Karlsruher Institut für Technologie

Extending a building-scale optimisation model to low-temperature district heating systems

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#SES4DH2018

4DH
4th Generation District Heating Technologies and Systems

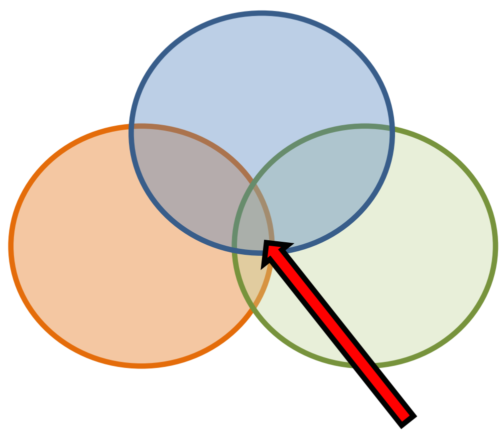
Literature overview and objective

DH Network optimisation

- Möller & Nielsen (2014)
- Möller & Lund (2010)
- Nielsen (2014)
- Delangle et al. (2017)
- Unternährer et al. (2017)

Decentralized building supply

- Akbari, Jolai & Ghaderi (2016)
- Omu, Choudhary & Boies (2013)
- Wouters, Fraga & James (2015)
- (Baetens et al. 2012)
- Coninck et al. (2014)
- Mehleri et al. (2013); (2012)



Study considers all three aspects

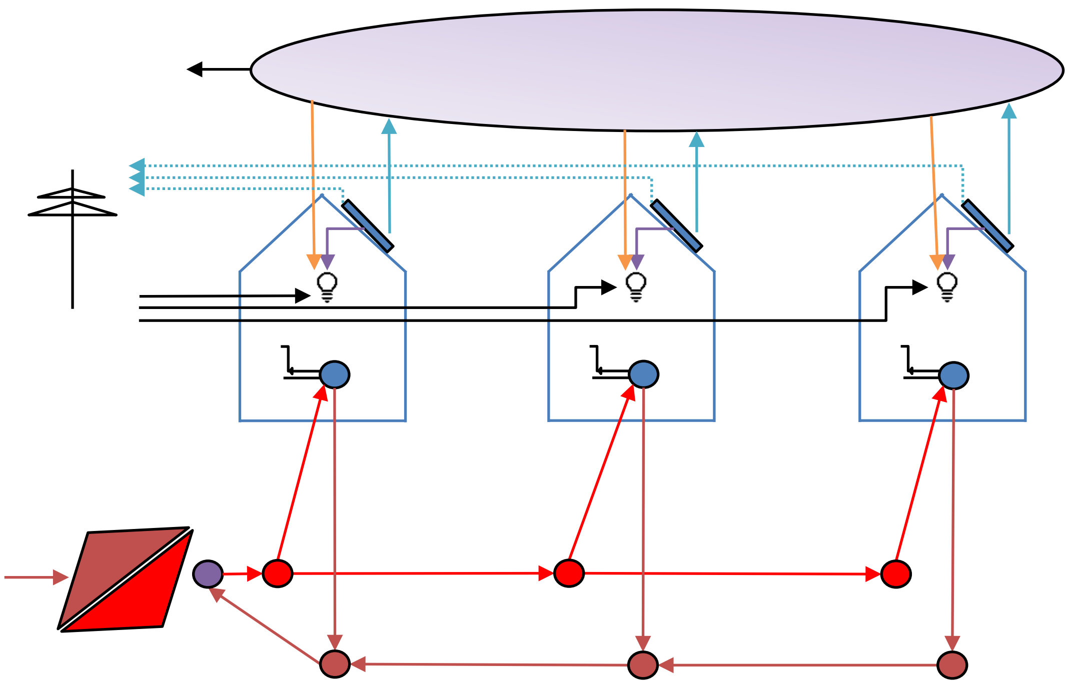
Centralized district supply

- Yang, Zhang & Xiao (2015)
- Orehounig, Evins & Dorer (2015)
- Walker et al. (2017)
- Wu et al. (2018)

Objective: Comparison of centralized and decentralized energy supply systems in urban areas with different residential areas

General approach to model extension

- Existing building-level MILP model extended to include heating grid
- Directional graph
- Building and heat generation plant shown as nodes
- Forward and return flow shown in the model
- Grid topology represented in the model by matrices



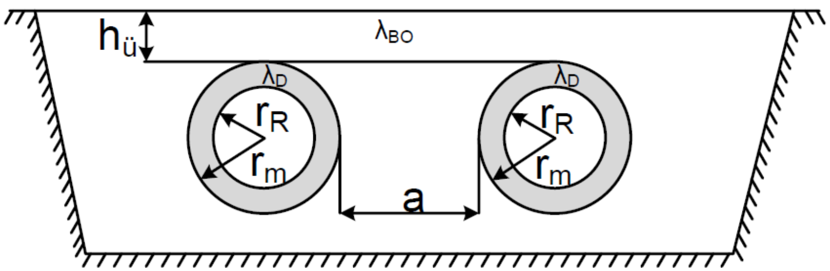
Dimensioning options for pipelines

- Each section is allocated a pipe diameter
- Available pipe diameters are linked to various properties

Properties	Data origin
Inner radius	Exogenous
External radius	Exogenous
Thermal conductivity of the insulation	Exogenous
Max. heat flow	Endogenous
Max. volume flow	Endogenous
Max. & average flow velocity	Exogenous
Material and installation costs	Exogenous
Heat losses	Endogenous
Pressure losses	Endogenous

Calculation of heat losses

$$loss_{max,R}^{Heat,l} = Surf_{R,l} * \Delta T_L * U_R$$

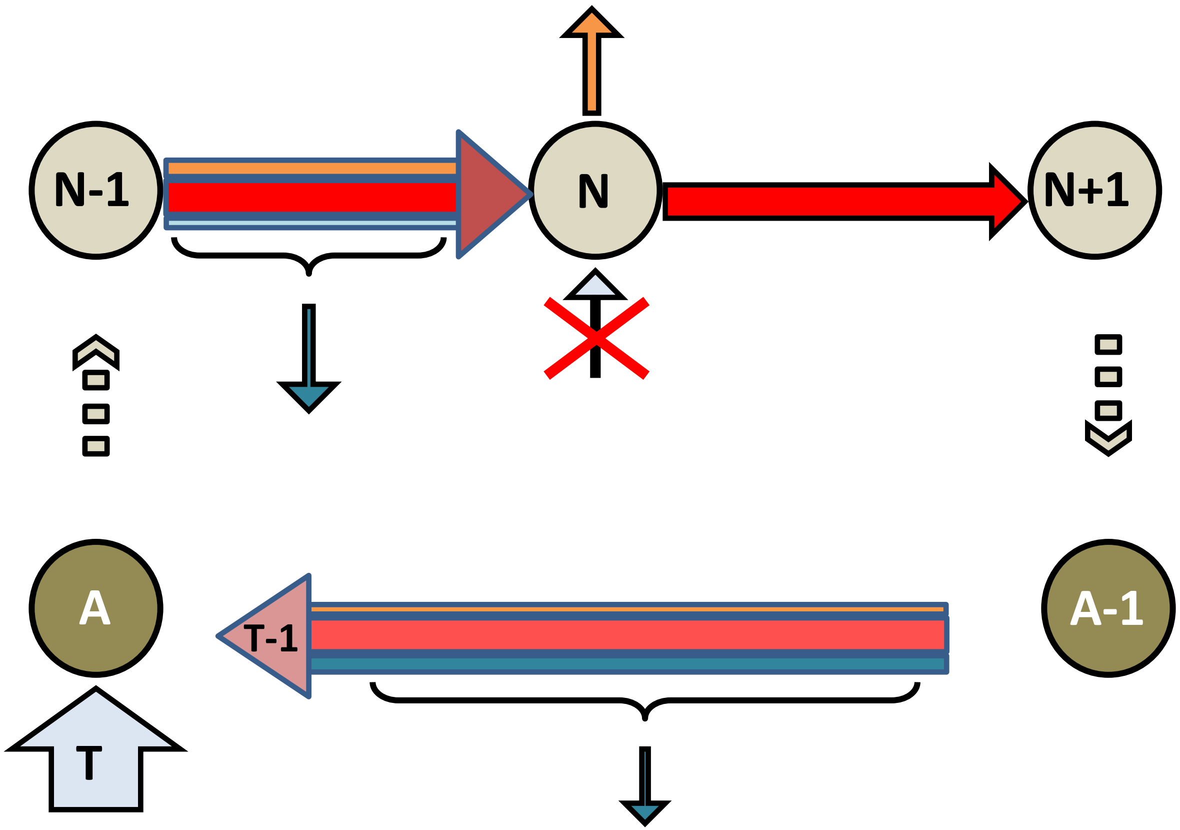
Relevant Surface	Difference in temperature	Heat transfer coefficient
		• Installation distance & overlap height the same for all pipe diameters

$$surf_R = 2 * \pi * l_R * r_R$$

$$\Delta T_L = \frac{T_{VL} + T_{RL}}{2} - T_{Bo}$$

$$U_R = \frac{1}{\frac{r_R}{\lambda_D} \ln\left(\frac{r_A}{r_R}\right) + \frac{r_R}{\lambda_{Bo}} \ln\left(\left(\frac{4(h_Ü + r_A)}{r_A}\right) + \frac{r_R}{\lambda_{Bo}} \ln\left(\left(\frac{2(h_Ü + r_A)}{a + 2r_A}\right)^2 + 1\right)^{0,5}\right)}$$

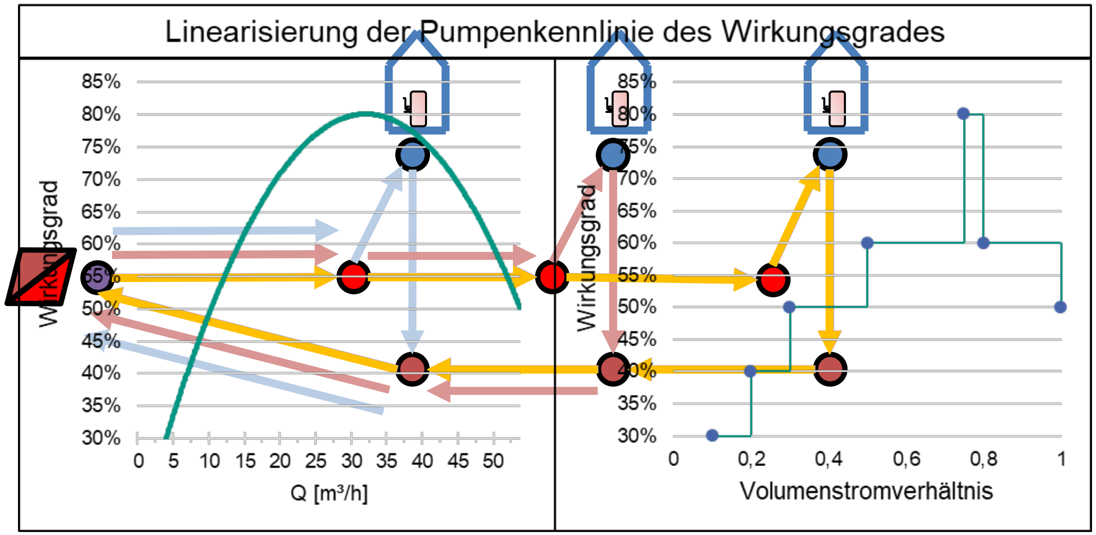
Balance Equation



Pipe diameters are defined on the basis of various restrictions

Description of the model extension

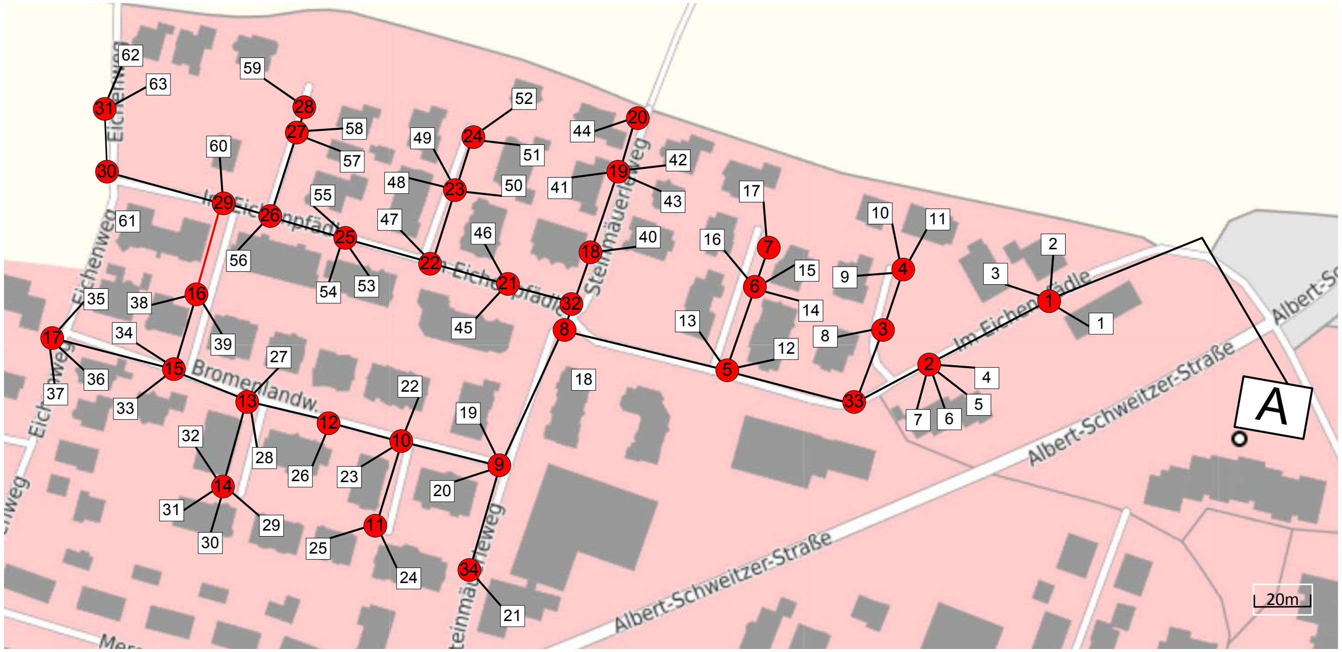
- Determination of the critical path in the model
- Determine maximum case for critical path
  - Maximum distance
  - Smallest pipe radii
  - Maximum case is subdivided for selection of head differences
- Consideration of the efficiencies in the model



Validation

- **Modifications of the model:**

Properties of the network	
Location	Böblingen, Germany
Length	2062 m
Connected houses	63



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Validation results

Comparison point	Model	Existing network
Annual heat losses	7,11%	25%

- Use of smaller pipe diameters in the model
- Lower flow temperature in the model
- Better insulation in the model

Validation results

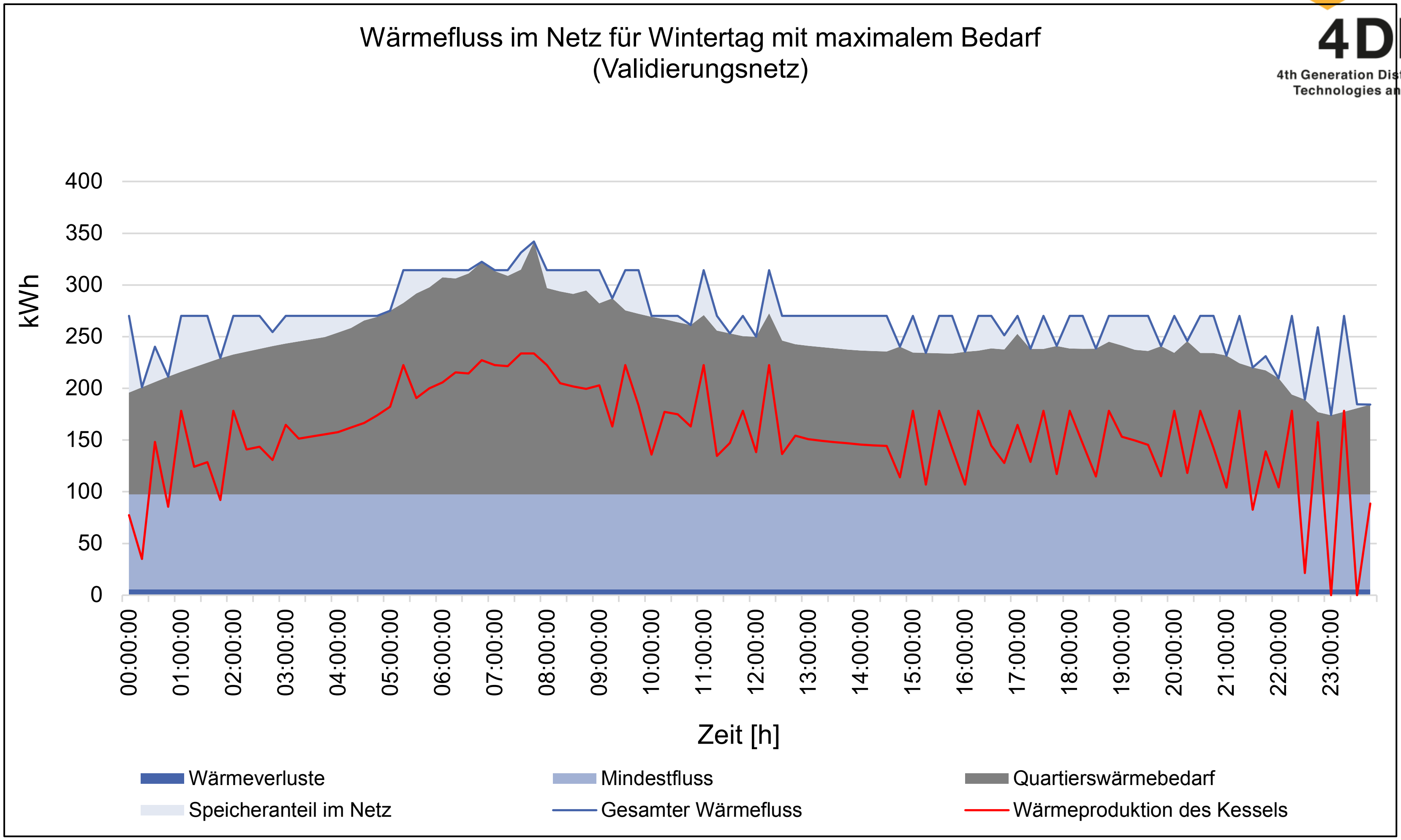
Comparison point	Model	Existing network
Annual heat losses	7,11%	25%
Deviation of the installed boiler capacity	Model 30 % lower	
Deviation of the installed pump capacity	Model 4% lower	

- Differences in the heat demand of the networks (lower peak load in the model)
- Reduced heat losses mean that less heat generally has to be generated
- Perfect foresight of the model

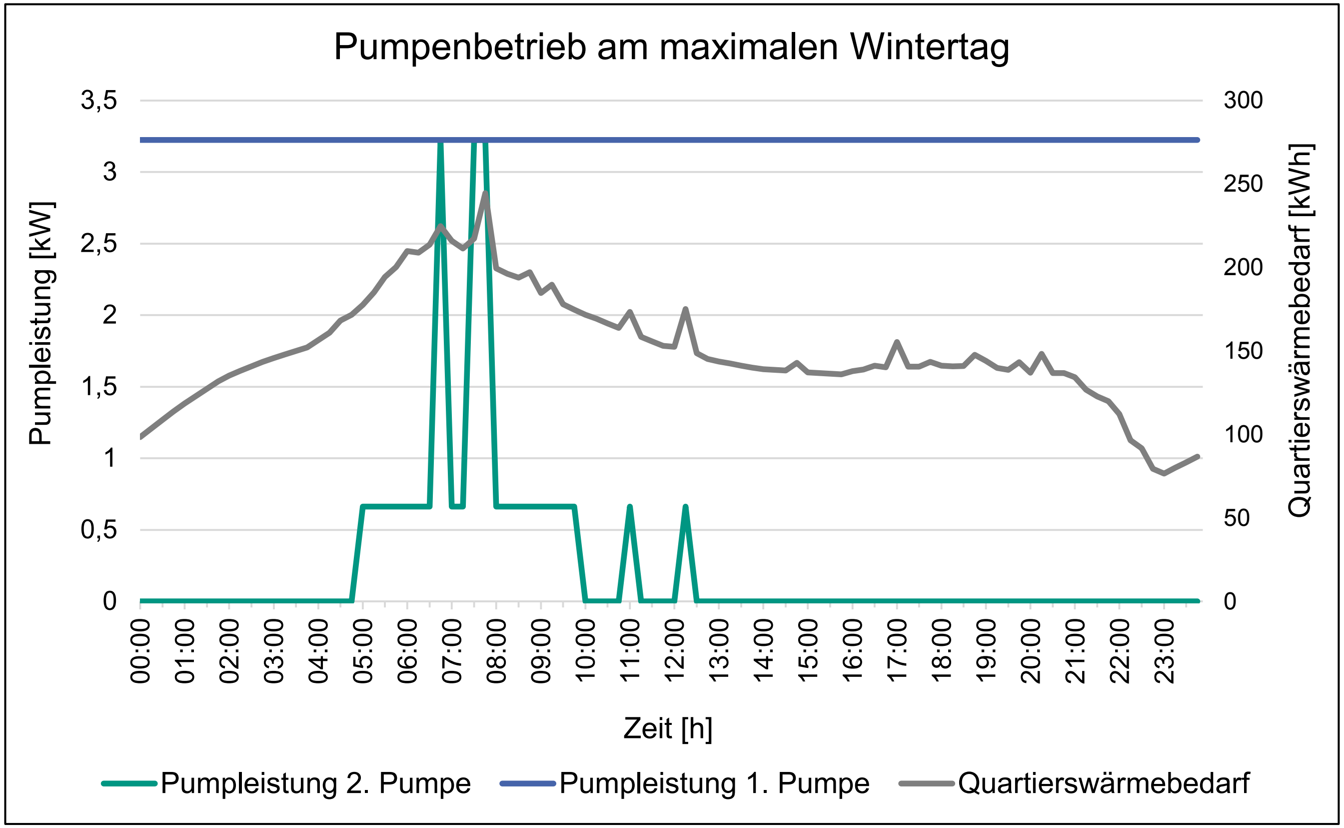
Validation results

Comparison point	Model	Existing network
Annual heat losses	7,11%	25%
Deviation of the installed boiler capacity	Model 30 % lower	
Deviation of the installed pump capacity	Model 4% lower	
Deviation of the annual heat production	Model 21 % lower	

Validation results: heat flow



Validation results: pump



Discussion

- Question of over-specification…
- Assuming not over-specified:
  - Runtime reduction by e.g. decomposition methods
  - Increase the temporal scope of the model
    - currently only 8 days
  - Consider more technologies
  - Better pump linearization trough SOS2-Constraints
  - Consider more realistic plant operating times
  - Possibility to allocate individual capacities to the houses

Summary and Conclusions

- MILP model for DH network layout and operation, given demand sinks and network topology
- Possible to model and compare centralized and decentralized systems (not shown here)
- Validation shows deviations from empirical data are plausible and system operation is realistic
- Further work should improve the pump and plant operation, e.g. part load efficiencies and ramp rates

Thank you for your attention!