Modelling of district heating networks at DLR-VE

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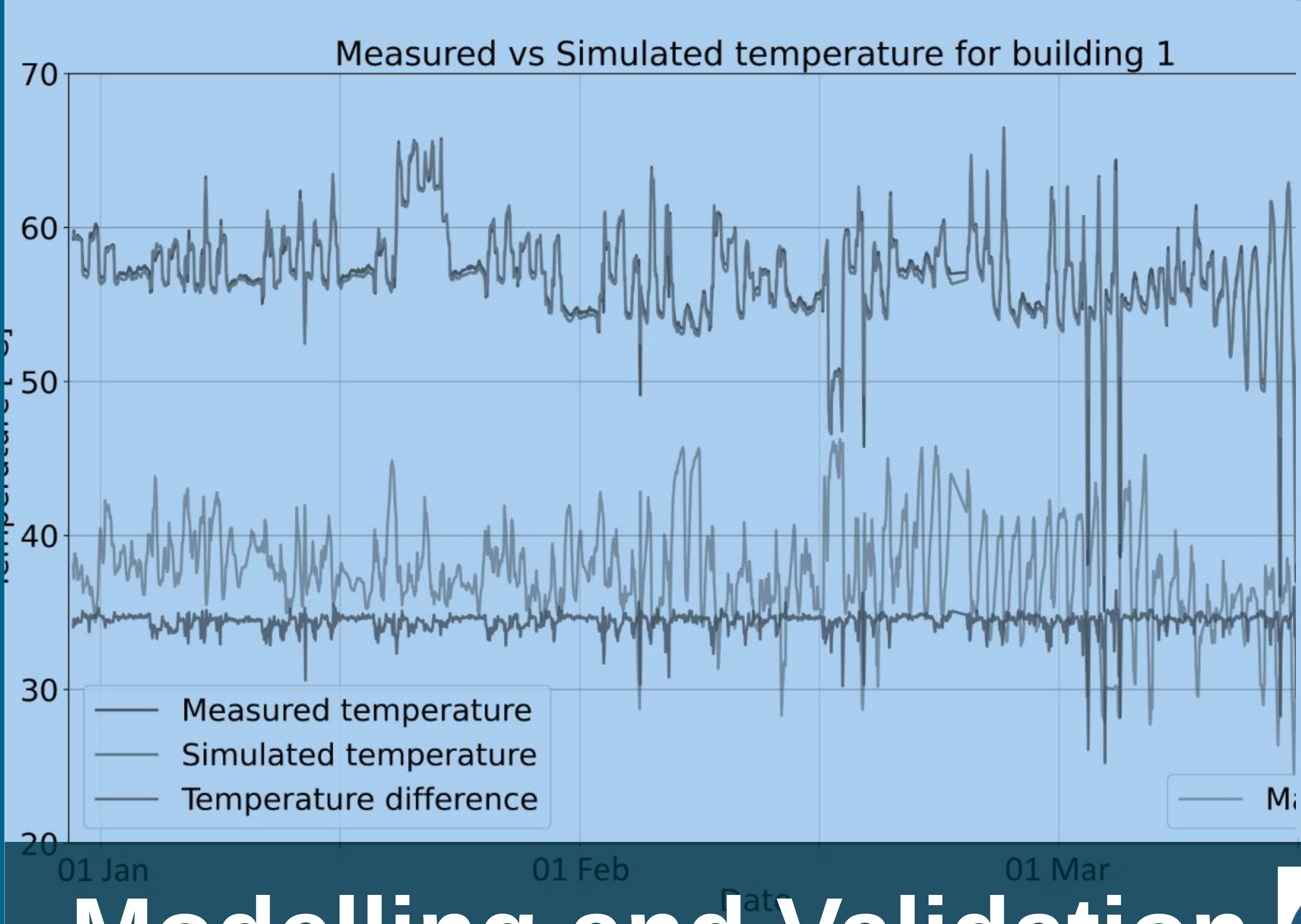
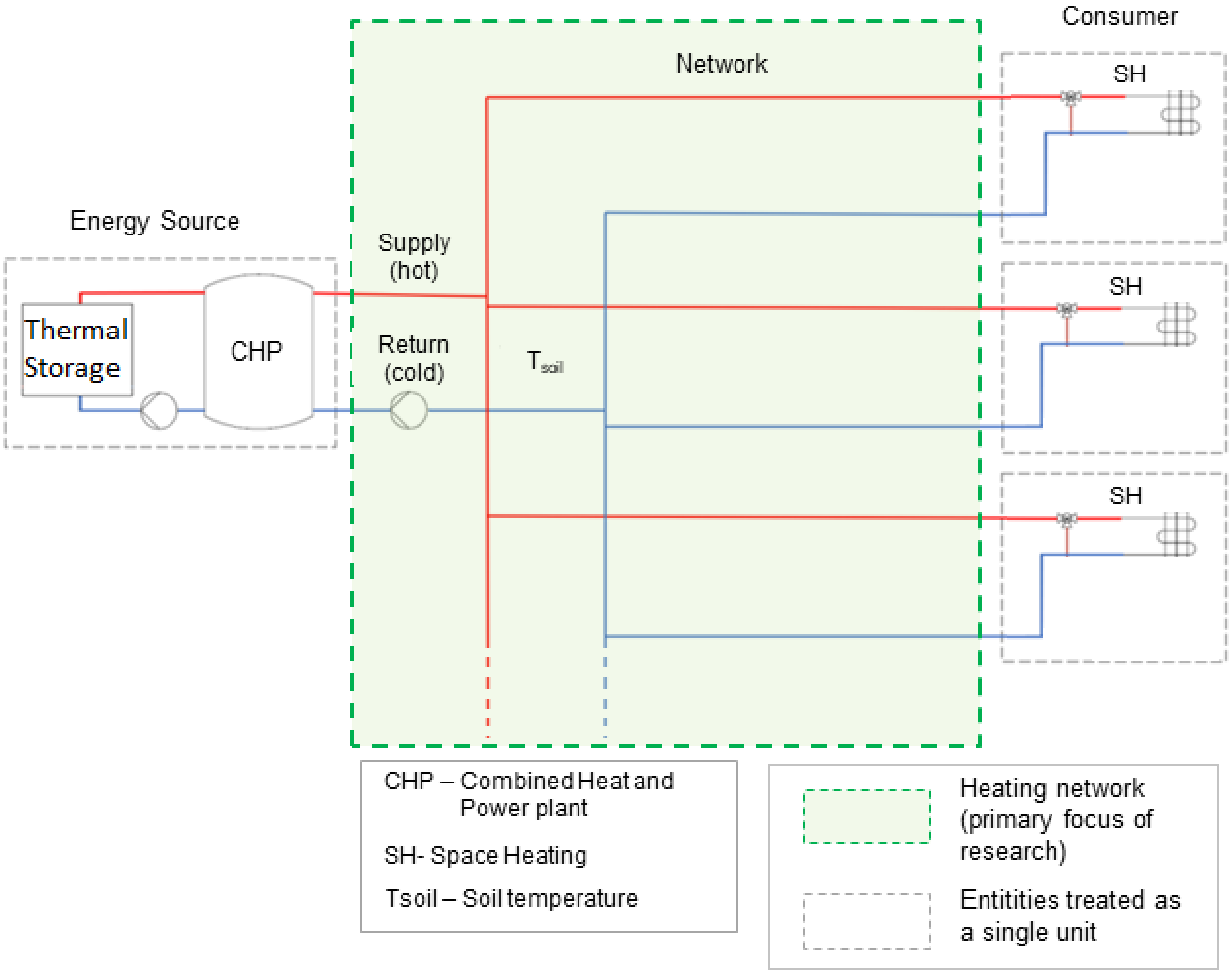


Modelling and Validation

tespy['tɛs.paɪ]
open energy modelling framework

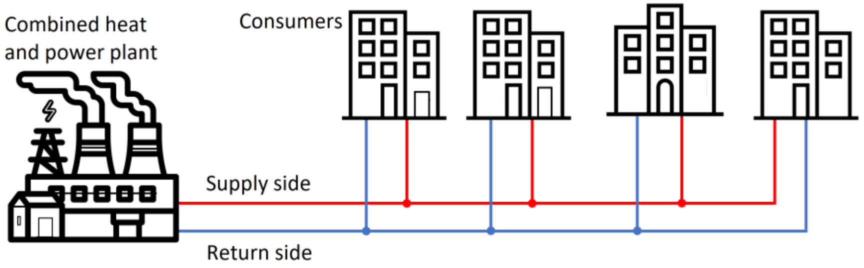
Focus and scope:



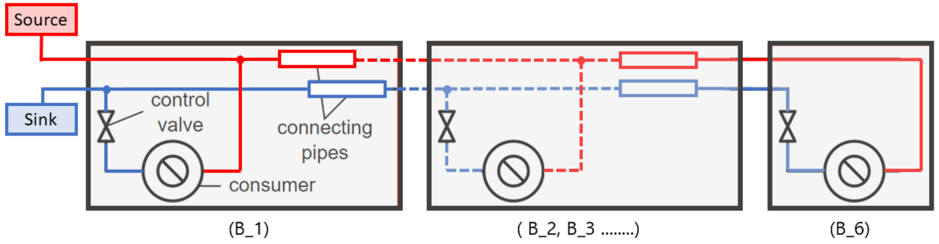
- **Main focus:**
  - Heating network
  - Thermal performance
- **Consumer:** Individual heat exchangers
- **Energy source:** Source + sink

Modelling of existing HTDN

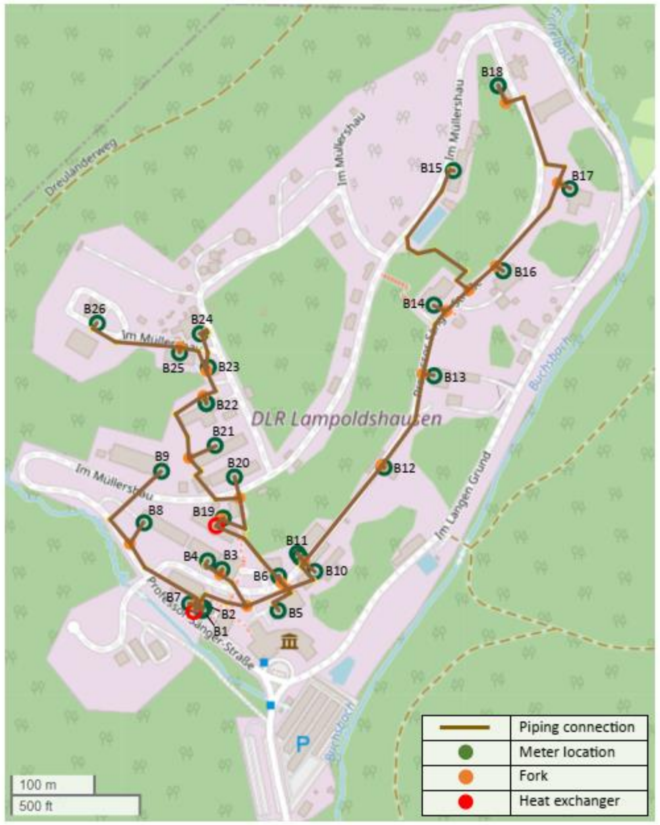
Typical DH network



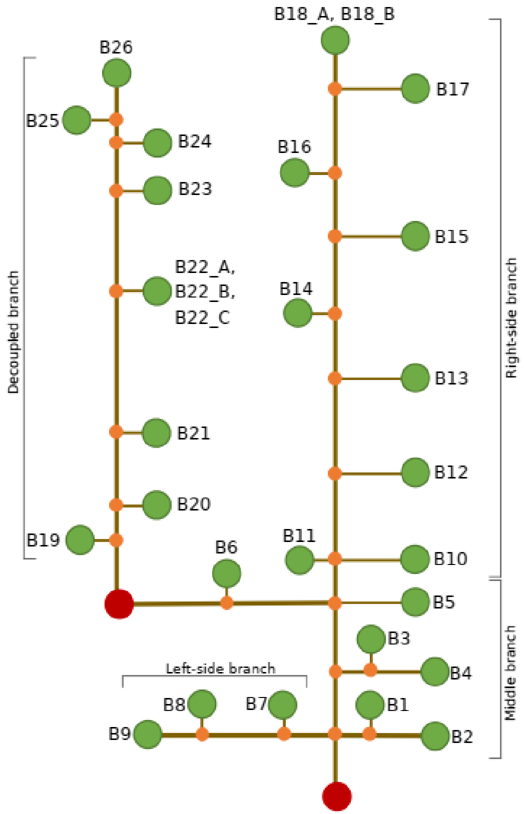
DHN modelled in TESPy



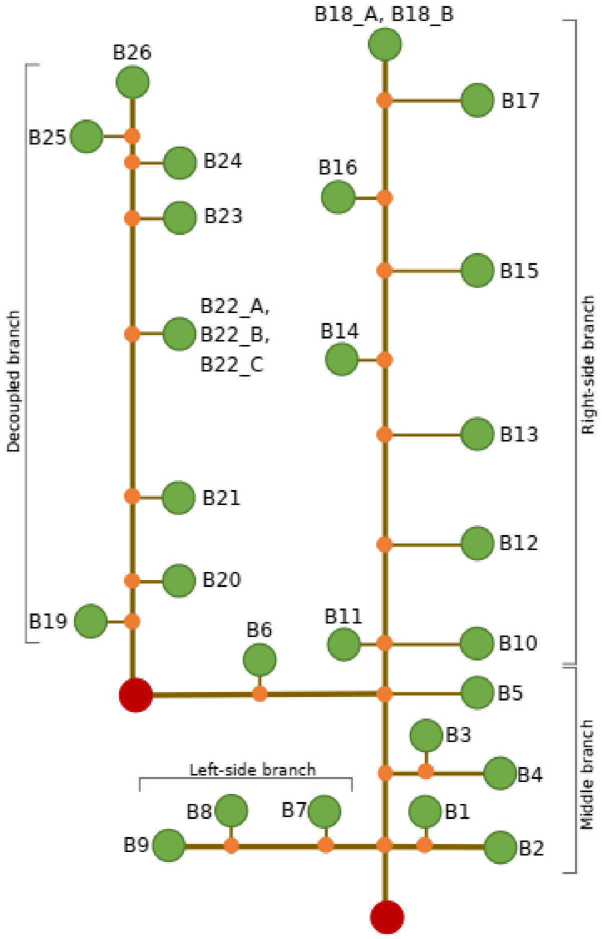
HTDN under study

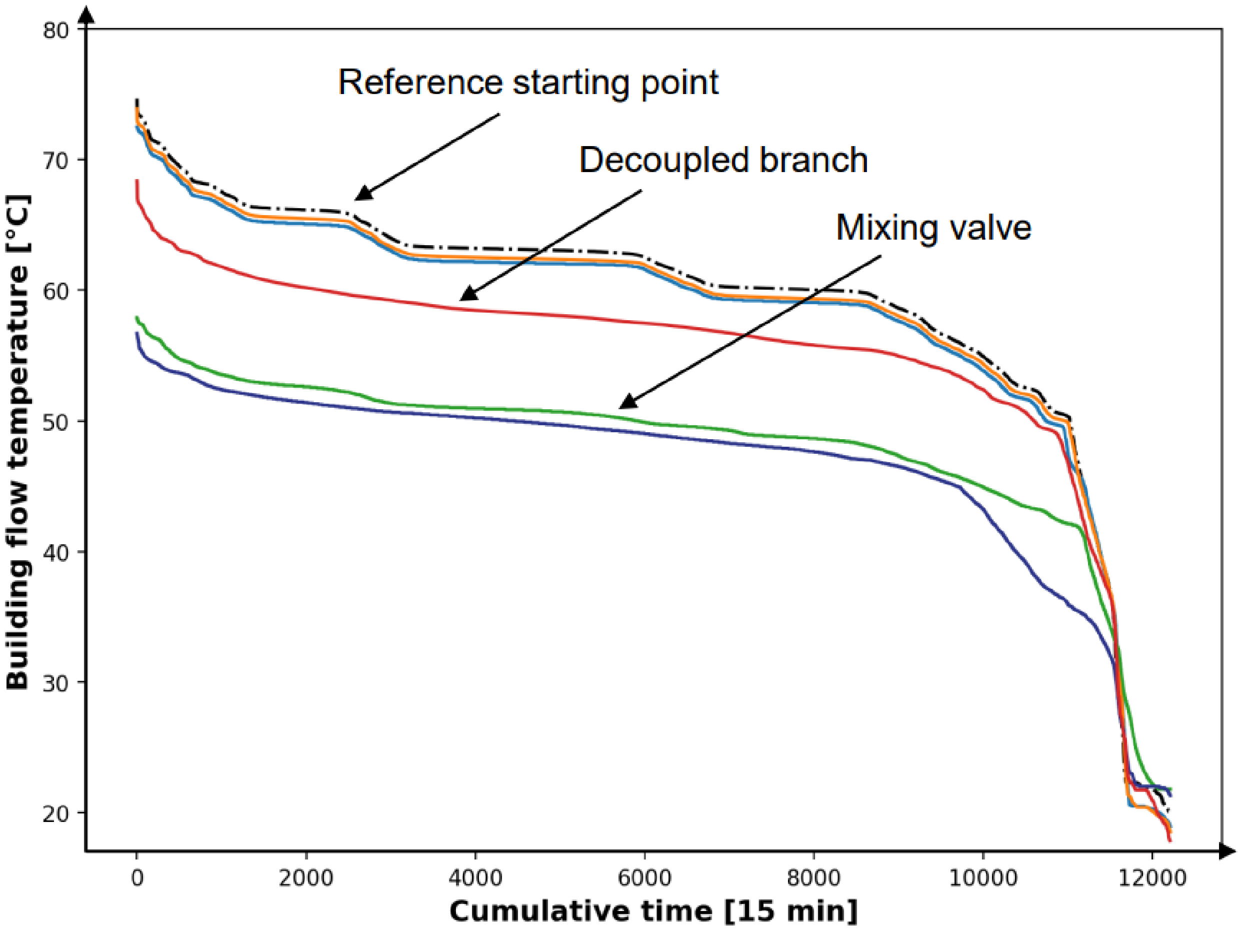


Network diagram



First glance at available data





Initial results

Input

- Pipe characteristics
- Mass flow
- Supply temperature
- Consumer demands
- Soil temperature

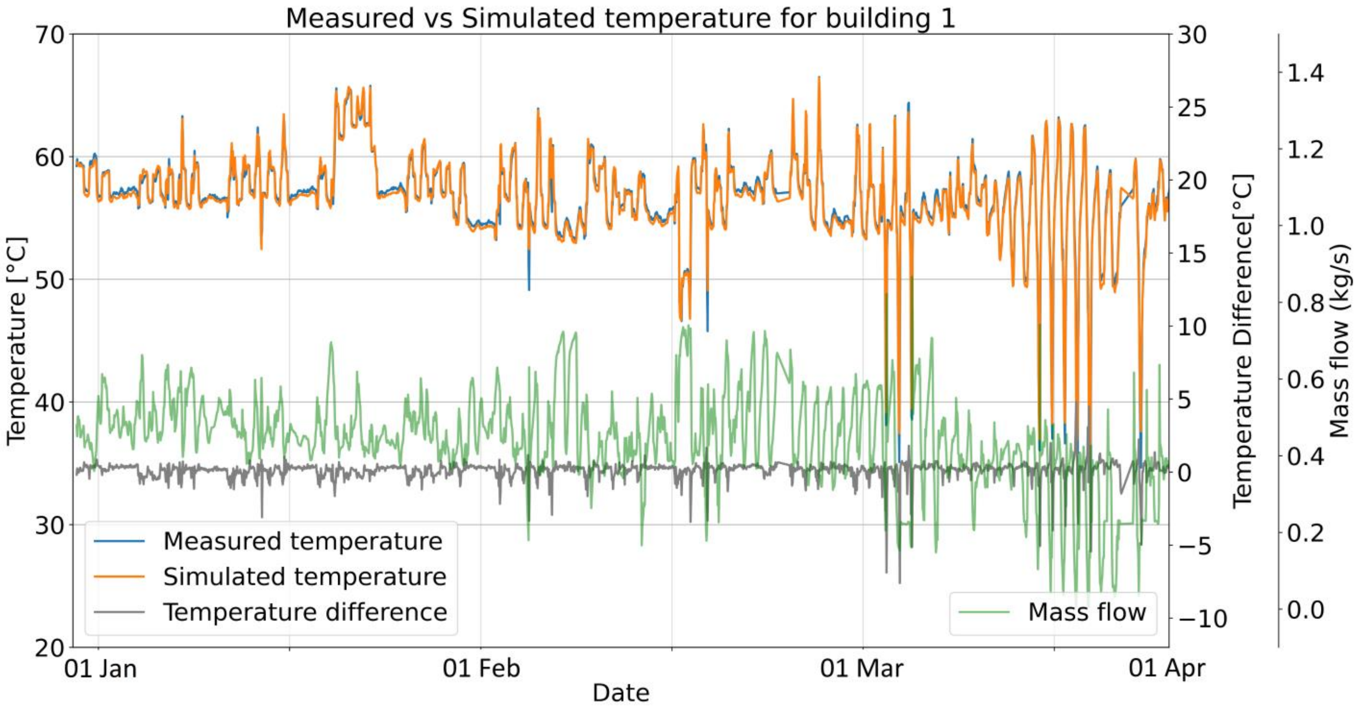
→

Tespy model

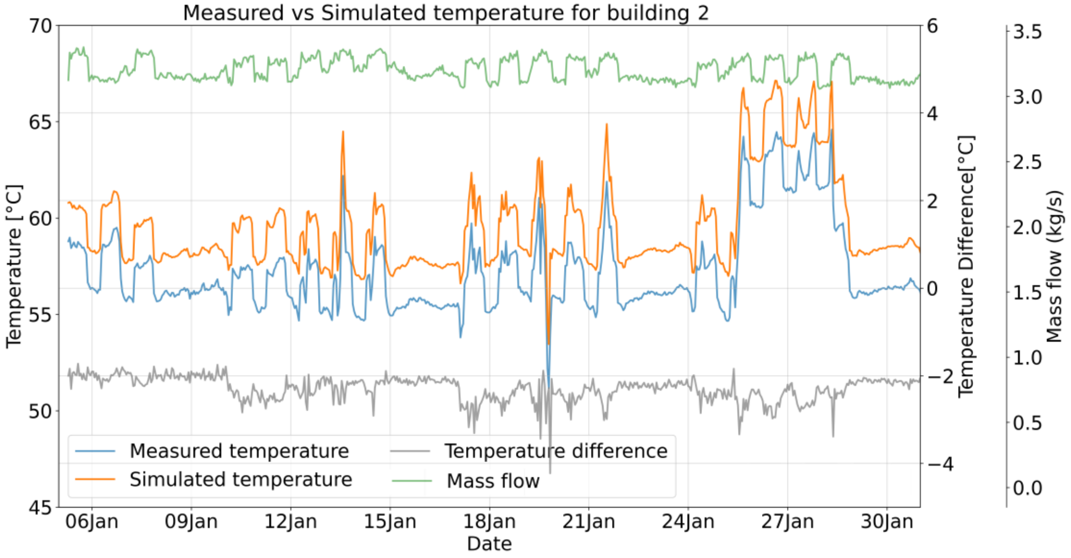
→

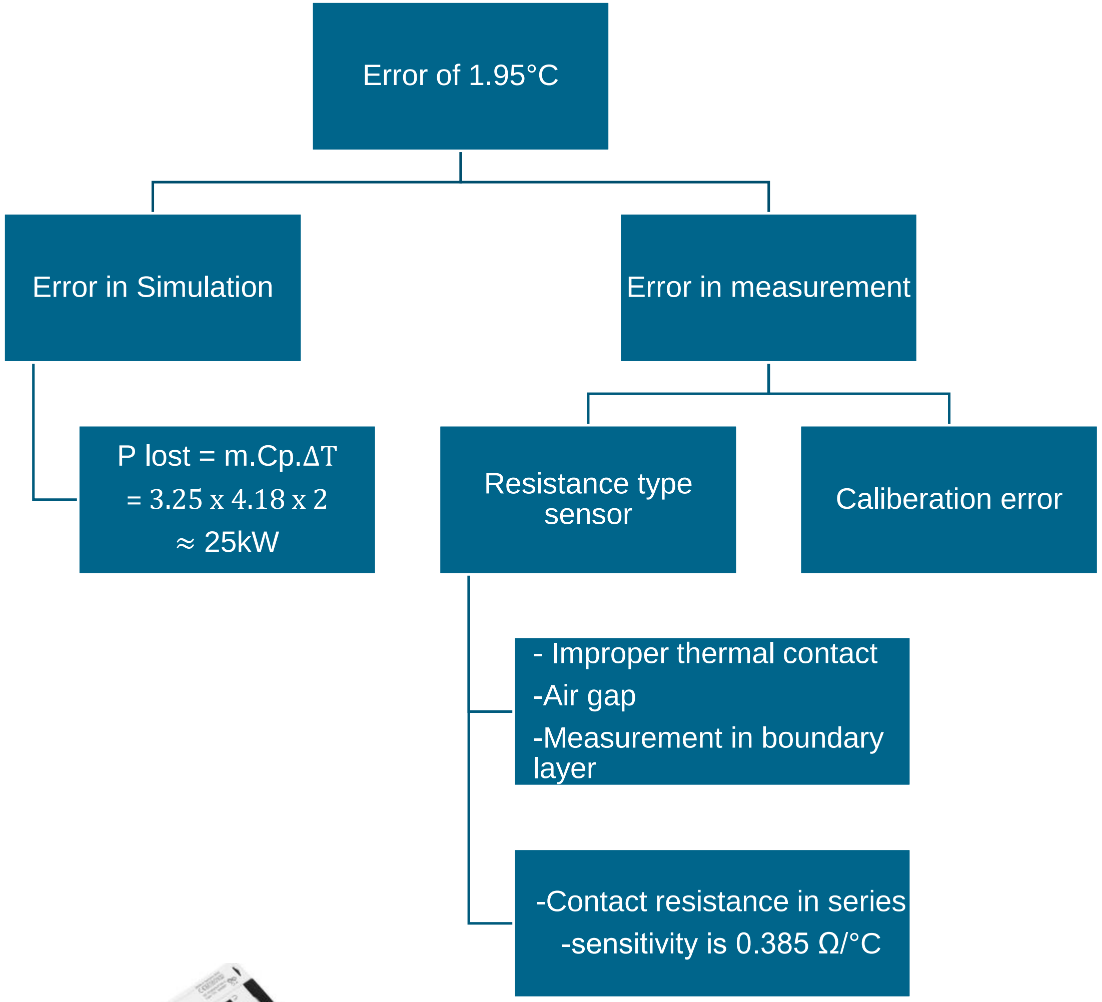
Output

- Network temperatures
- Pipe thermal losses
- Total energy consumption



Analysing the erorr for building 2:





Error of 1.95°C

Error in Simulation

Error in measurement

P lost = m.Cp.ΔT
= 3.25 x 4.18 x 2
≈ 25kW

Resistance type sensor

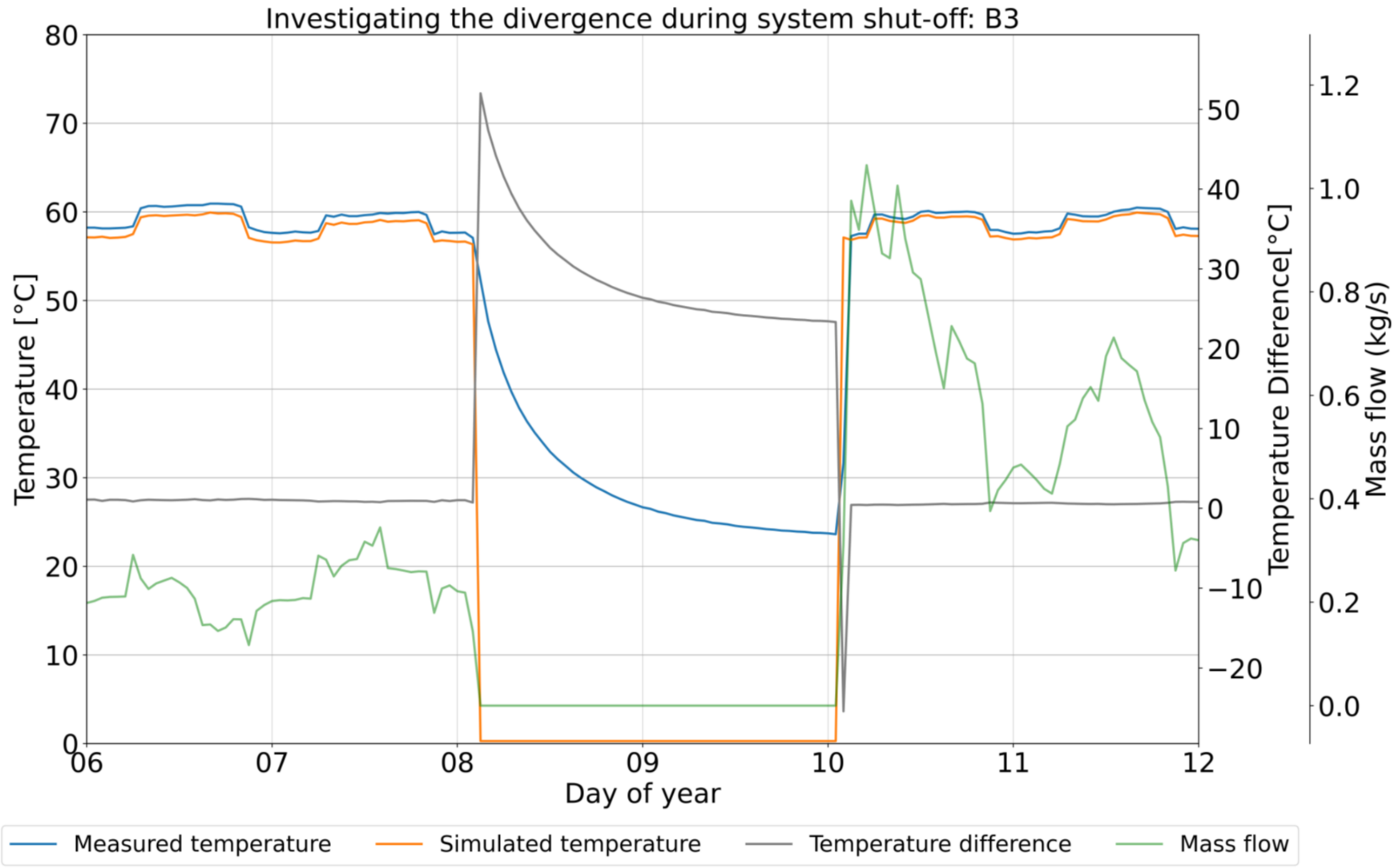
Caliberation error

- Improper thermal contact
-Air gap
-Measurement in boundary layer

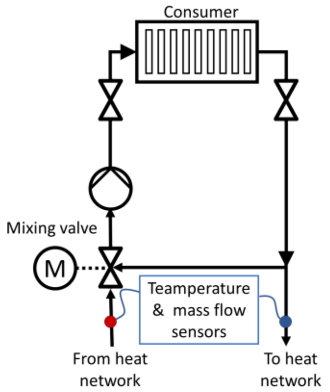
-Contact resistance in series
-sensitivity is 0.385 Ω/°C

DAQ_datasheet

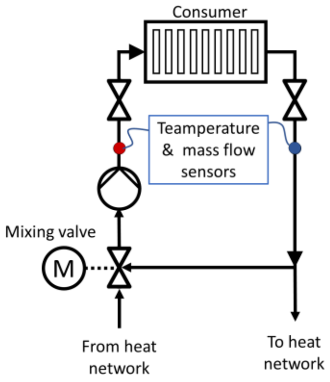
System shutoff: (Effect of thermal inertia)



Modelling of adiabetic mixing valves

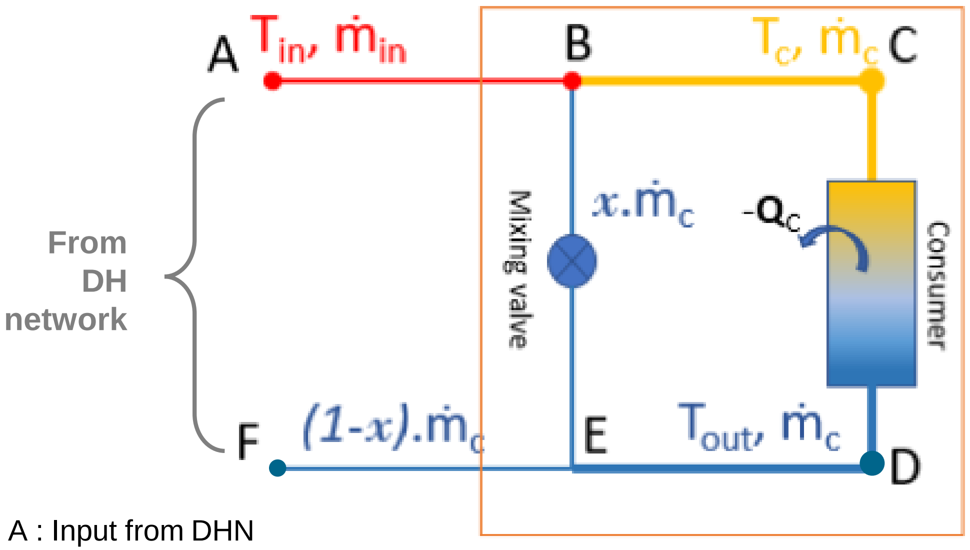


(A)



(B)

Calculation for return-mixed-buildings



A : Input from DHN
C: Location of Meter

$$x = \frac{(T_c - T_{in})}{(T_{out} - T_{in})}$$

Mixing Valve logic :

if $T_{in} > T_{set}$,
$m = x.m_c$

Assumptions:

Tin ≈ input of previous building

Mass balance: @B

$\dot{m}_c = \dot{m}_{in} + x.\dot{m}_c$

Energy balance: @B

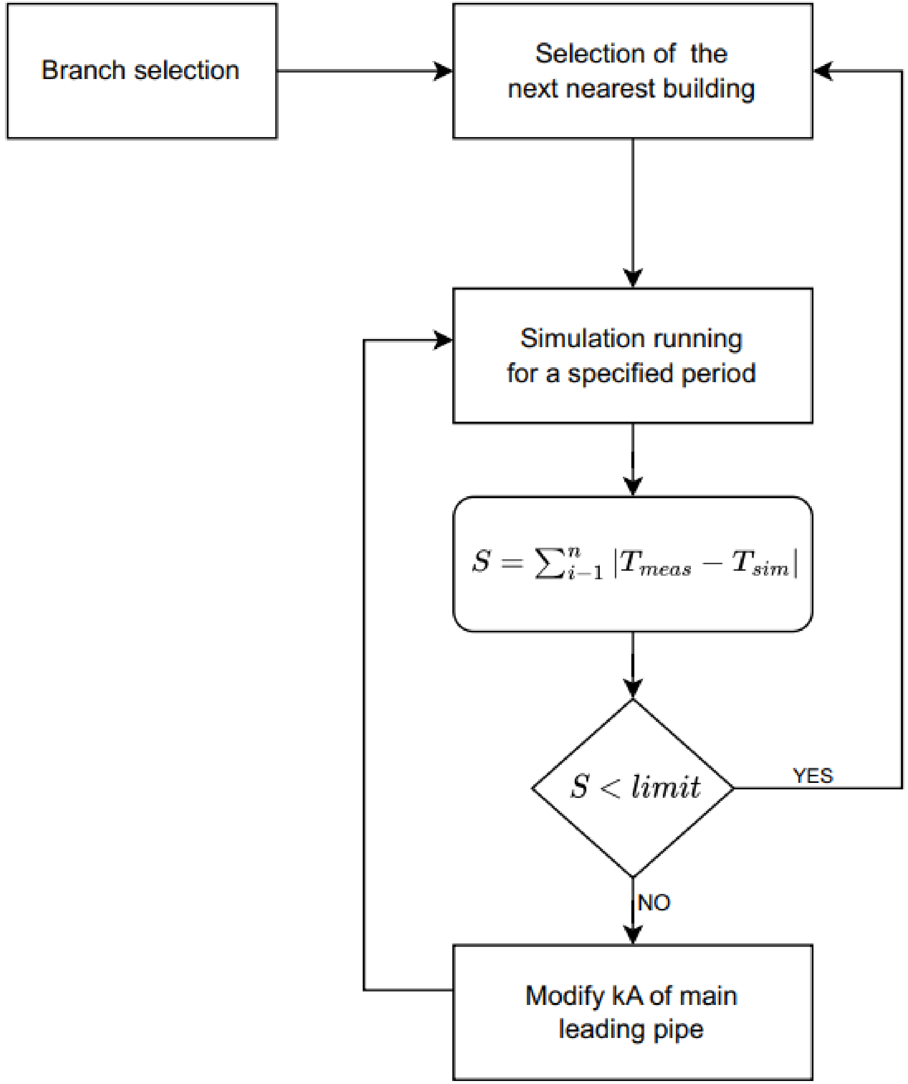
$h_{in}.\dot{m}_{in} + h_{out}\, x.\dot{m}_c = h_c.\dot{m}_c$

For single phase liquid, h α T

$T_{in}.\dot{m}_{in} + T_c\, x.\dot{m}_c = T_c.\dot{m}_c$

Model calibration

- Calibration parameter: aggregated heat conduction (*UA*) , described by $Q = U \cdot A \cdot \Delta T_{log}$
- Target parameter: deviation between the measured and the simulated inlet temperature at all consumers (T_{in})
- Simulation period: 12 hours in January (high demand)
- Desired maximum deviation: 0.5 ◦C



Branch selection

Selection of the next nearest building

Simulation running for a specified period

$S = \sum_{i-1}^{n} |T_{meas} - T_{sim}|$

$S < limit$

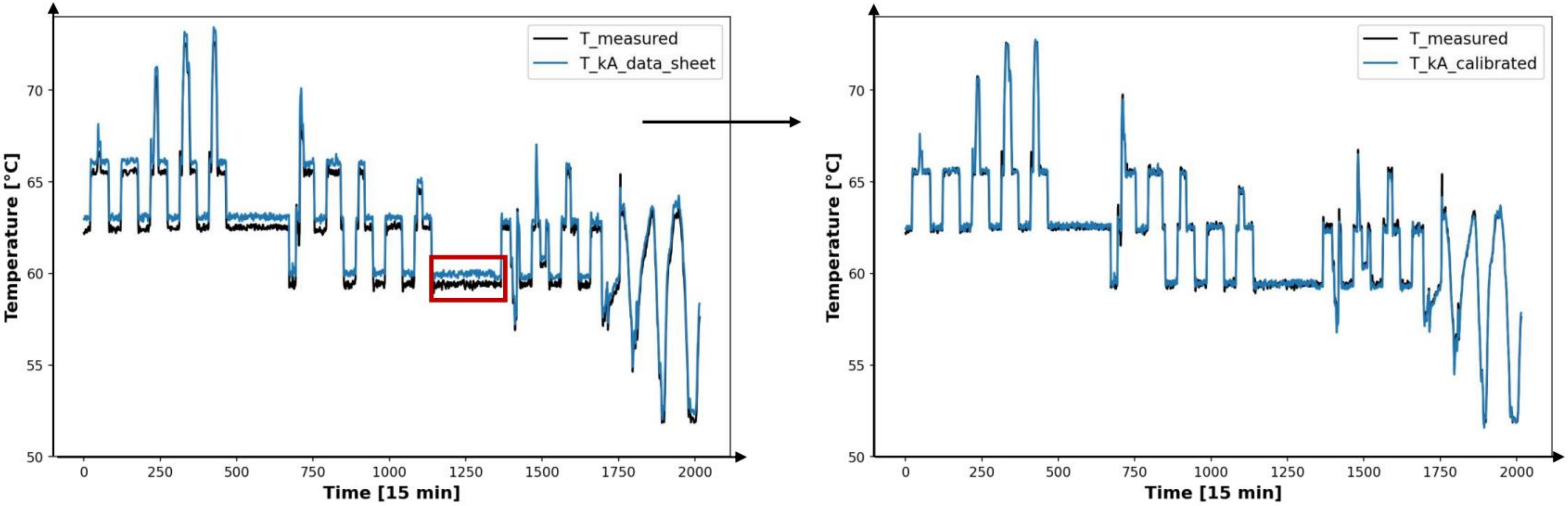
YES

NO

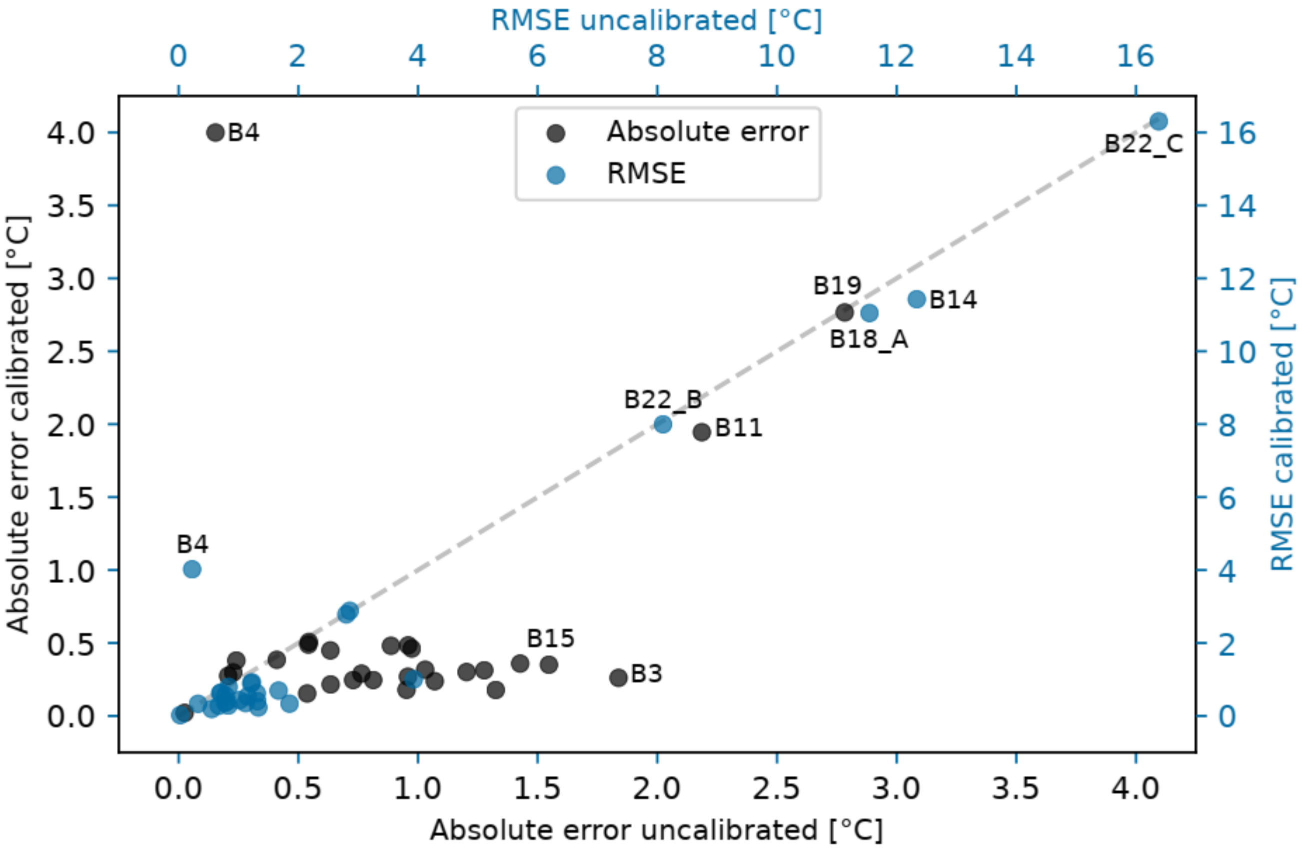
Modify kA of main leading pipe

Iterative calibration method based on an specific branch of the system

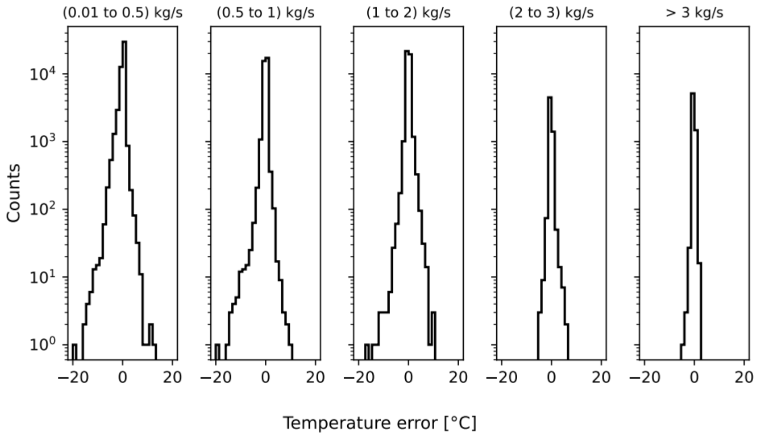
Calibration: Example



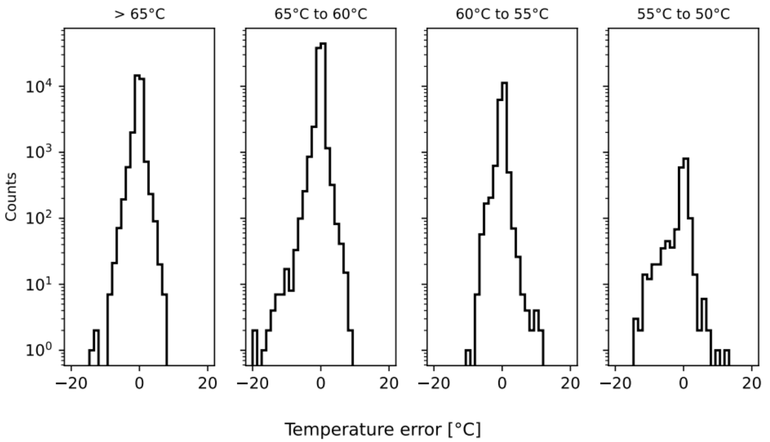
Calibration summary



Comparison of uncalibrated and calibrated model absolute mean error and RMSE for the month of January

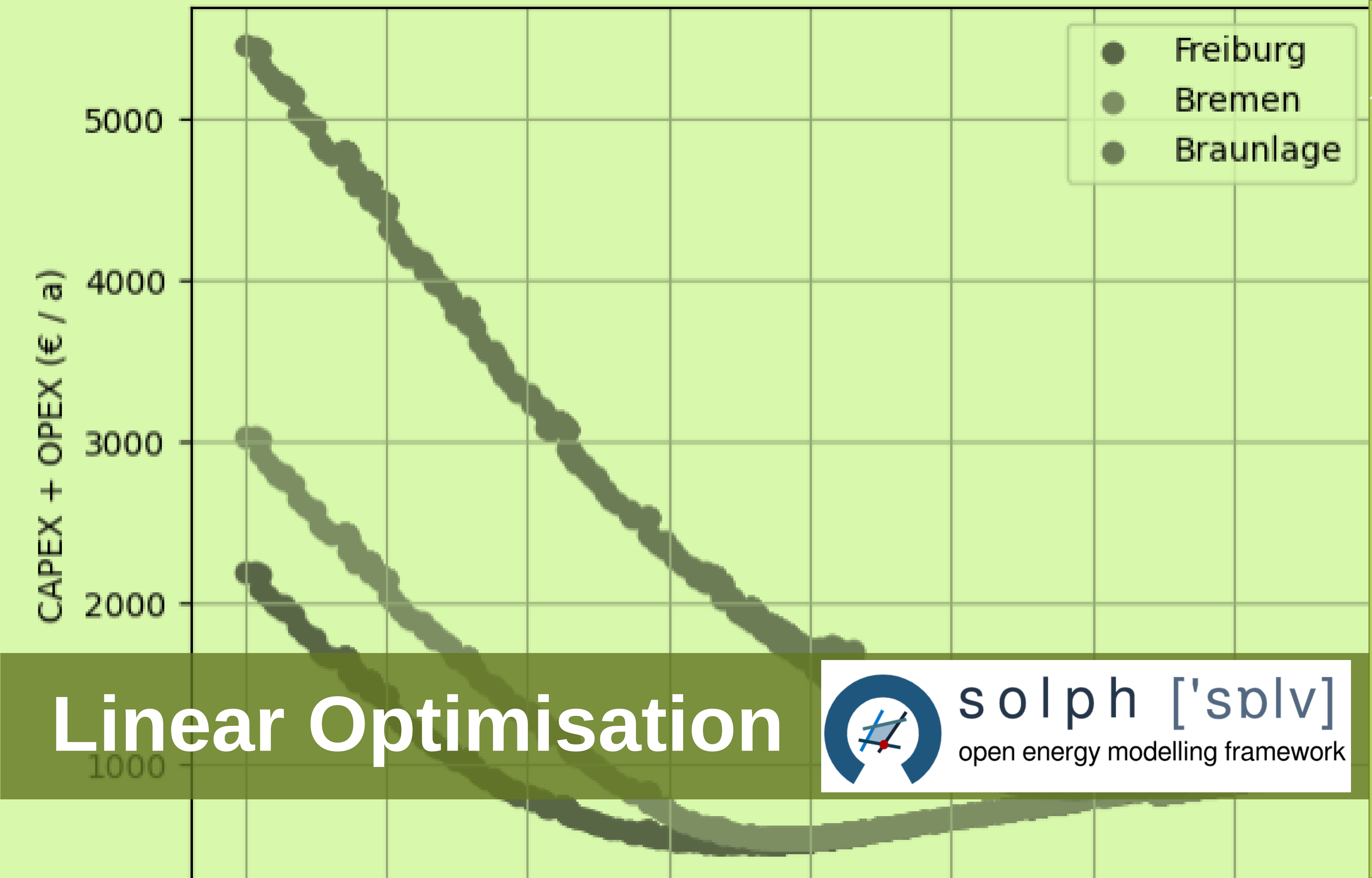


Temperature error at different mass flow regimes



Temperature error at different inlet temperature regimes

Linear Optimisation

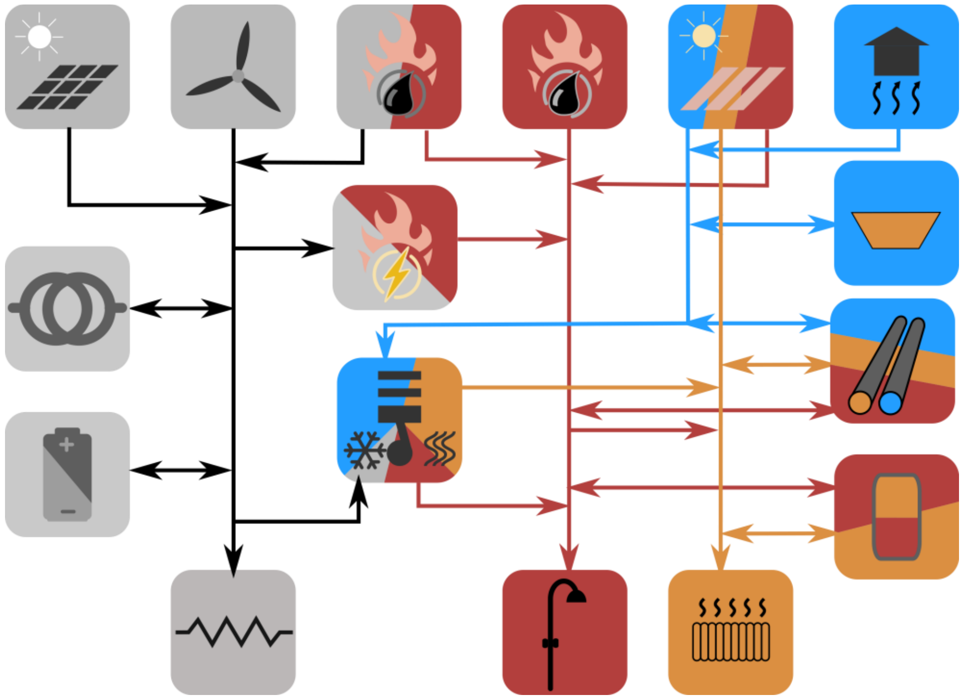


solph ['sɒlv]

open energy modelling framework

Model template for residential energy supply systems (MTRESS)

- Simplified creation of energy system models
- Currently integrates electricity, heat, and gas as energy carriers
- Written in Python, using *oemof.solph*
- Variable selection and dimensioning of components
- Integrates with PyGMO for optimisation of the dimensioning
- Variable time steps allow calculations at different levels of detail



https://github.com/mtress/mtress; doi:10.1109/OSMSES54027.2022.9768967

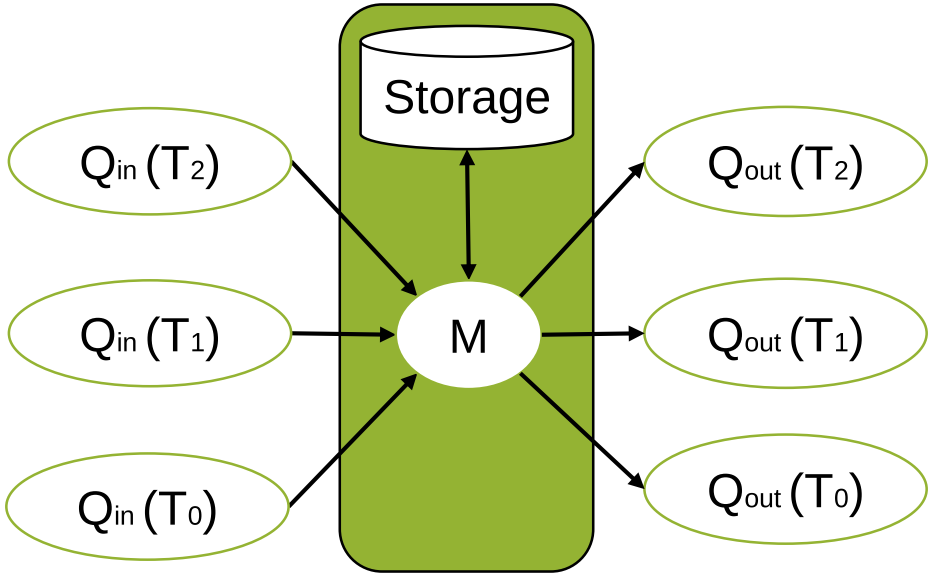
Storage formulations

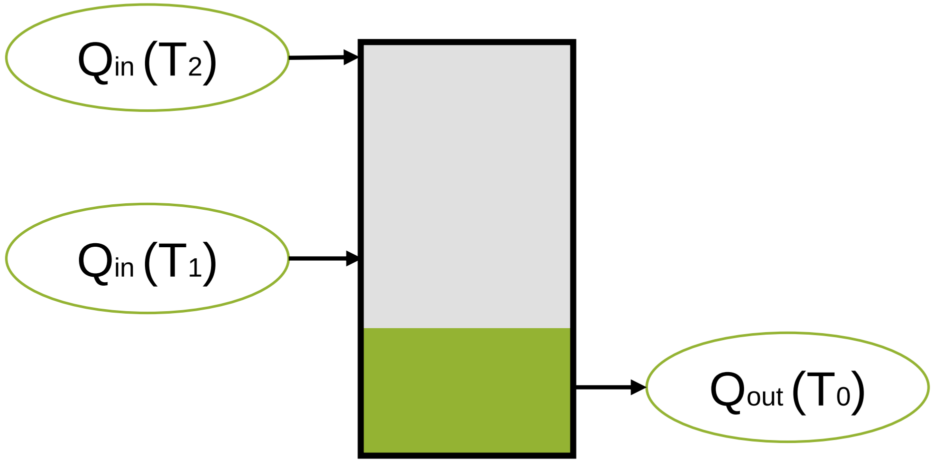
Single input (and output)

- One active flow per time step
- Storage temperature in next timestep has to be lower than the input level

Multiple inputs (and outputs)

- Multiple active fows per time step
- Fully mixed: Energy flow bounded by difference between temperature levels
  → sequential flows
- Layered: Energy flow always allowed
  → parallel flows

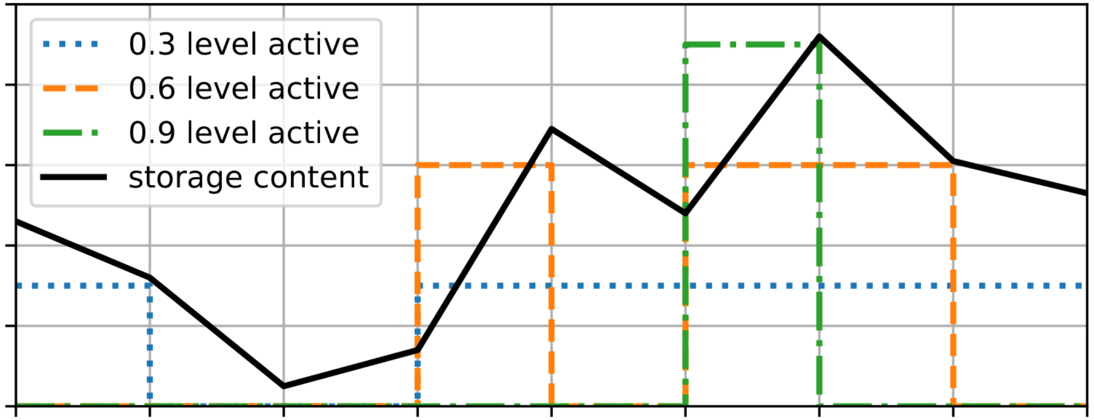




arXiv:2211.14080

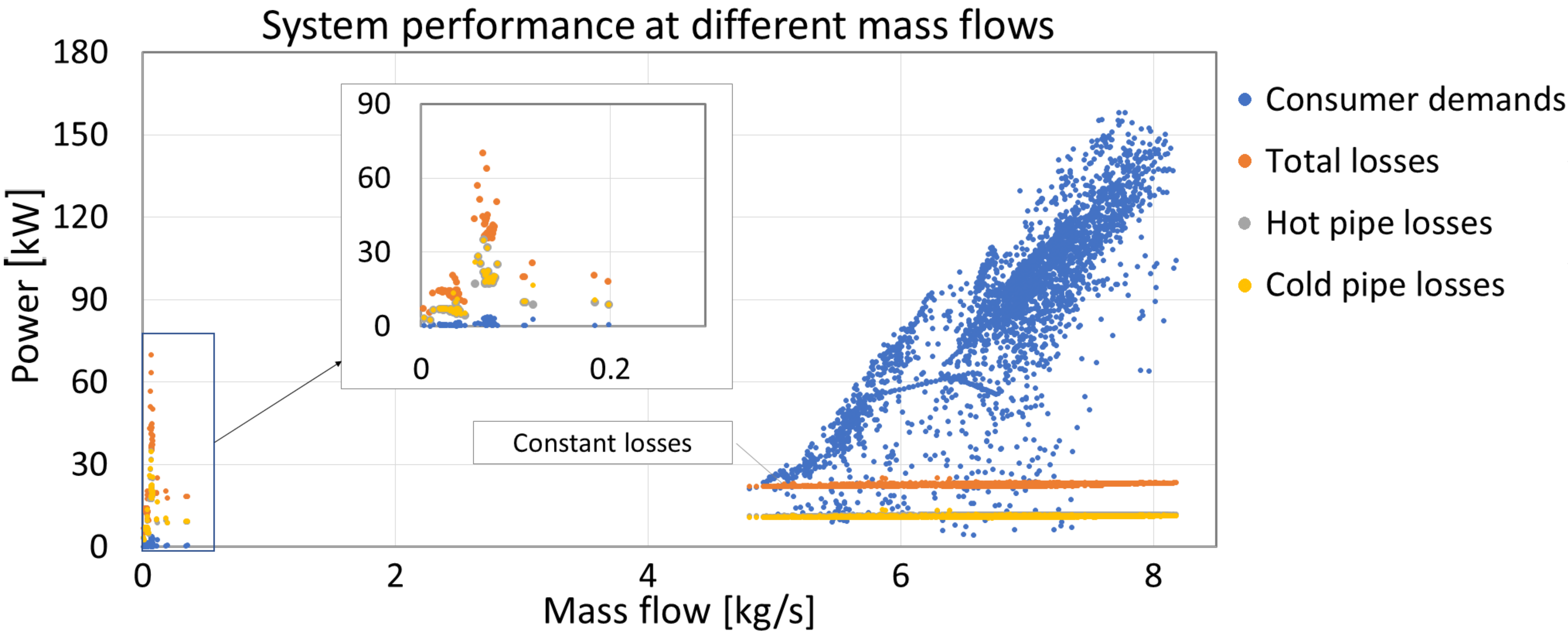
Fully mixed: Supply depending on storage quantity

- Temperature proportional to the stored energy
- For heat storages a layered storage model is reasonable
- The storage level influences the uses of the stored energy, e.g. at low temperatures the energy cannot be used for DHW



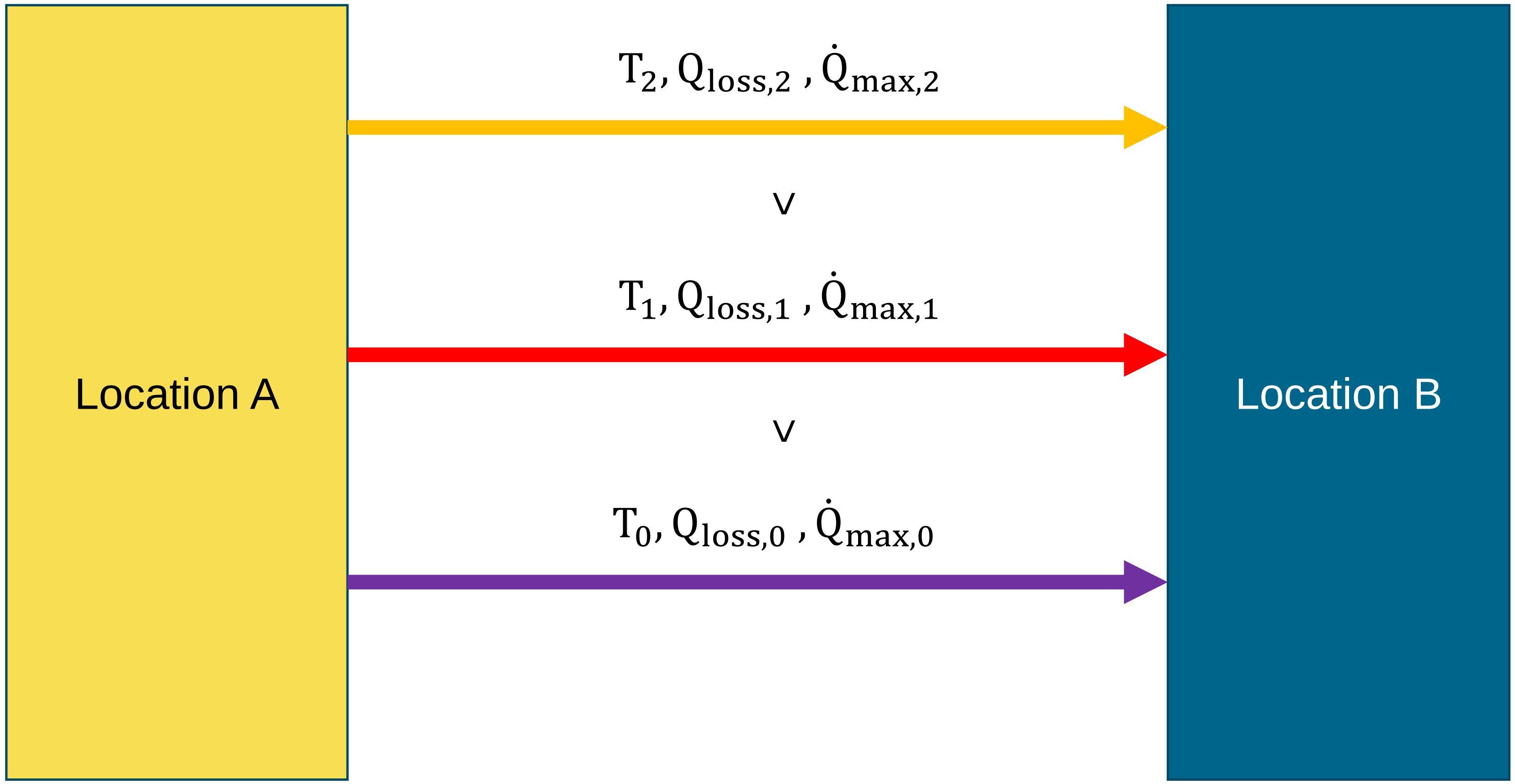
arXiv:2211.14080

Heat losses in typical networks



N. Gaikwad, MSc thesis, Transformation Scenarios for HT DHN …

MILP heat network model


$T_2, Q_{loss,2}, \dot{Q}_{max,2}$

$\vee$

$T_1, Q_{loss,1}, \dot{Q}_{max,1}$

$\vee$

$T_0, Q_{loss,0}, \dot{Q}_{max,0}$

MILP formulation of heat pumps with part load efficiency

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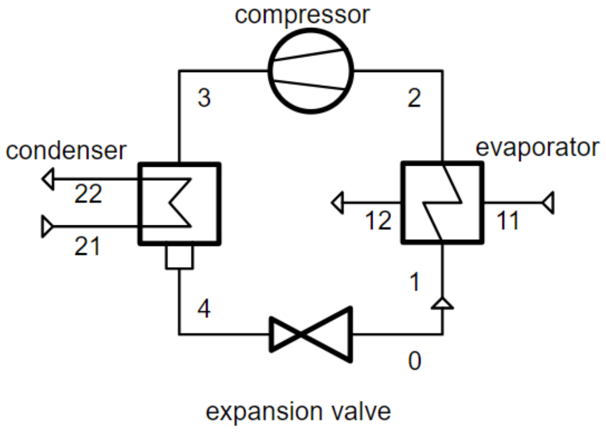
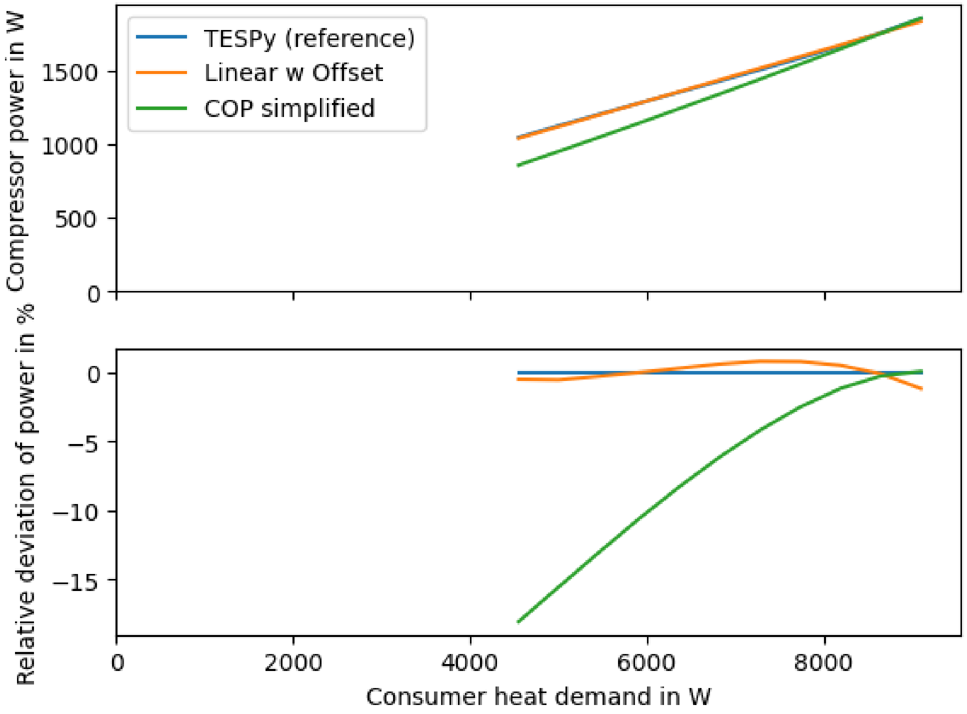


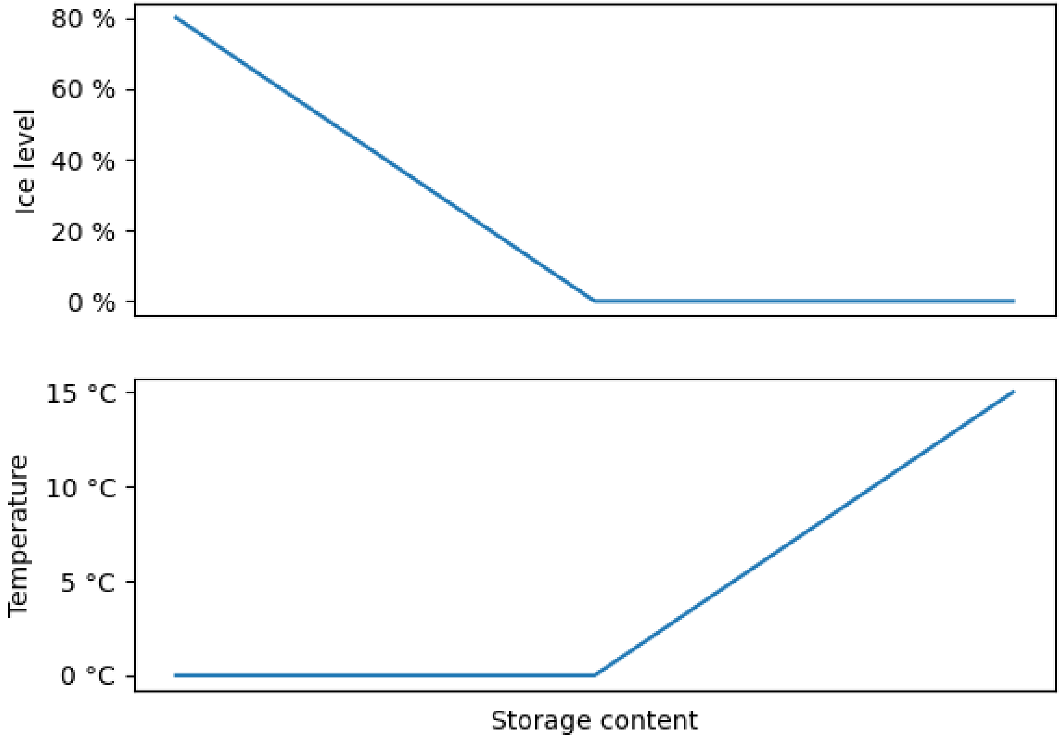
- Mixed-integer linear formulation
  - Constant losses (when active)
  - One binary variable per time step
- Significantly changes operation
  - Part load often outweighs *COP*(*T*)
  - Energy prices/possibility of own consumption has larger influence
- Limited effect on other results (whole system)
- Not advised for long time horizons (due to much higher complexity)



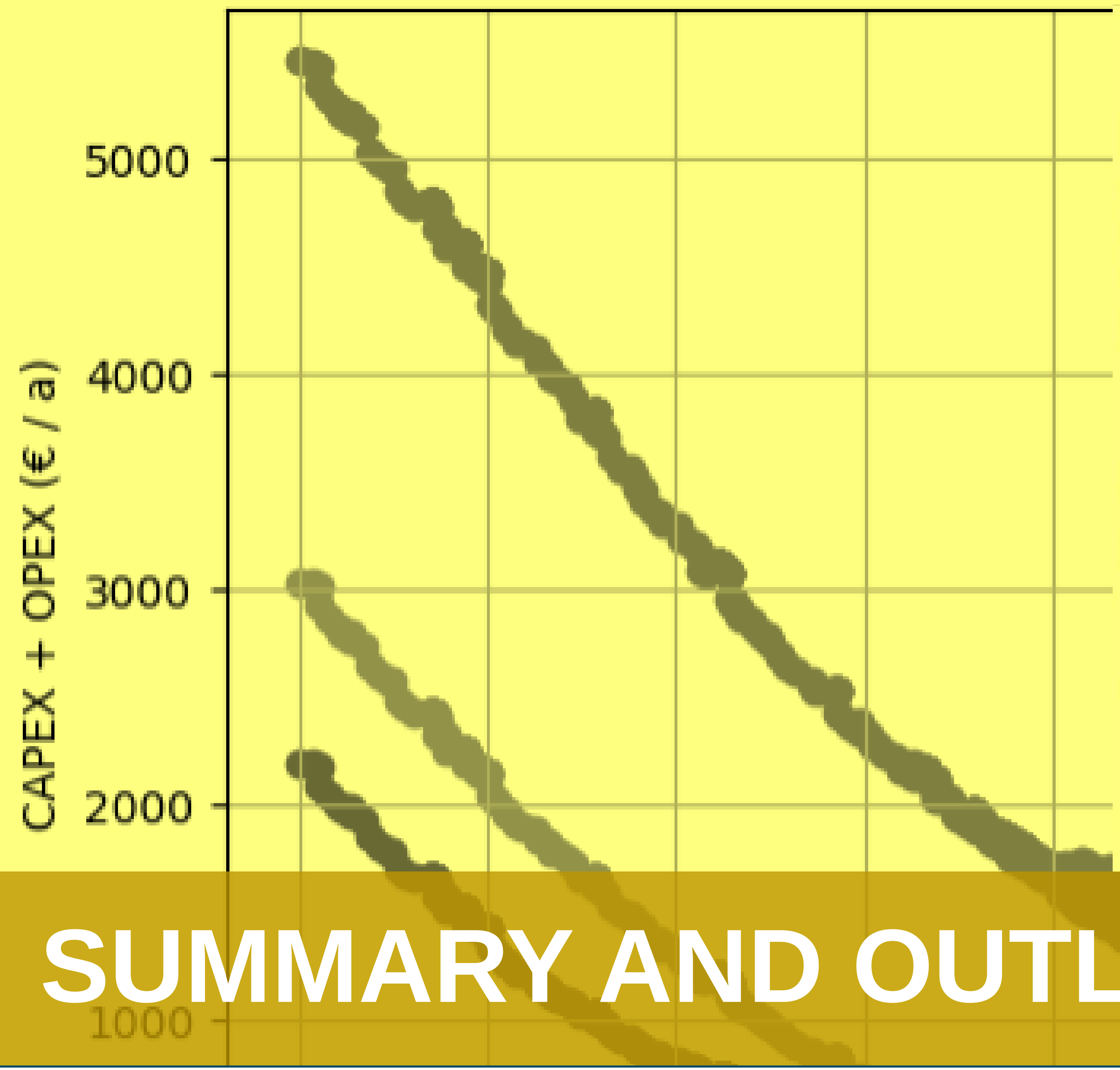
F. Witte, P. Schönfeldt; oemof Workshop on Modeling of Heat Pumps

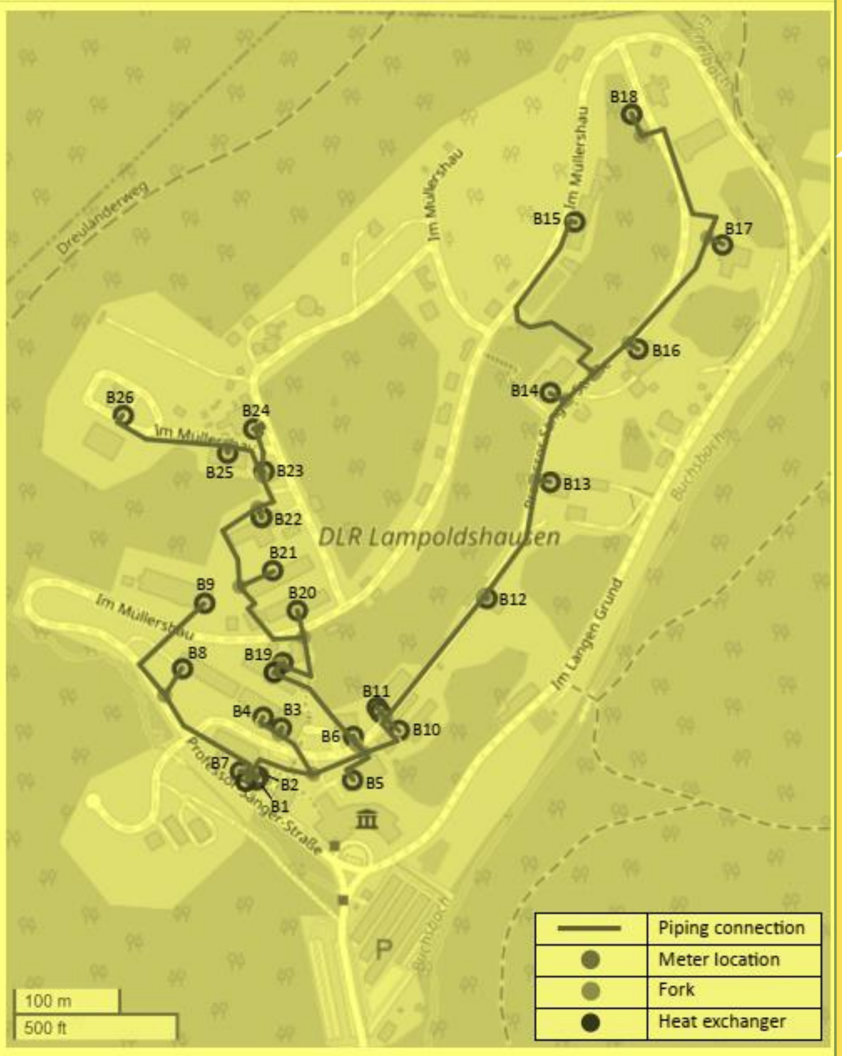
Ice storage implementation is in the works

- Two states: liquid and frozen
- Ice formation on the heat exchanger produces counteracting effects
  - Surface area increases
  - Ice has an insulating effect
- Temperature has a non-linear relationship to the storage level (relevant for heat pump COP)
- Two implementations in the works
  - Ice storage component for *oemof*
  - Separate storages for the liquid and frozen state



Courtesy of Maximilian Hillen



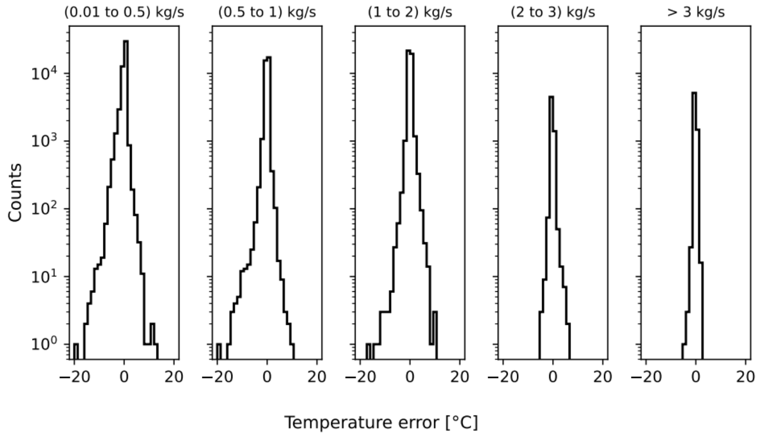


SUMMARY AND OUTLOOK

Summary and Outlook

Calibration of static model

- Steady-state model reproduces network behavior
- Successfully calibrated model
- Next: Use for Off-Design tests



Linear optimisation

- Losses independent of flow
- Discrete temperatures → optimize flow
- Next: Integrate puzzle pieces