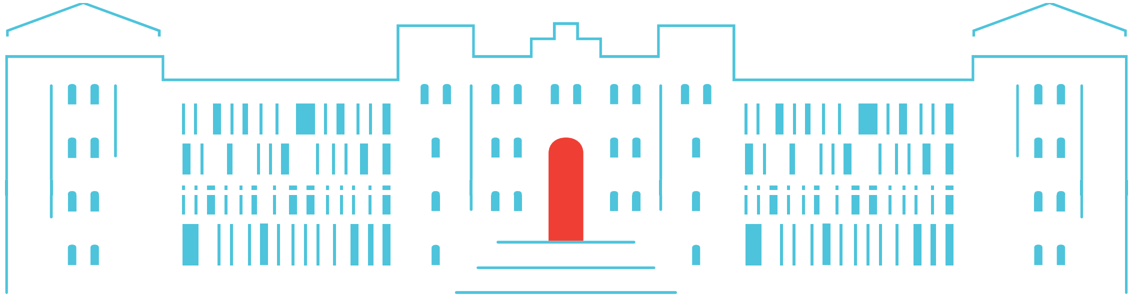
A tool-chain for development and simulation of large-scale district heating network models

TUHH
Technische Universität Hamburg

22.02.2026

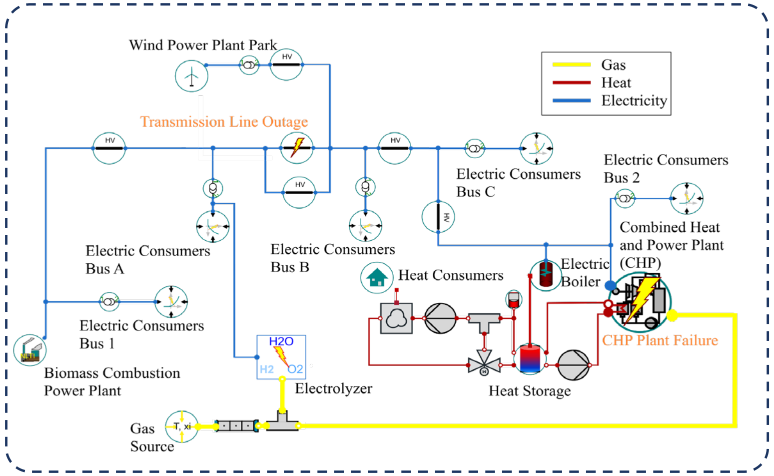


Arne Speerforck, Jan Westphal, Jonathan Vleth

Motivation

So far:

Using the TransiEnt Library to simulate coupled energy systems

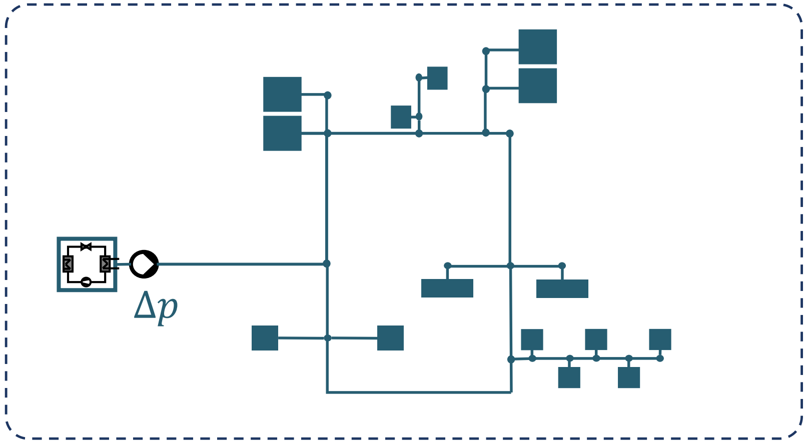


TransiEnt Library → **Models published on Github**

Now:

1. Dynamic simulation of large, meshed heating networks with several thousand heat transfer stations without aggregation
2. Automatic generation of District heating networks (DHN) and DHN models

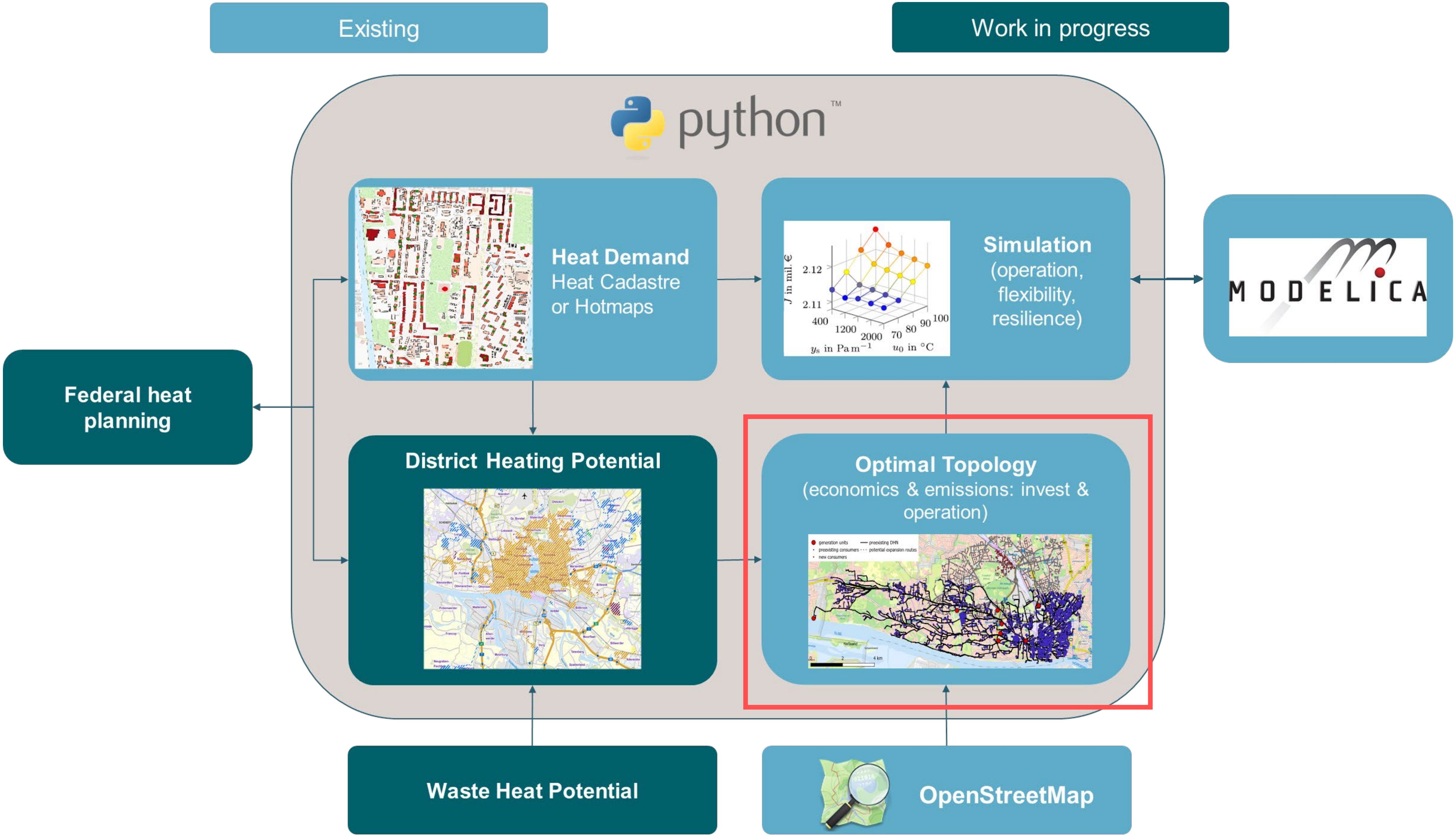
Simulation in OpenModelica and Dymola



Objectives:

– Investigation of thermal inertia that can be used for operational optimization
  – Storage dynamics
  – Grid inertia

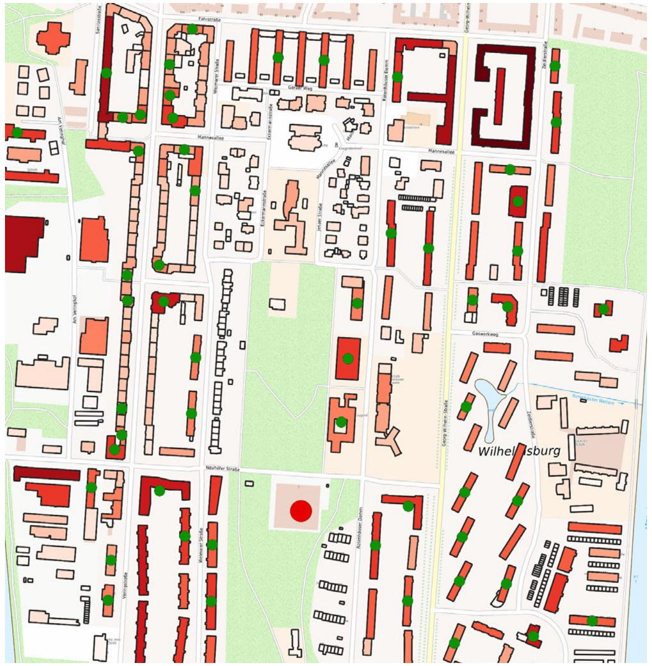
} **Load-Shifting** **Demand-Side-Management**



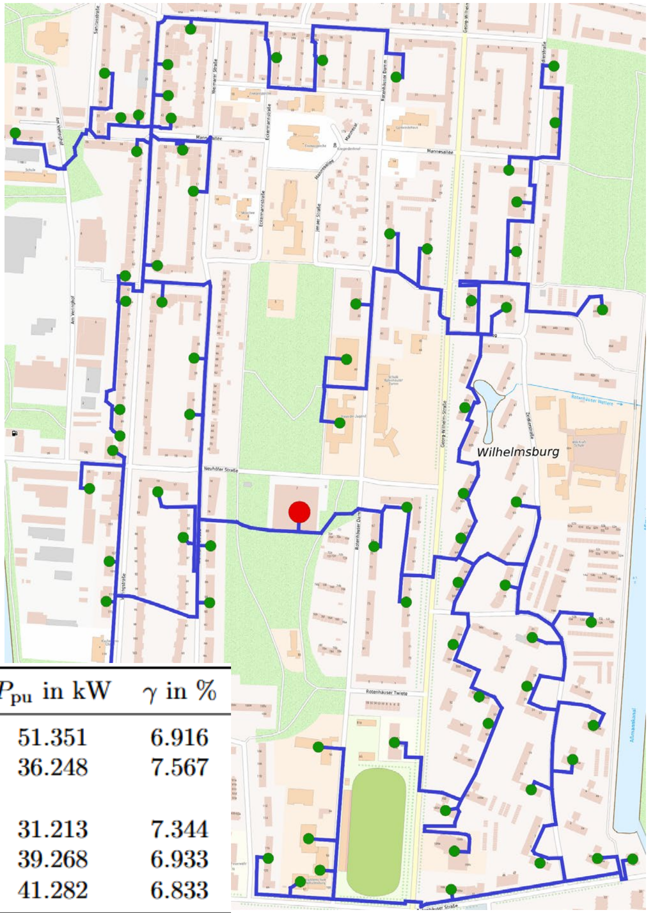
Existing
Work in progress
python
Heat Demand
Heat Cadastre or Hotmaps
Simulation
(operation, flexibility, resilience)
MODELICA
Federal heat planning
District Heating Potential
Optimal Topology
(economics & emissions: invest & operation)
Waste Heat Potential
OpenStreetMap

Optimal topology search

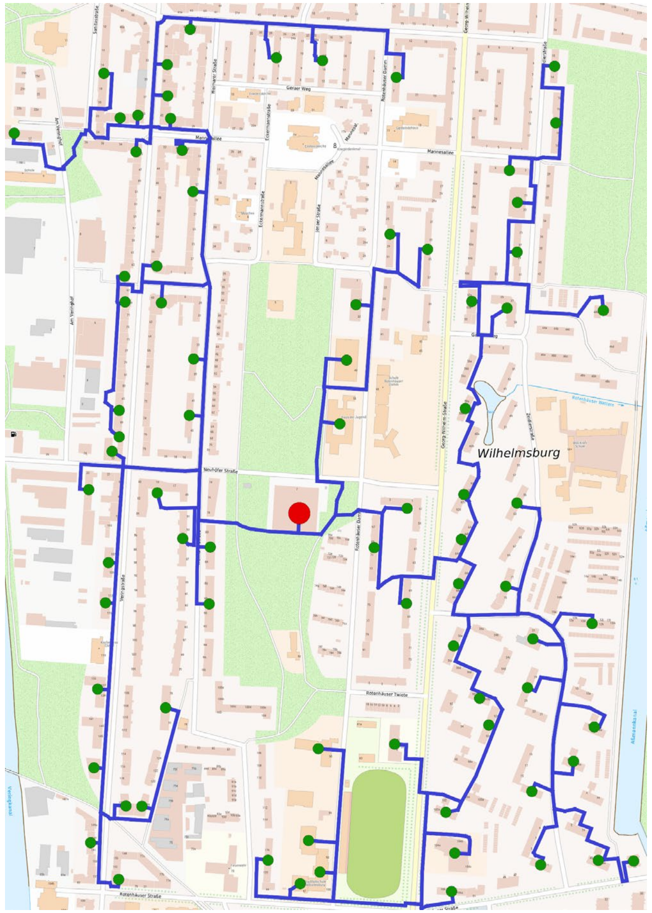
Heat map



Steiner Tree



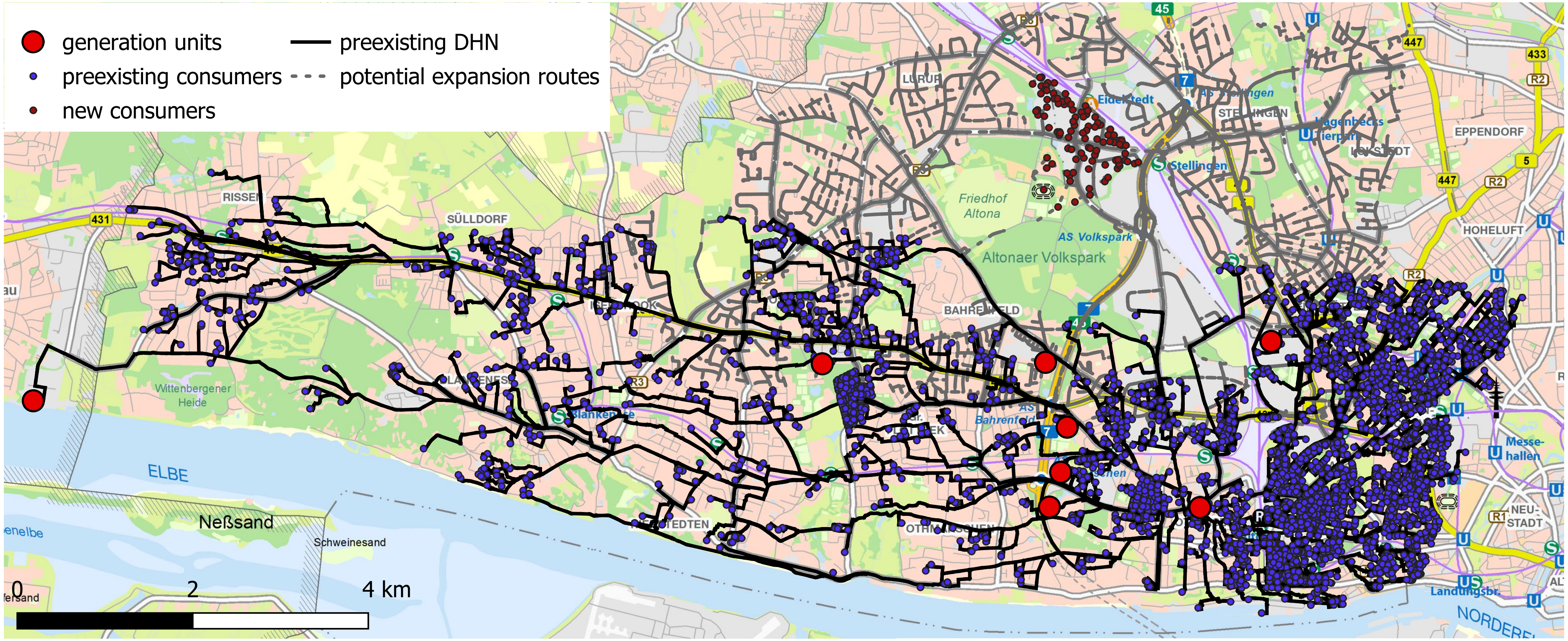
Constrained Steiner Tree



Algorithm	ℓ_{Σ} in km	ℓ_{cc} in km	t_{comp} in s	P_{pu} in kW	γ in %
Kou (*networkX*)	18.368	1.562	61.752	51.351	6.916
Shortest path	25.395	0.915	0.853	36.248	7.567
Constrained Steiner					
$\beta = 1$	23.081	0.915	108.478	31.213	7.344
$\beta = 1.25$	18.984	1.121	57.7	39.268	6.933
$\beta = 1.5$	17.865	1.315	44.668	41.282	6.833

Vieth et al.: *District heating network topology optimization and optimal co-planning using dynamic simulation.* Advances in Applied Energy. 2025

Optimal DHN Expansion Planning

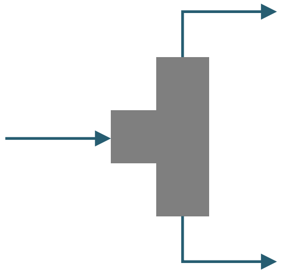


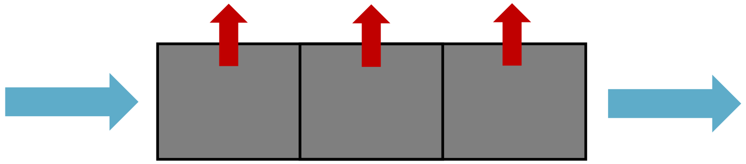
Vieth et al.: *Automated District Heating Network Expansion Planning with Resilience Considerations.* 2025

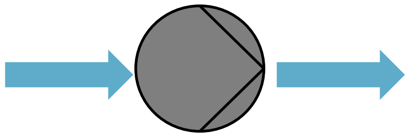
Modeling Concept 1

Main concept:

1. Use of a suitable consumer model and mass flow states to avoid non-linear implicit systems inspired by [1]
2. No use of fluid models
3. Exclusive discretisation of the energy balance to utilize sparse properties





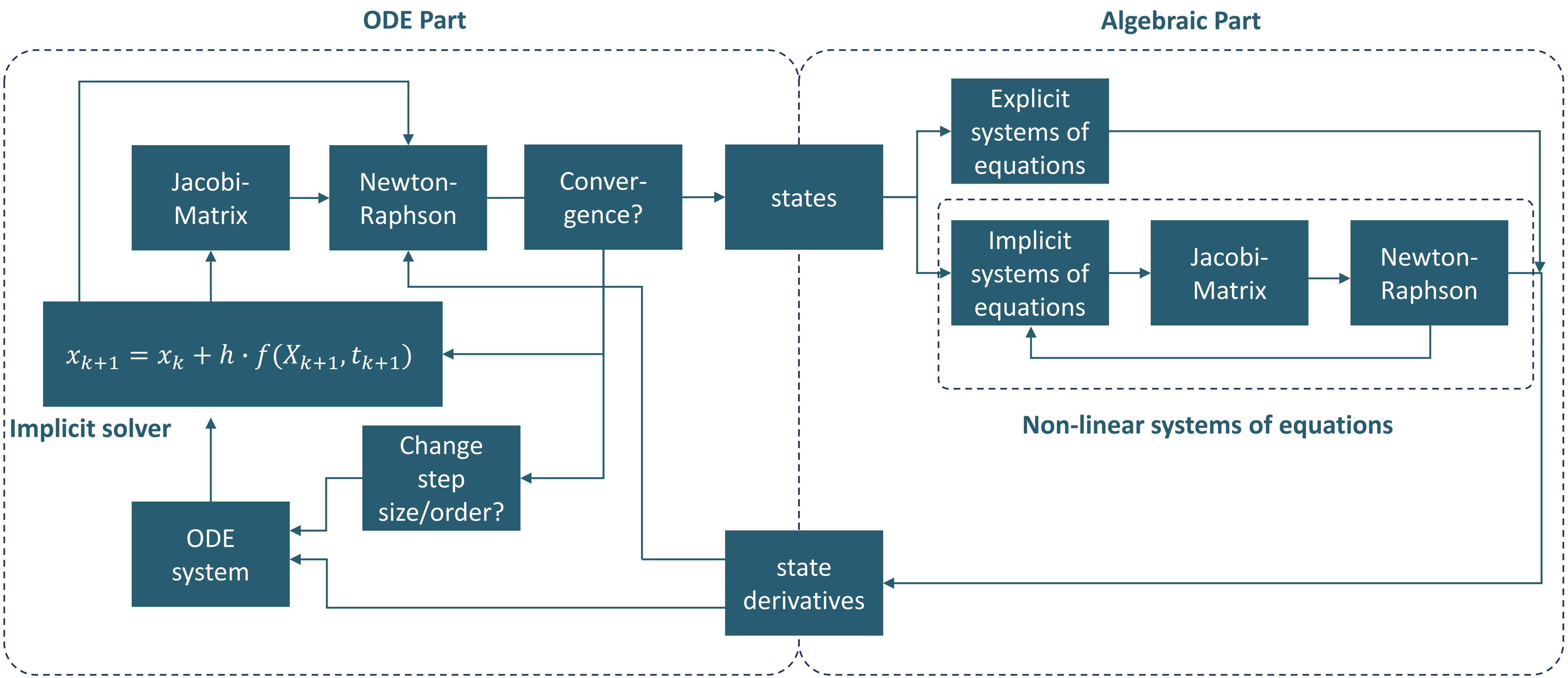


Basics of the modeling concept

- Constant fluid properties (no media models)
- Connectors (h, m_flow, p)
- Transient energy balance in pipe and junction models
- Steady-state momentum and mass balance + linear pressure loss model Except: Pipe model -> physical pressure loss model (fluid dissipation) & use of an unsteady momentum balance

[1] Dirk Zimmer, Robust object-oriented formulation of directed thermofluid stream networks (2020)

Basic solution process of the model



Solution: Adding a mass flow state

Structure graph of the model:

I. $\dot{m}_1 + \dot{m}_2 + \dot{m}_3 = 0$

II. $p_1 - p_2 = \dot{m}_2 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}}$

III. $p_1 - p_3 = \dot{m}_3 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}}$

IV. $\dot{m}_2 + \dot{m}_4 = 0$

V. $p_2 - p_4 = \frac{d\dot{m}_2}{dt} \cdot L + \dot{m}_2{}^2 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}{}^2}$

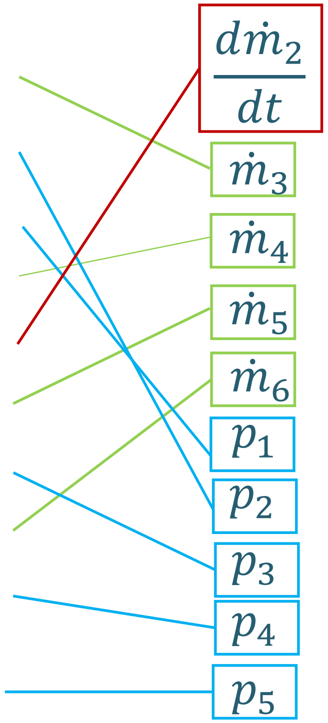
VI. $\dot{m}_3 + \dot{m}_5 = 0$

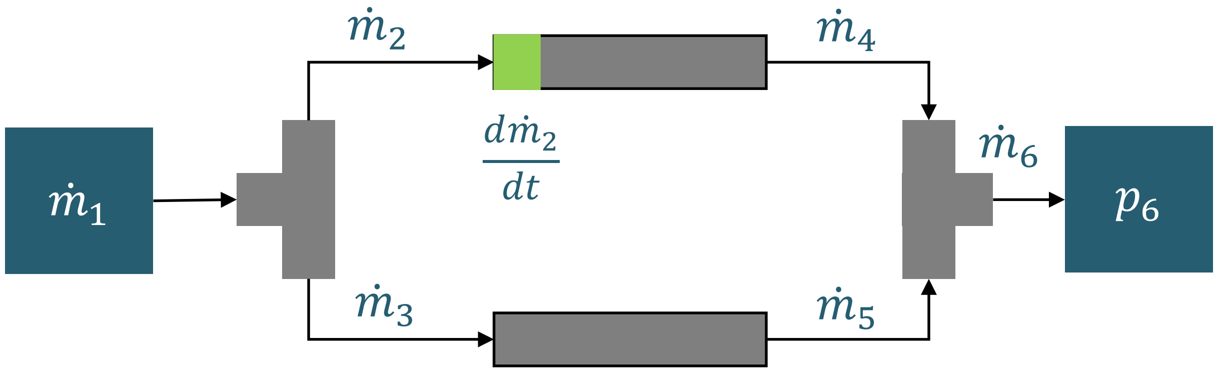
VII. $p_3 - p_5 = \dot{m}_3{}^2 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}{}^2}$

VIII. $\dot{m}_4 + \dot{m}_5 + \dot{m}_6 = 0$

IX. $p_4 - p_6 = \dot{m}_4 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}}$

X. $p_5 - p_6 = \dot{m}_5 \cdot \frac{\Delta p_{\text{nom}}}{\dot{m}_{\text{nom}}}$



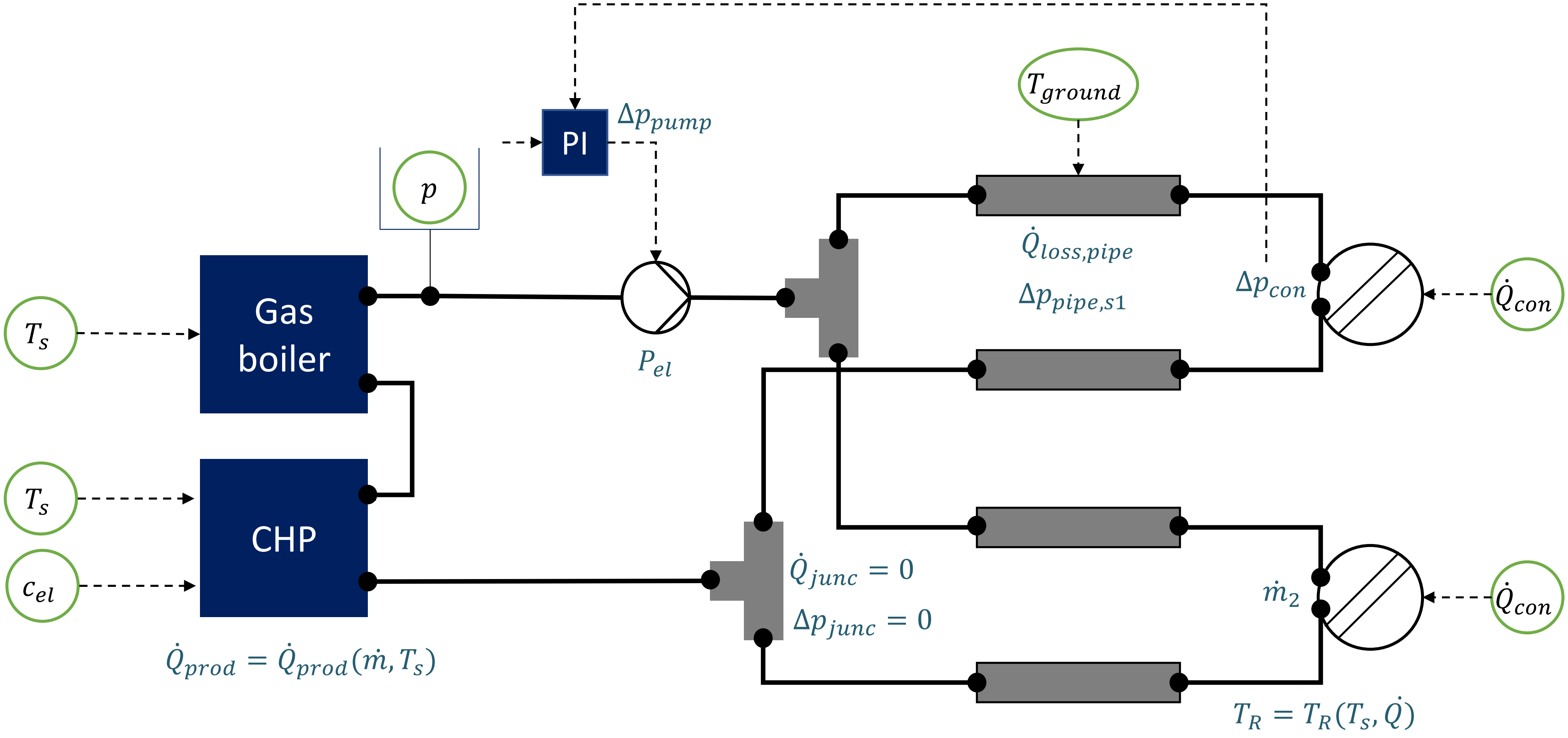


Screenshot of the Statistics:

Sizes of linear systems of equations: { }
Sizes after manipulation of the linear systems: { }
Sizes of nonlinear systems of equations: { }
Sizes after manipulation of the nonlinear systems: { }
Number of numerical Jacobians: 0

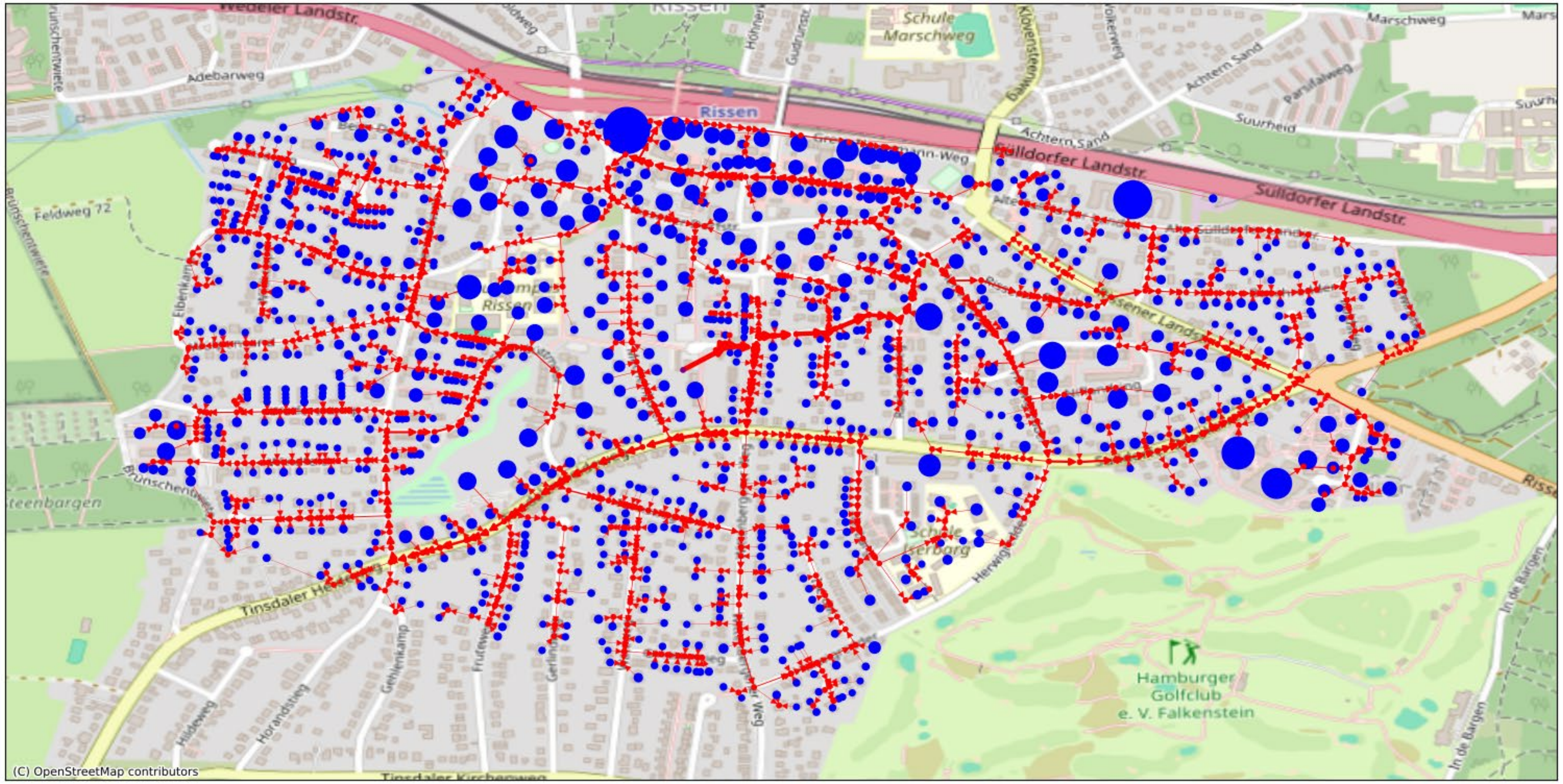
System of equations can be solved explicitly!

Modeling Concept 2

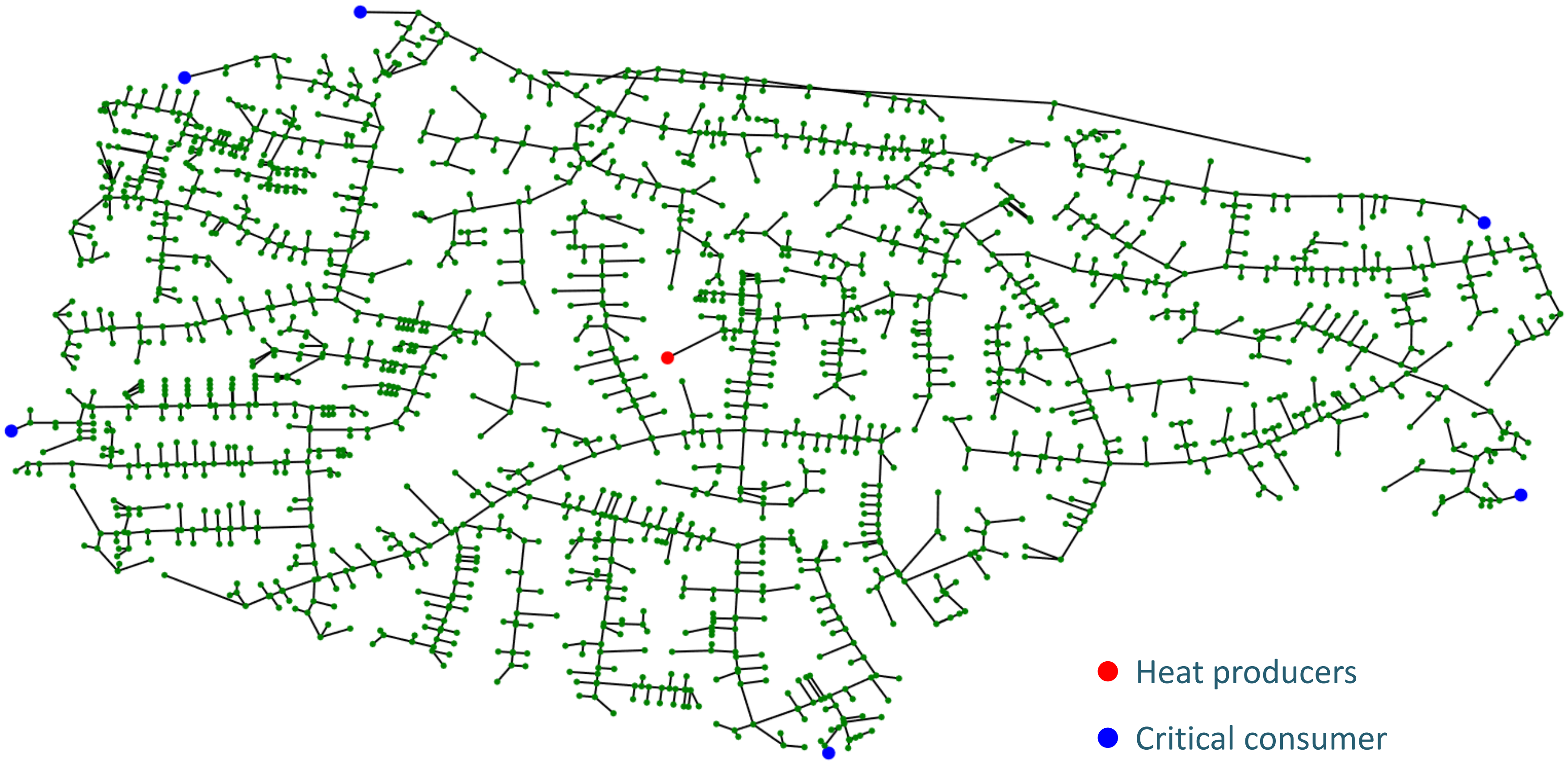


DHN Rissen

Rissen Constrained Steiner 2.0 Supply Network



Simulation of a larger-scale DHN



DHN Topology:

- Automatic generated district heating network
- District heating network of a suburb of the city of Hamburg

DHN Data:

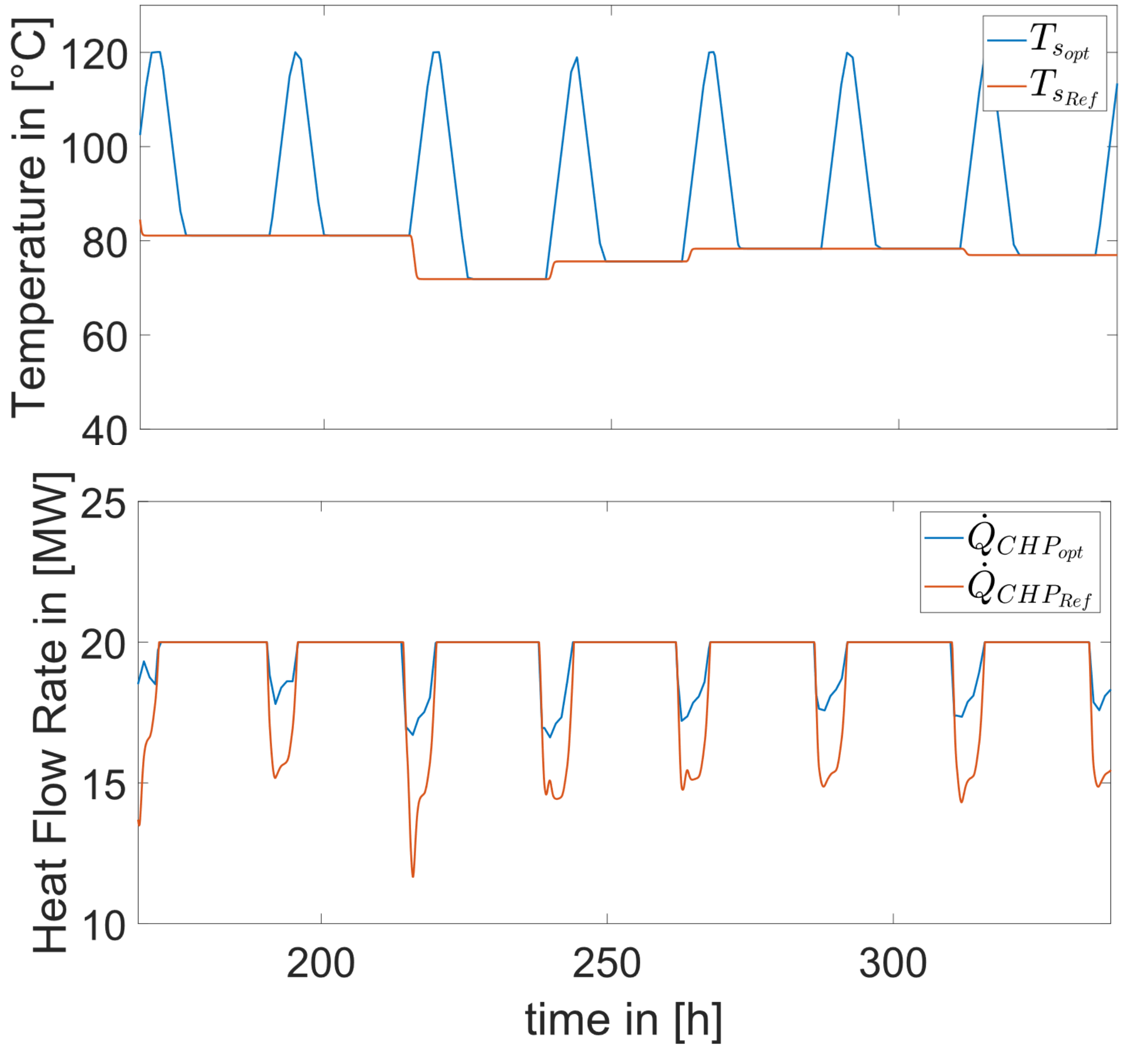
Network length: 96,298 km

Max. Heat load: 34,14 MW

Simulation Time (1 Year): ≈ **6 hours**

Number of Substations: **1050**

Supply Temperature and CHP heat production

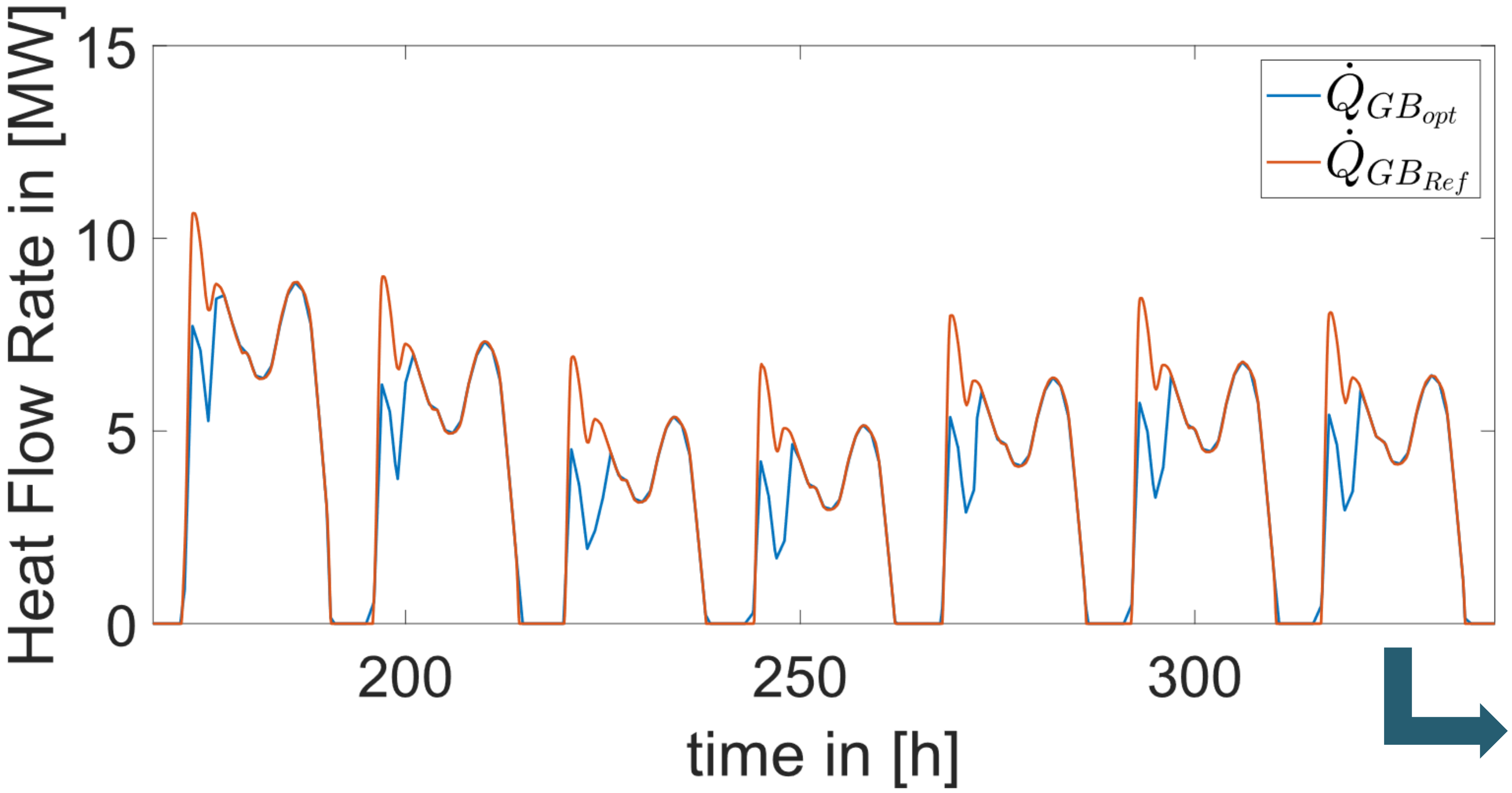


- Supply temperature for two scenarios (Ref and opt)
- Increase of the supply temperature to store energy temporarily in the DHN

But: Increased supply temperature leads to higher heat losses

- Heat production of CHP for two scenarios
- Increased heat production of the CHP in the optimized scenario in exchange for lower peak heat production

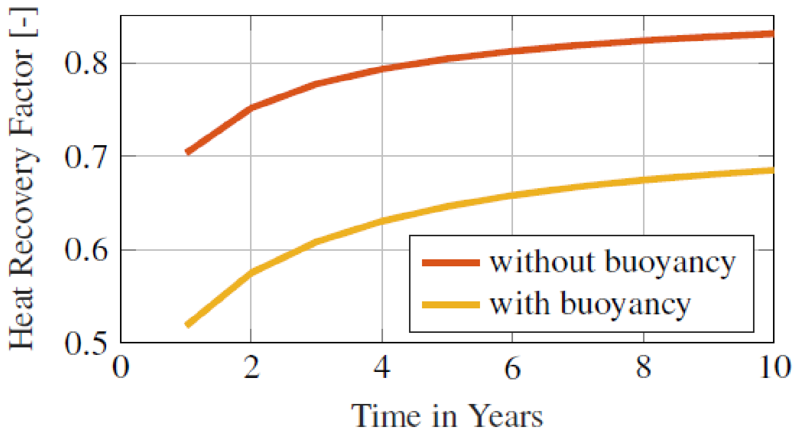
Heat production of the gas boiler



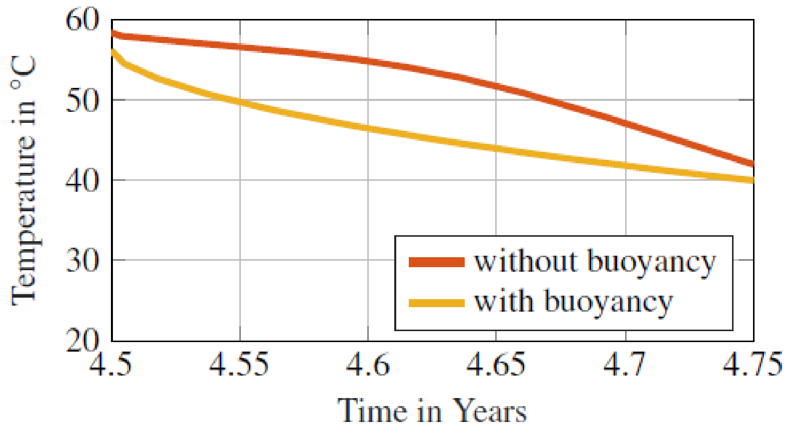
- Heat flow rate of the gas boiler (peak generation) for two scenarios
- Using the DHN as a short-term-storage
- Optimizing the supply temperature to reduce the peak generation of the gas boiler in exchange for higher combined heat and power plant heat production

9.5 % reduction of peak heat production

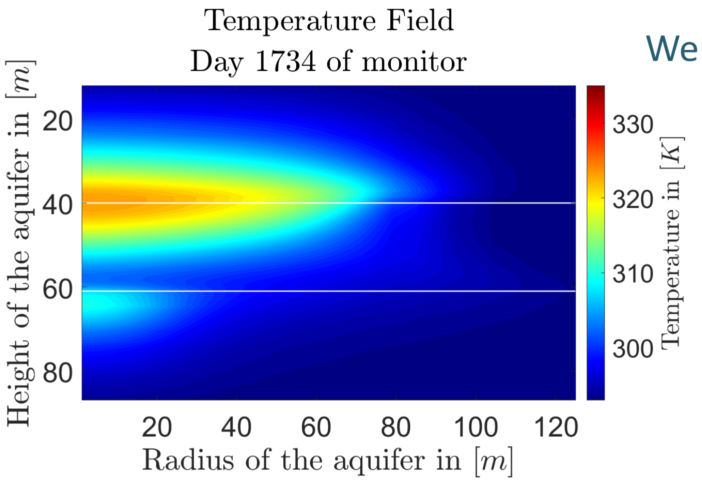
Why Modelica? Example auf Aquifer Thermal Storage



Heat Recovery Factor over 10 Years of operation



Well head temperature curve in the 4th year of operation



Temperature distribution in an ATES at 4th Year after the production phase

Conclusion

- Modeling concept for the simulation of unaggregated DHN with several thousand substations
- Automatic generation and parametrization of DHN topologies
- Automatic model generation of DHM simulation models from DHN topologies
- Optimization of the supply temperature enables load shifting for reduction of costly peak heat generation

TransiEnt Library

EffiziEntEE

iNeP

Thank you!

Arne Speerforck
Jan Westphal
Jonathan Vieth
Institute for Engineering Thermodynamics

tuhh.de

TUHH
Technische Universität Hamburg