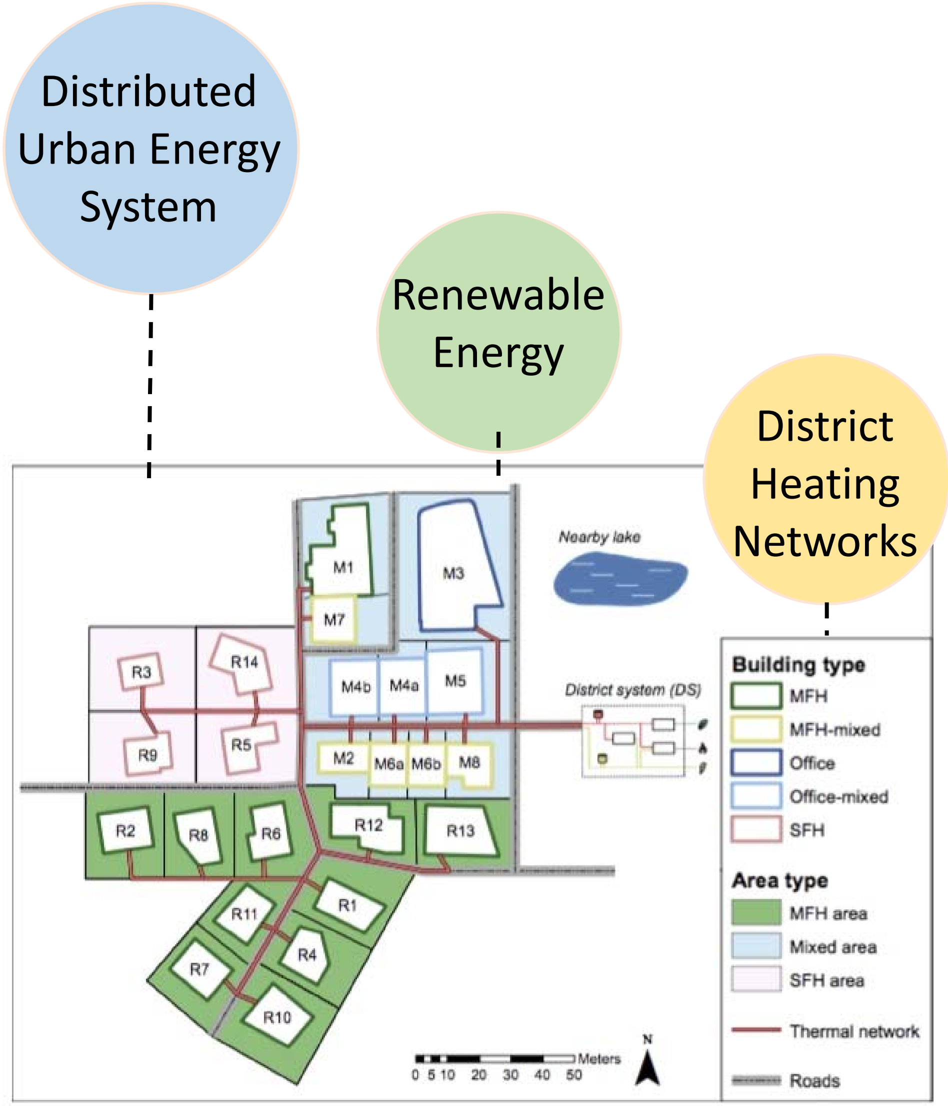
Introduction



Map of the urban district with mixed building types and ages [1]

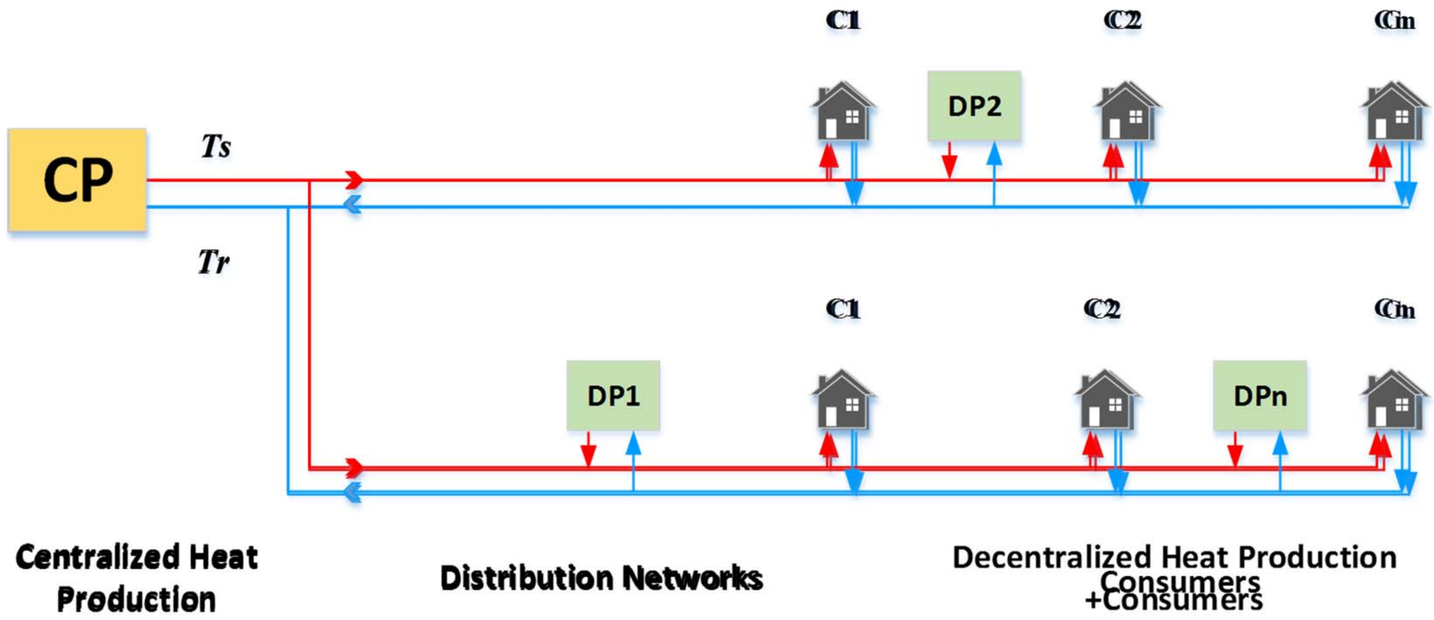
- Investigate on the potential of renewable integration into district heating networks
- Develop a proper approach for network representation, able to evaluate network performances for difference configurations and find the optimal system design

[1] G. Mavromatidis, Model-based Design Of Distributed Urban Energy Systems Under Uncertainty, PhD thesis, ETH Zurich,2017

District Heating System : Components

- Centralized Heat Production
- Distribution Networks
- Consumers **+ Decentralized Renewable Source**

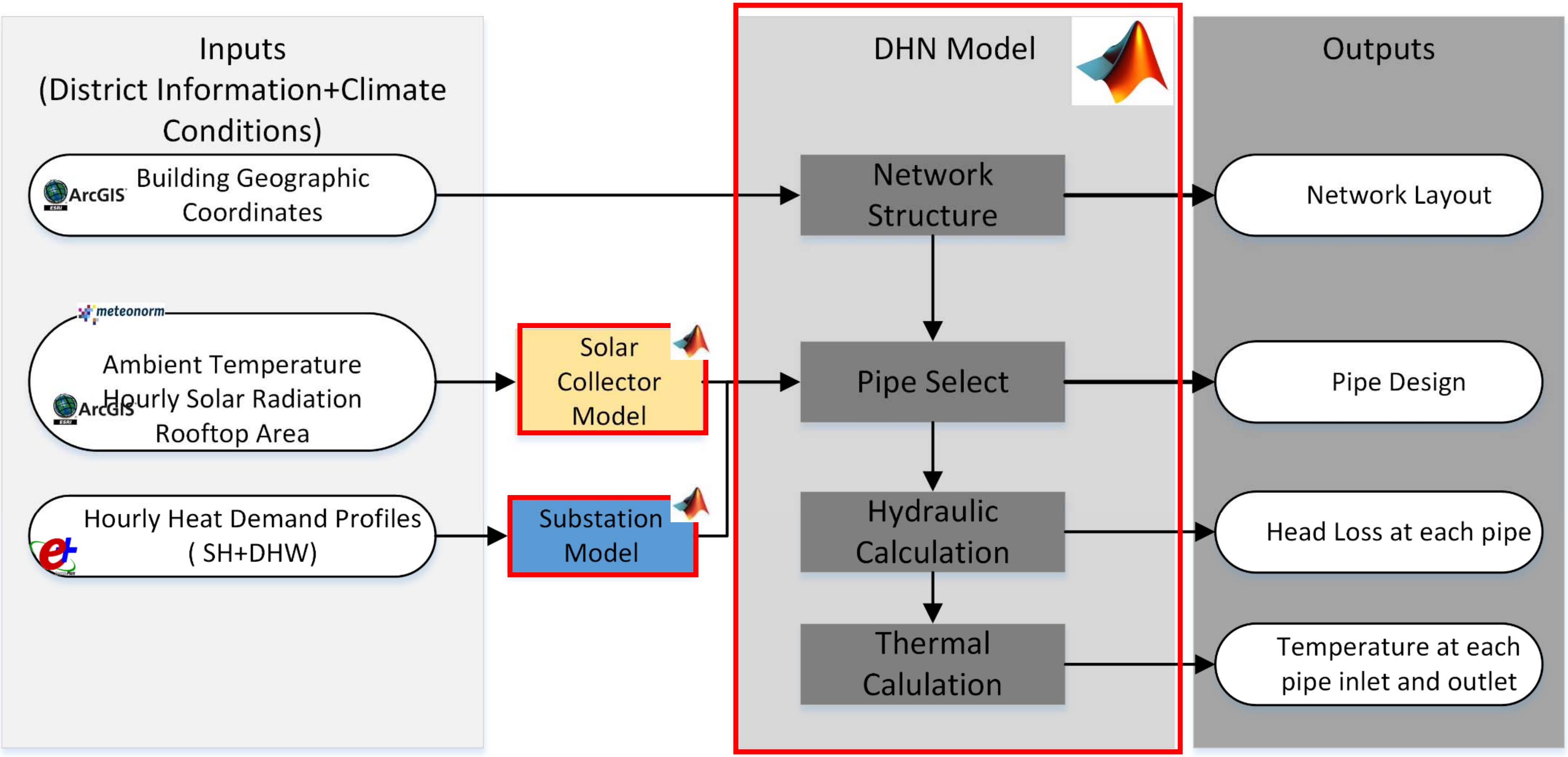
Ts Supply Temperature
Tr Return Temperature
C Consumer
CP Centralized Production
DP Dentralized Production



Modelling Framework

Modelling Framework

- A simulation model combined with network design



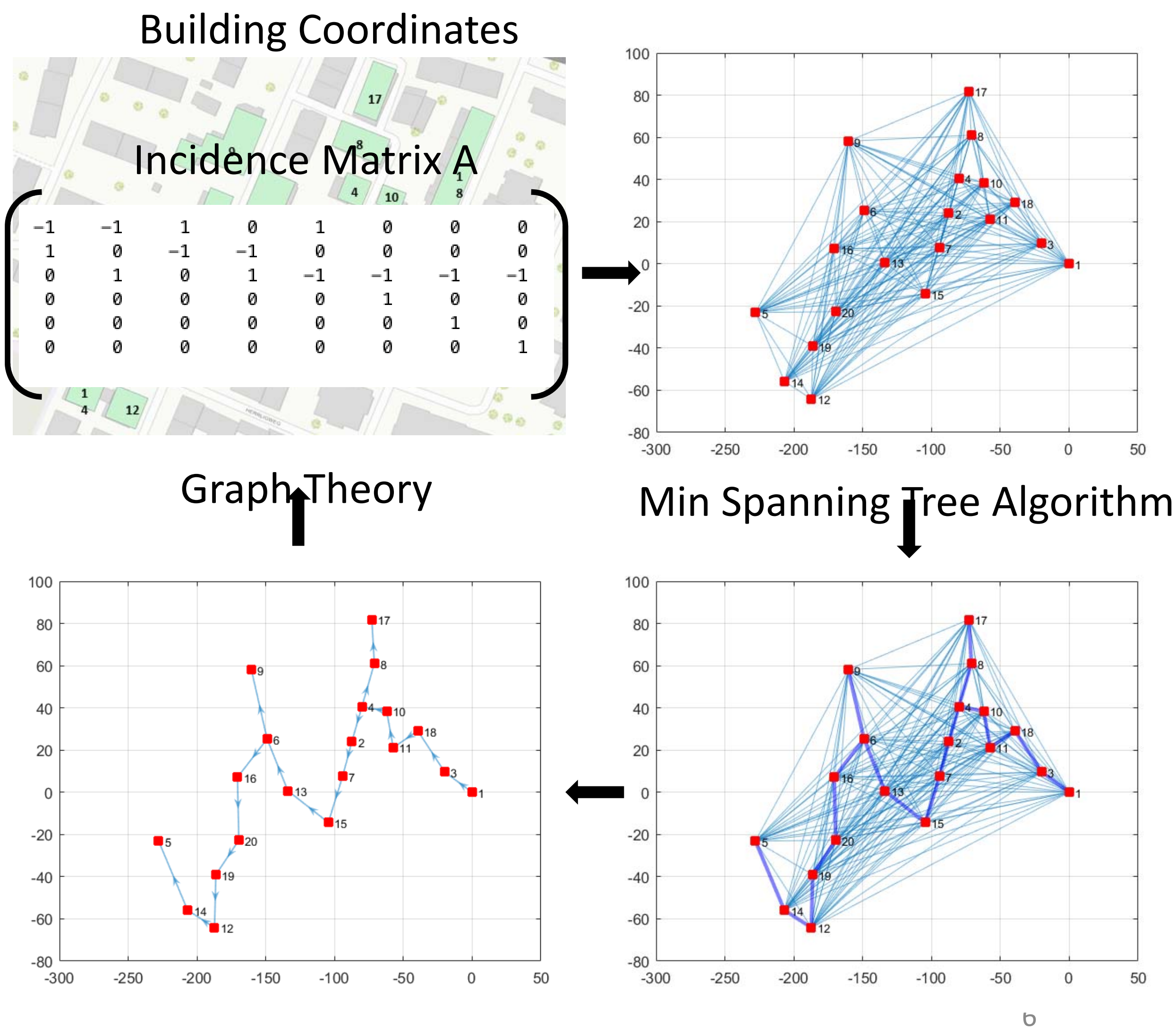
Network Model

- Multi-time step steady-state thermal hydraulic model

Network Structure

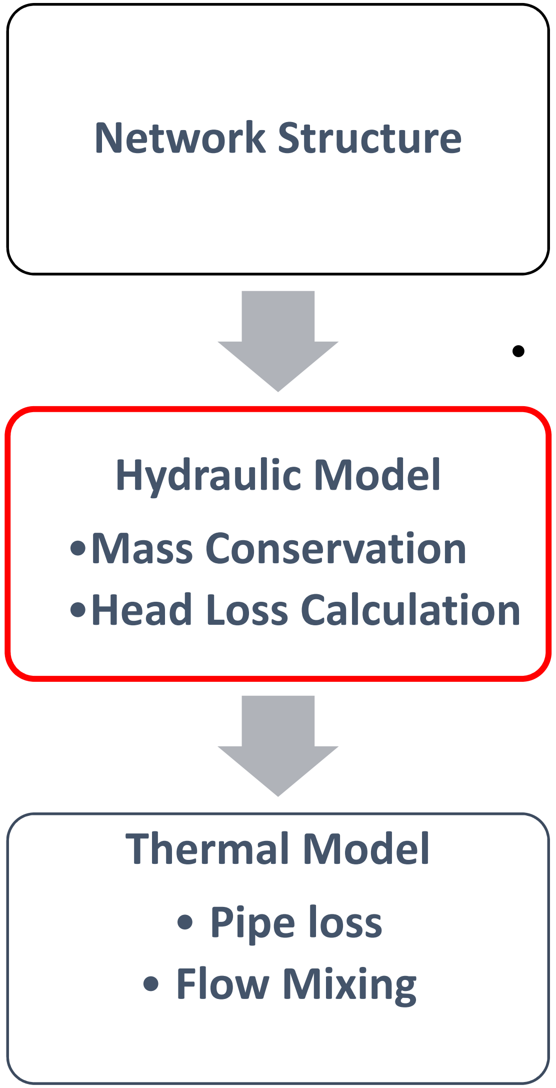
Hydraulic Model
- **Mass Conservation**
- **Head Loss Calculation**

Thermal Model
- **Pipe loss**
- **Flow Mixing**



Network Model

- Multi-time step steady-state thermal hydraulic model



- Mass Conservation incorporated with incidence Matrix:

$$\boldsymbol{A} \times \dot{\boldsymbol{m}} = \dot{\boldsymbol{m}}\boldsymbol{s}$$

- Darcy-Weisbach Equation (pressure drop) and friction factor f_D :

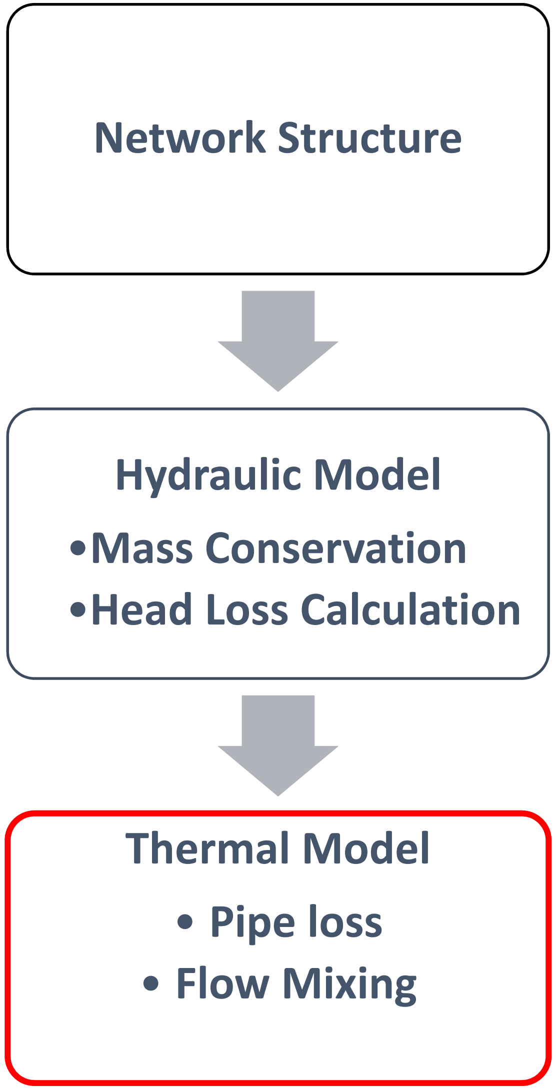
$$\Delta P_{ij} = f_D \cdot \frac{8L_{ij}}{\rho \cdot \pi^2 \cdot {d_{ij}}^5} \cdot {\dot{m}_{ij}}^2$$

$$f_D = \frac{64}{R_e}$$

$$\frac{1}{f_D} = -2log\left(\frac{\varepsilon/d_{ij}}{3.7} + \frac{5.74}{{R_e}^{0.9}}\right)$$

Network Model

- Multi-time step steady-state thermal hydraulic model



- Thermal loss along pipe:

$$T_{out} = T_g + \left(T_{in} - T_g\right) \cdot e^{-\frac{k_{ij} \cdot L_{ij}}{\dot{m}_{ij} \cdot cp}}$$

- Mixing of Flow:

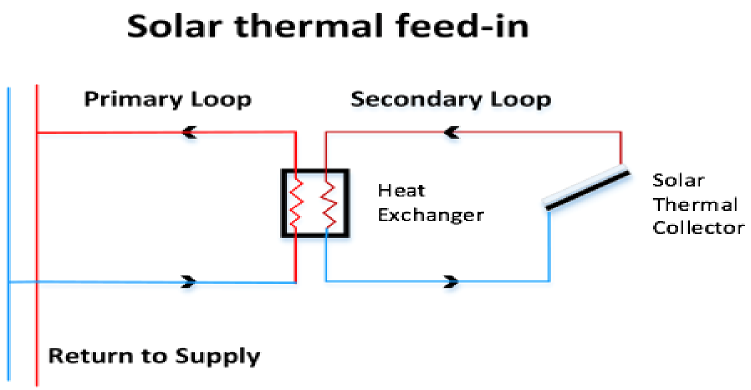
$$\dot{m}_{mix} T_{mix} = \sum_{i}^{n} \dot{m}_i T_i$$

T_{out} outlet temperature
T_{in} inlet temperature
T_g ground temperature T_g
k_{ij} pipe thermal transfer coefficient
$\dot{m}_{ij}$ pipe mass flowrate

Source and Sink Model

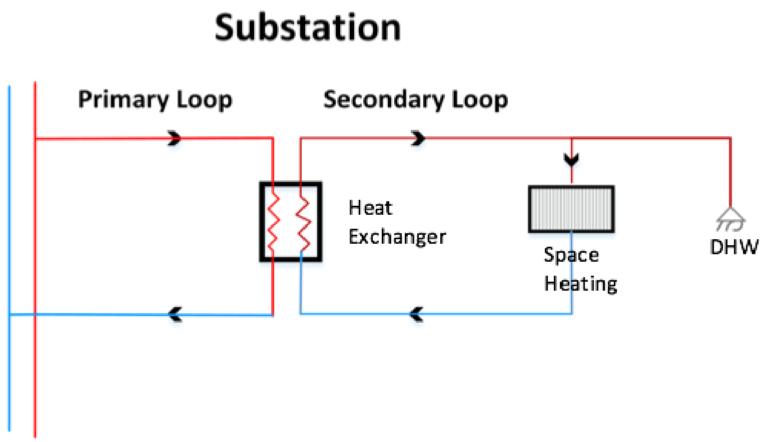
- **Source**

Solar Collector Model



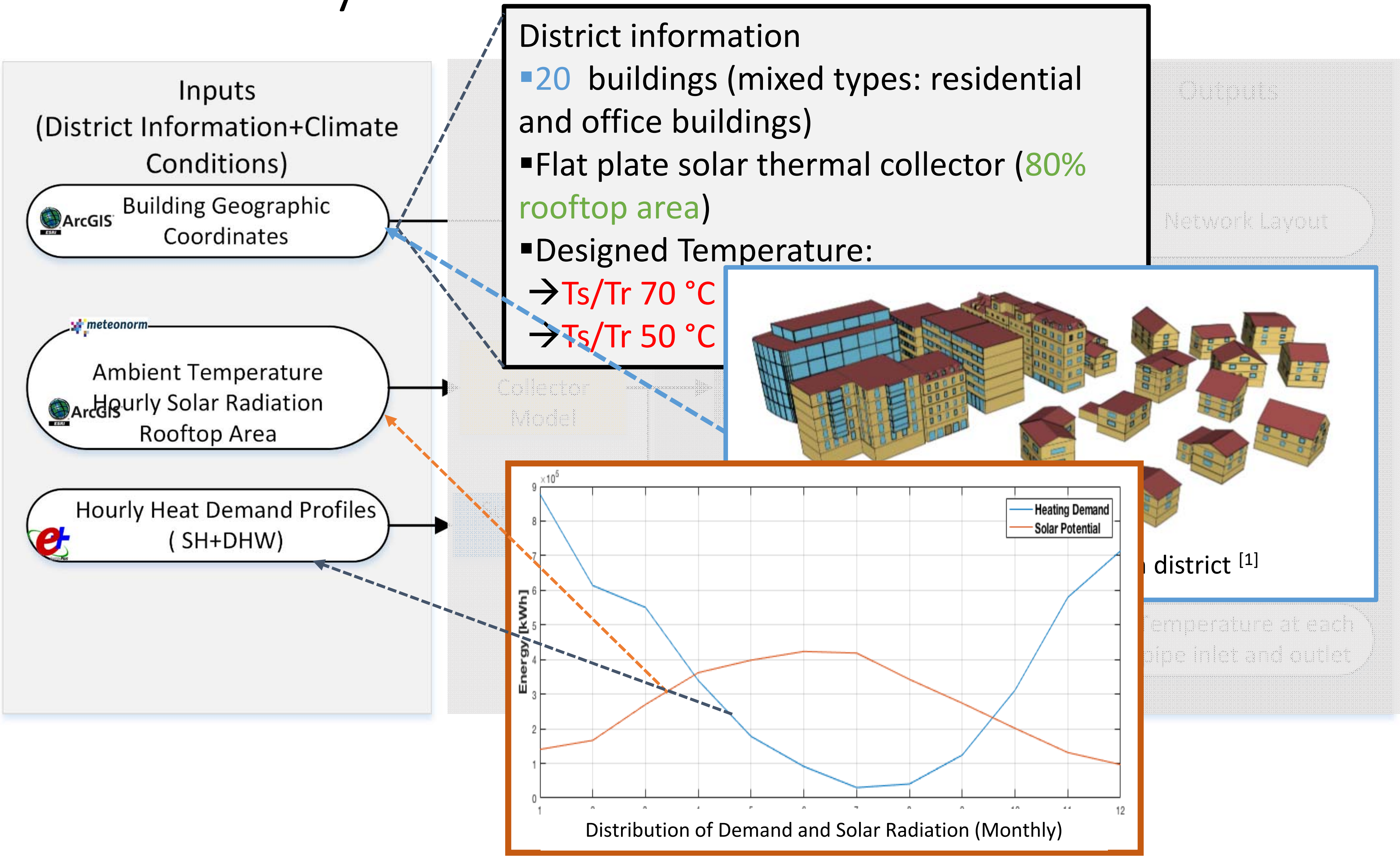
- **Consumer**

Substation Model



Case Study

Case study: artificial district



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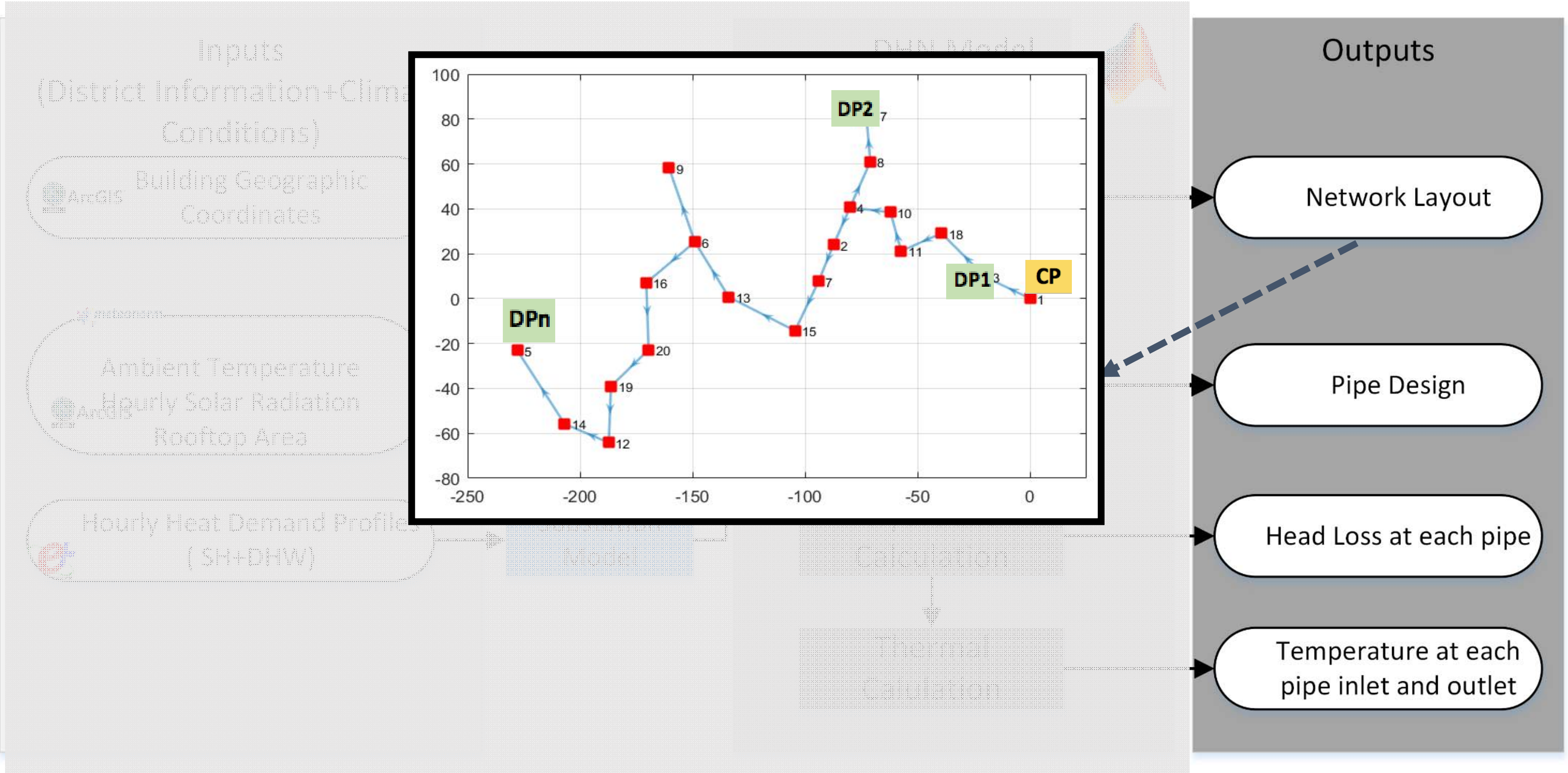
Case study: artificial district



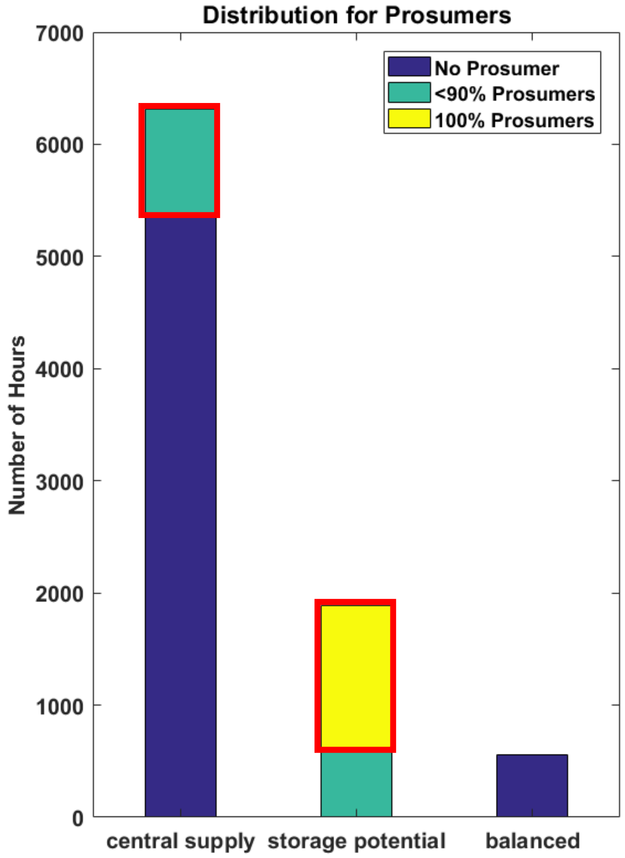
Case study: artificial district

District information

- 20 buildings (mixed types: residential and office buildings)
- Flat plate solar thermal collector (80% rooftop area)
- Designed Temperature:

→Ts/Tr 70 °C – 30 °C

→Ts/Tr 50 °C – 25 °C

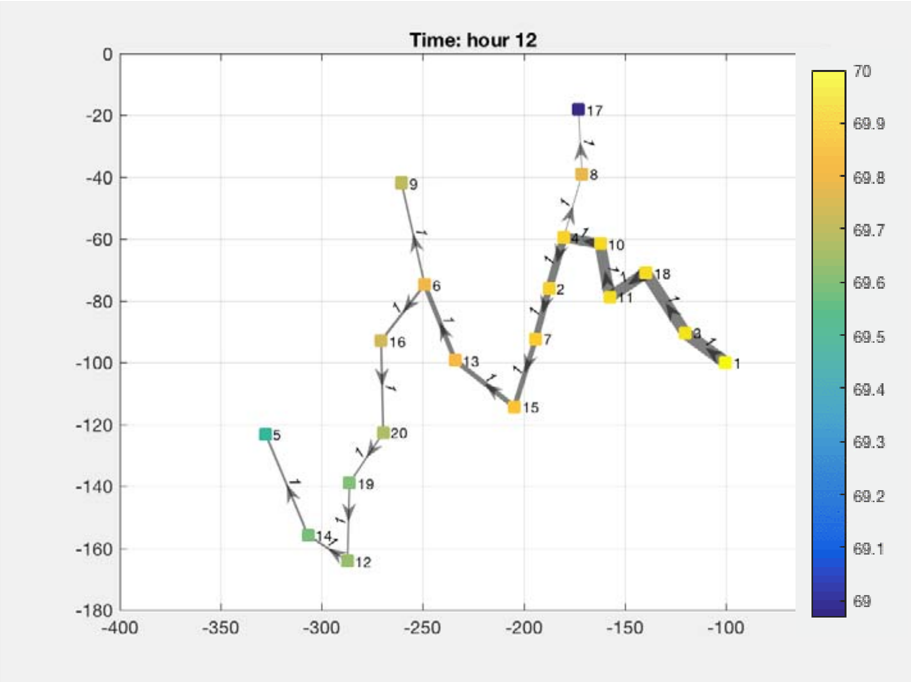


Some simulation results

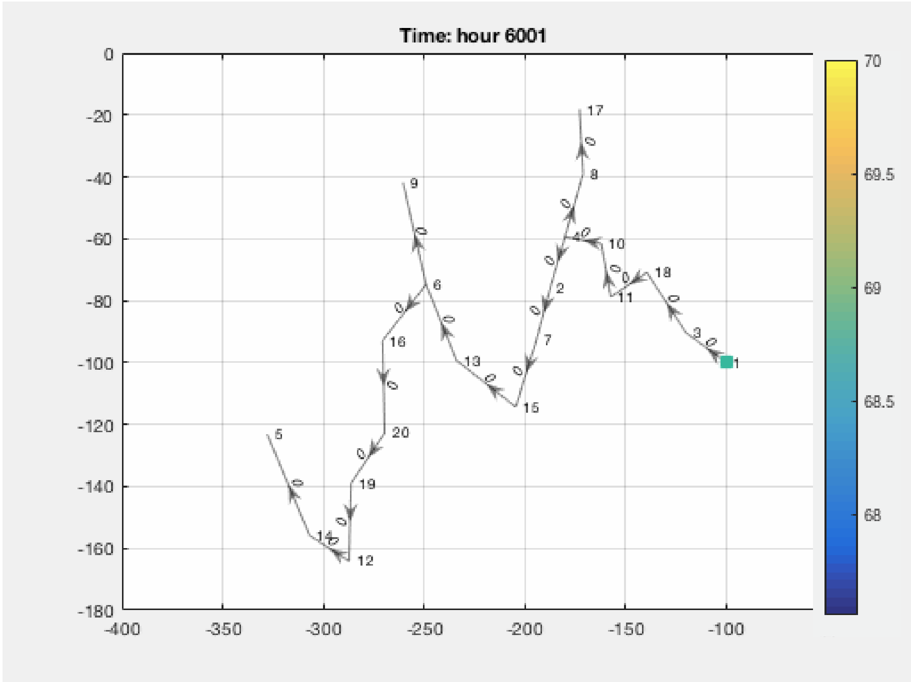
Case study: Results

- Hourly Temperature and Mass flow Rate Distribution

Winter Day



Summary Day

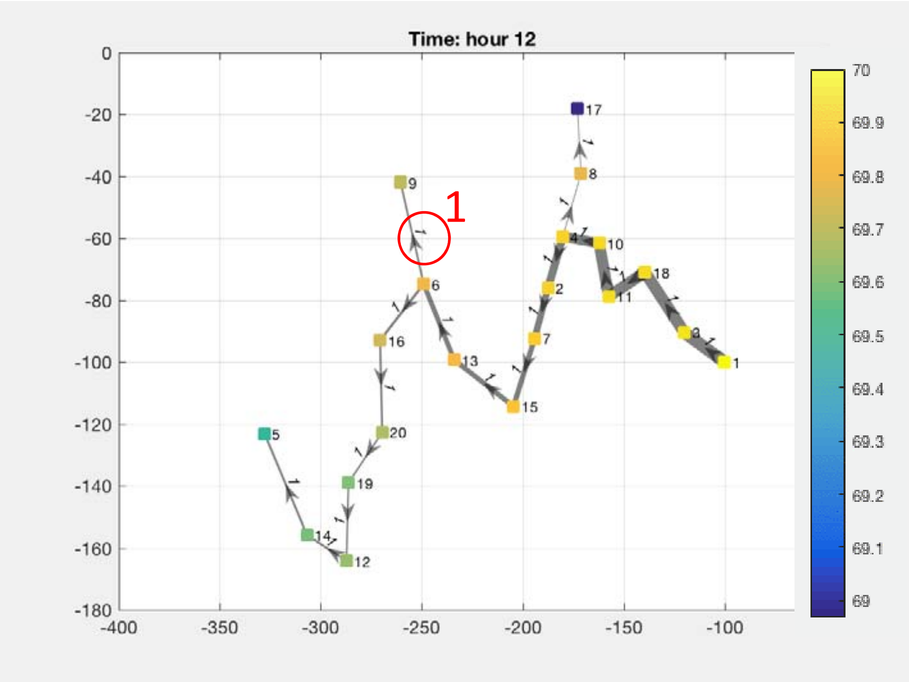


Remark :
+1: flow direction aligned with arrow direction
- 1: flow direction opposite with arrow direction
0: no mass flow rate

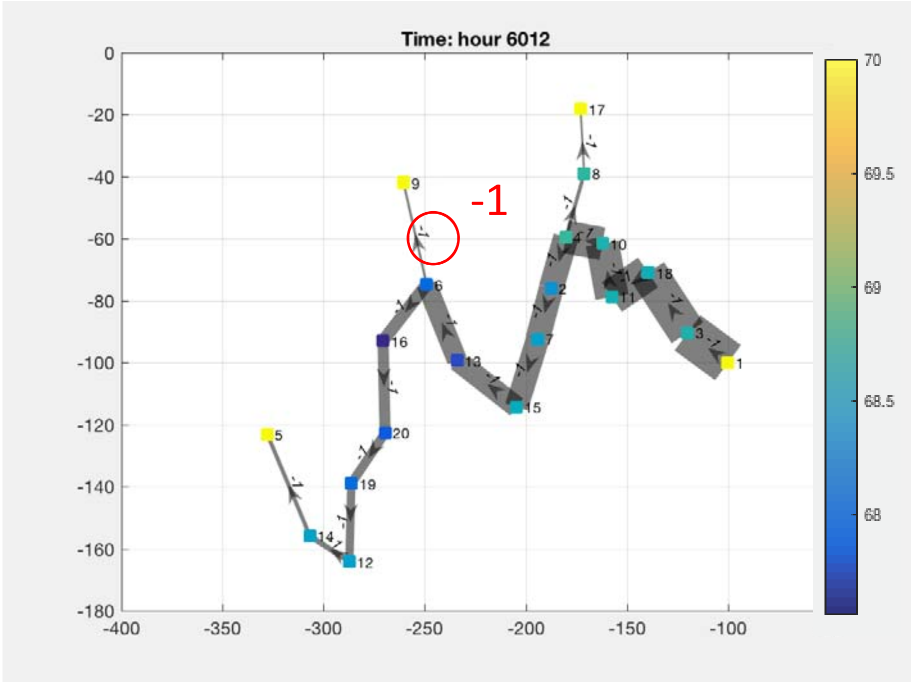
Case study: Results

- Hourly Temperature and Mass flow Rate Distribution

Winter Day



Summary Day



Remark :
+1: flow direction aligned with arrow direction
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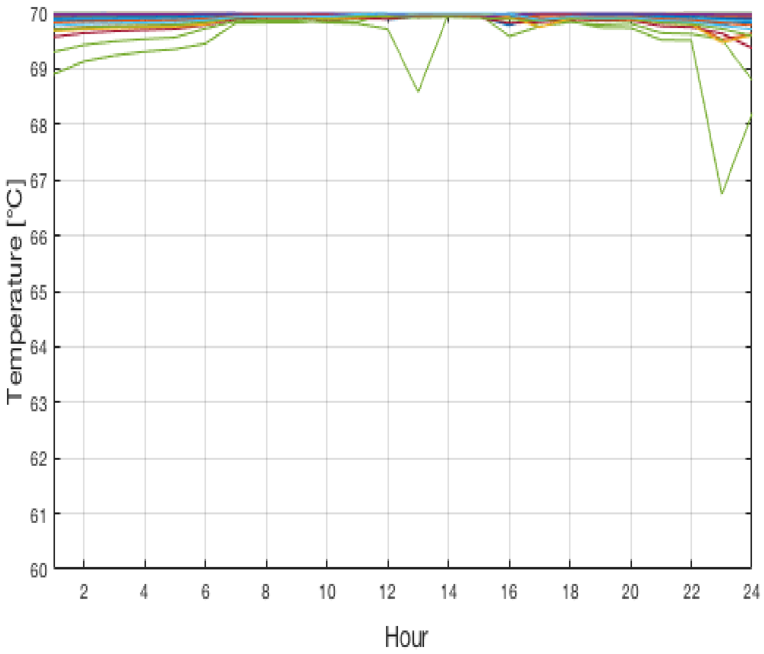
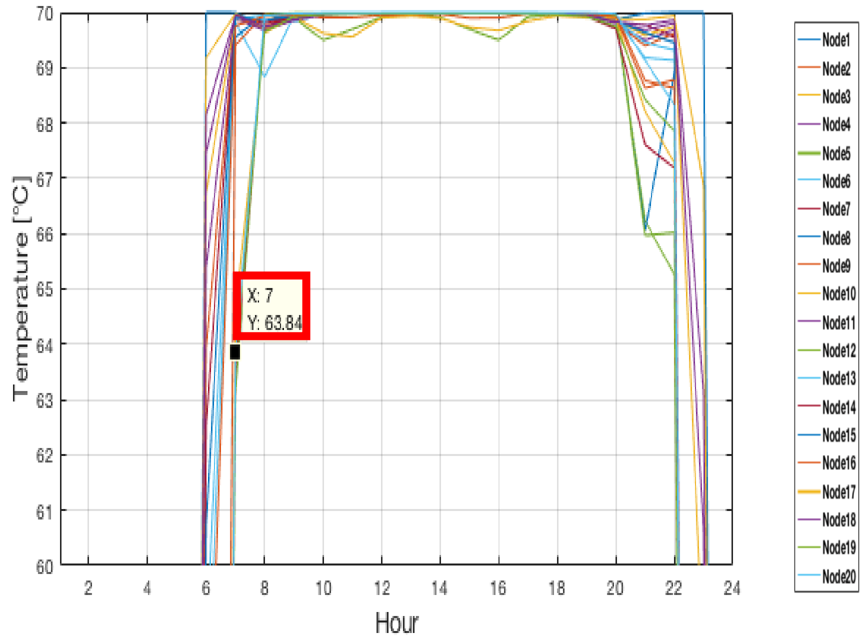
Case study: Results

- Temperature delivered at each consumer on a typical winter and a summer day

Winter Day



Summer Day



- ➢ Temperature variation is rather small in winter with the current operation strategies
- ➢ In summer, temperature drop is rather significant. Sometimes not hot enough for domestic hot water supply

Parametric Study

Parametric Study

Linear heating density (LHD)

$$LHD = \frac{Q_{total}}{L}$$

L | Q_{total}

L_base **x 2 x 3 x 4 … x 10**

- [3.44 1.7 1.15 0.86 0.69 0.57 0.49 0.43 0.38 0.34] *MWh/m* yearly

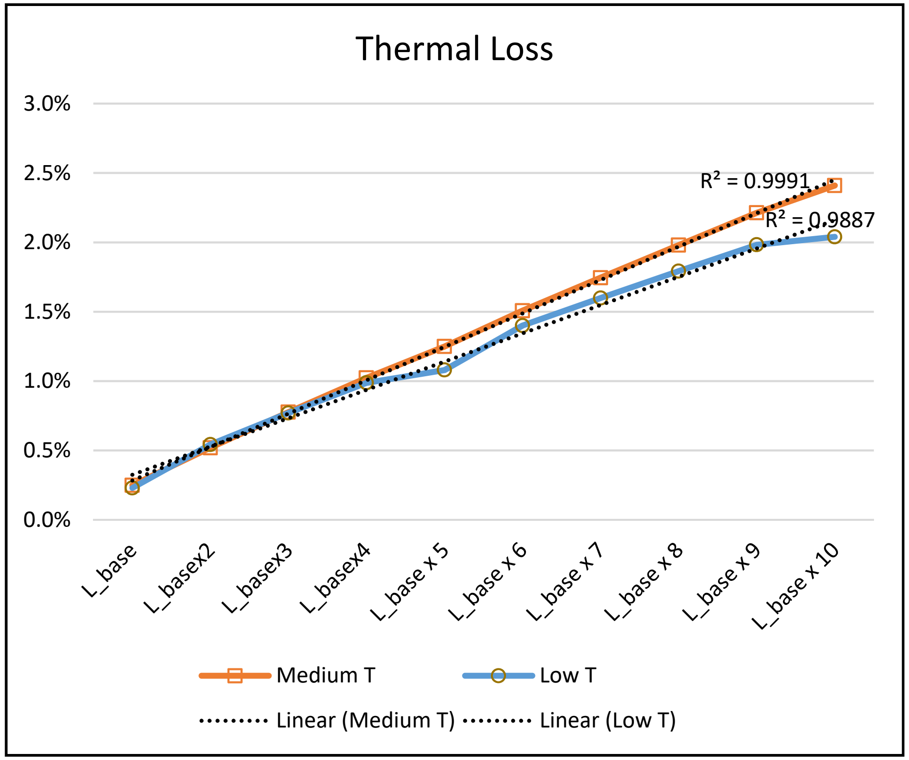
Q_base **x 1/2 x2 x 3**

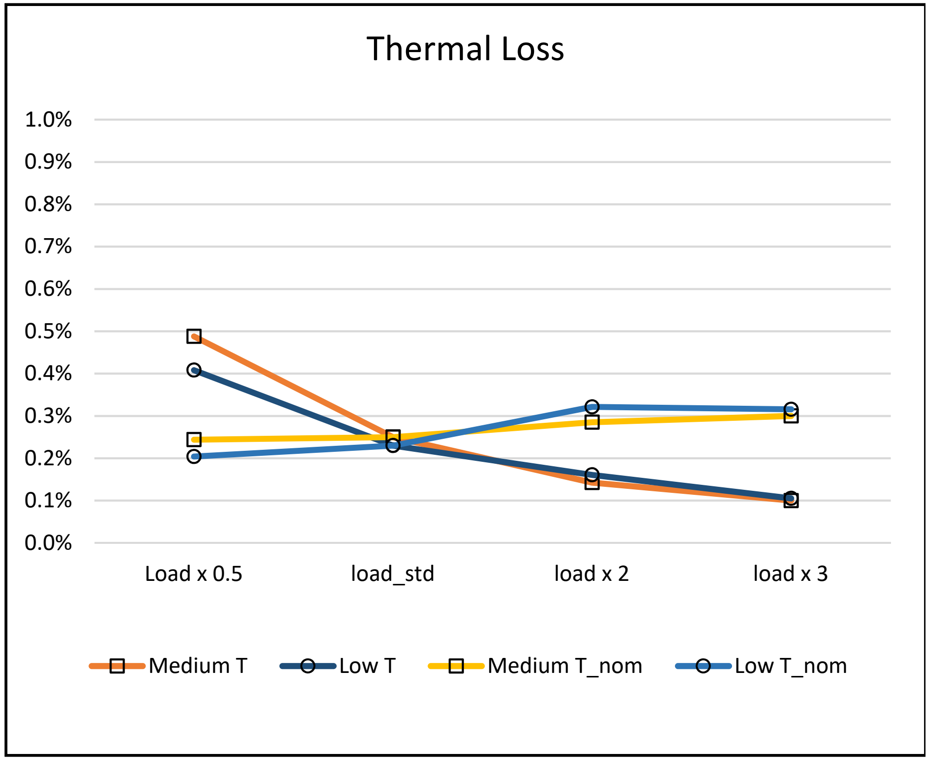
- [1.72 3.44 6.89 10.33] *MWh/m* yearly

Parametric Study

$$LHD = \frac{Q_{total}}{L}$$

L $\qquad$ Q_{total}





Conclusion:

- Focus on the decentralized solar energy integration to networks and evaluate thermal performances
- High potential for seasonal storage in summer
- Demonstrates some operational problem in summer with only DHW demand
- Thermal loss is almost linear correlated with distribution pipe lengths, while rather less sensitive to the total load
- Thermal performance with respect to different temperature schemes is less significant for shorter pipes.

Outlook:

- Perform exergy analysis
- Apply the methodology for different system configuration
- Incorporate cost data for economic analysis and cost effective design purpose
- Combine the network representation with optimization methods for system optimization
- Incorporate with short and long term storage technologies

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Thanks for your attention

sccer future energy efficient buildings & districts

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Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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Commission for Technology and Innovation CTI

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