Hochschule Düsseldorf
University of Applied Sciences

Zentrum für Innovative Energiesysteme
Centre of Innovative Energy Systems

USECASE: DIGITAL TWIN OF A HYBRID DISTRICT HEATING PLANT WITH HEATPUMP

Dennis Götzelmann (MSc.)

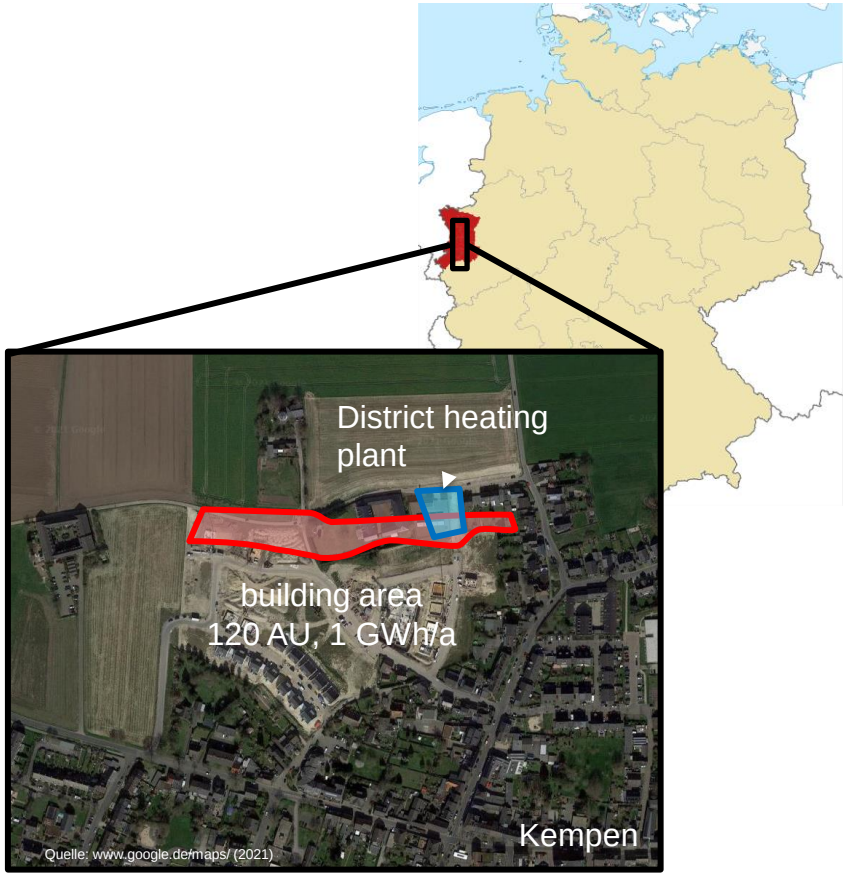
University of Applied Sciences Düsseldorf
Centre of Innovative Energy Systems (ZIES)

Carnot User Meeting 2022

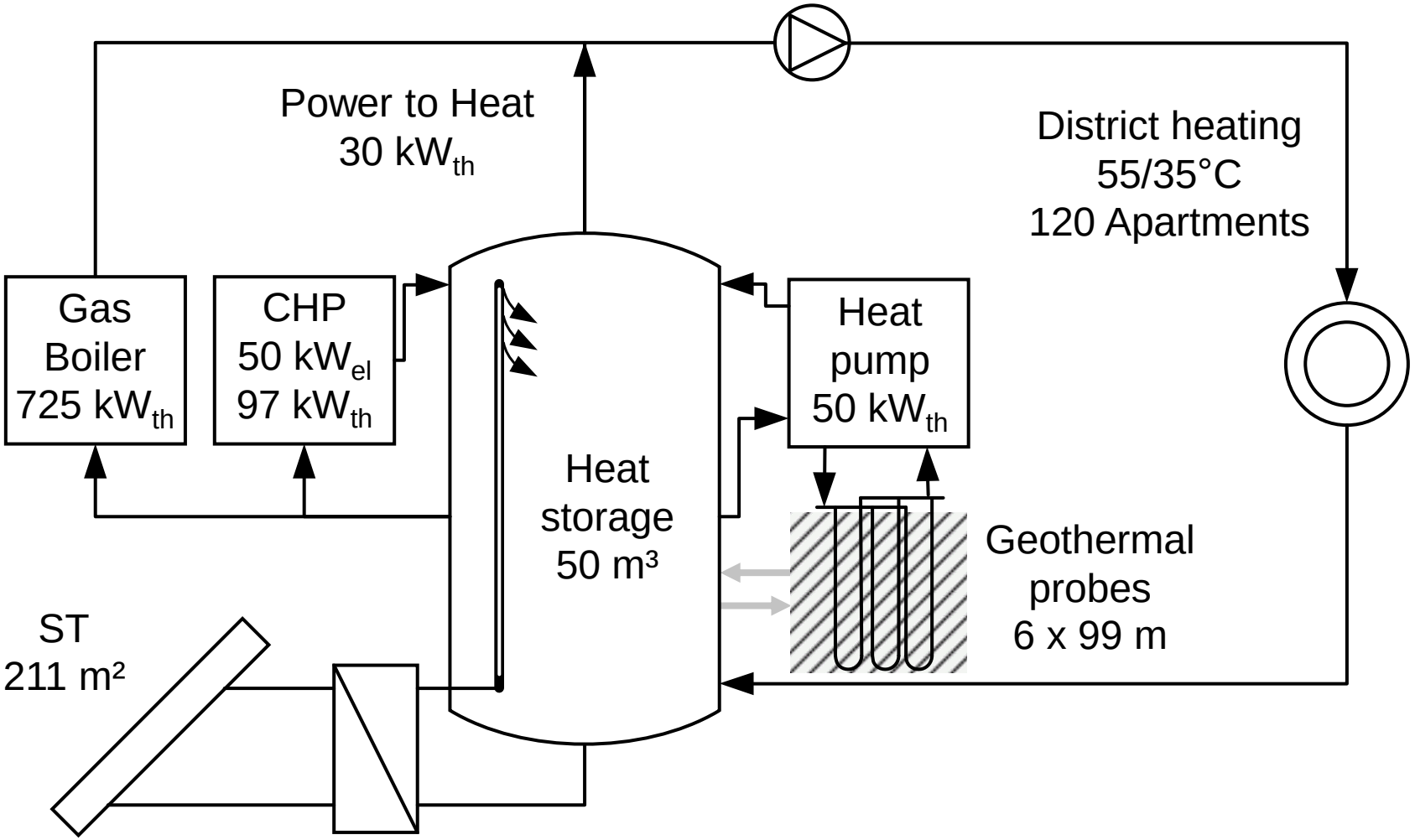
RESEARCH PROJECT BESTHEATNET

Project Content

- **Low-temperature local heating grid**
- high share of renewable energies for a new building area in Kempen (planning and construction)
- **Intelligent control** for self-learning optimization of heat/electricity generators operation (development and test)
- **Project partners**
  University of Applied Sciences Düsseldorf, Centre of Innovative Energy Systems
- Stadtwerke Kempen GmbH



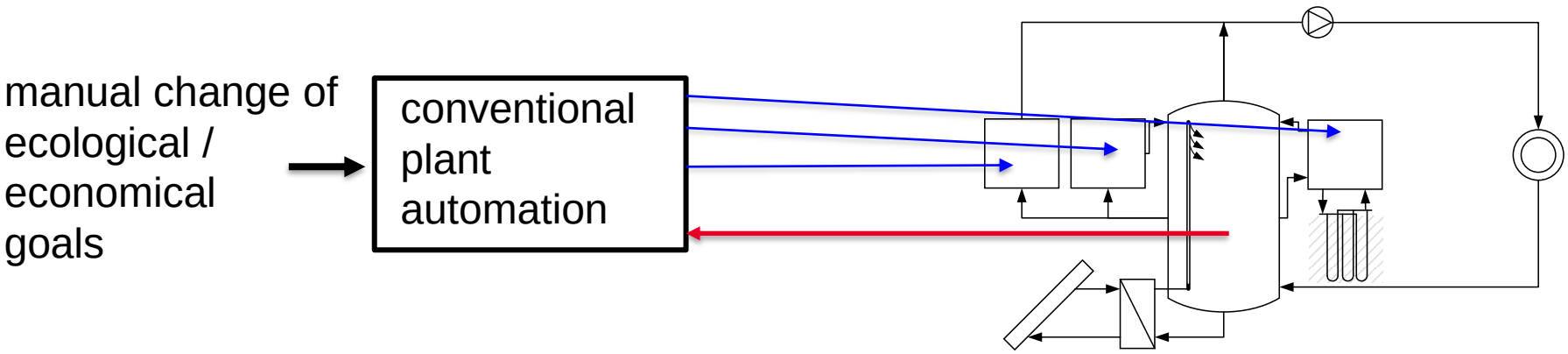
THE HYBRID DISTRICT HEATING PLANT (OVERVIEW)



DISTRICT HEATING PLANT (IMAGES)

CONVENTIONAL PLANT CONTROL:

Automatisation based on fixed settings
(e.g. temperatures in the heat storage)



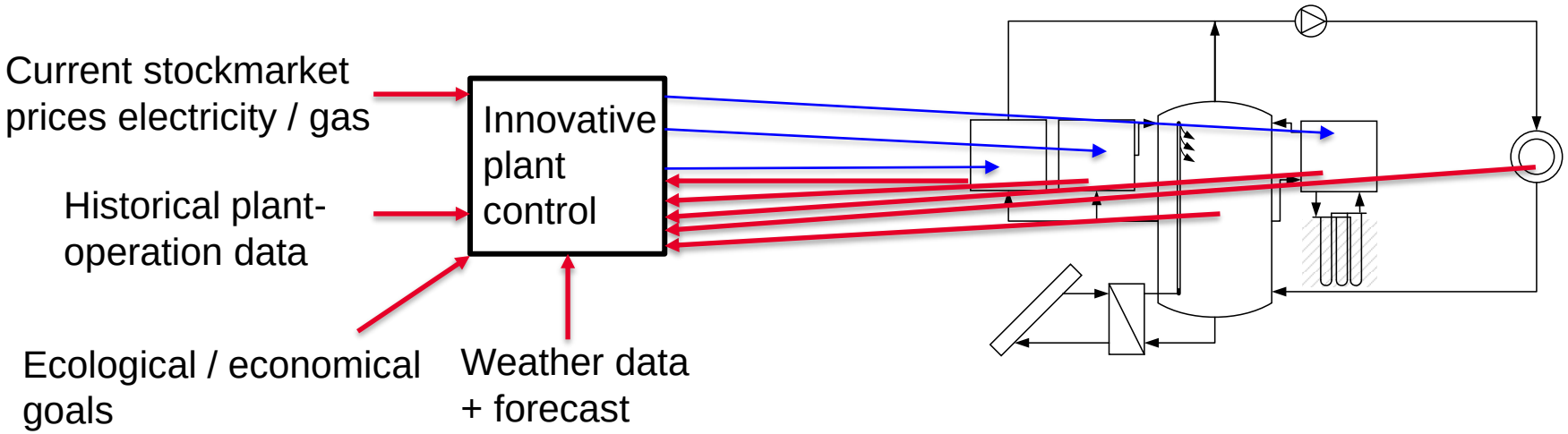
E.g. maximum use of CHP → Minimal operating costs (current energy-economic boundary conditions, -> will change)

Problems:

- Change in economic boundary conditions or system behavior?
- Consideration of ecological boundary conditions?

PROJECT MAIN GOAL: INNOVATIVE PLANT CONTROL

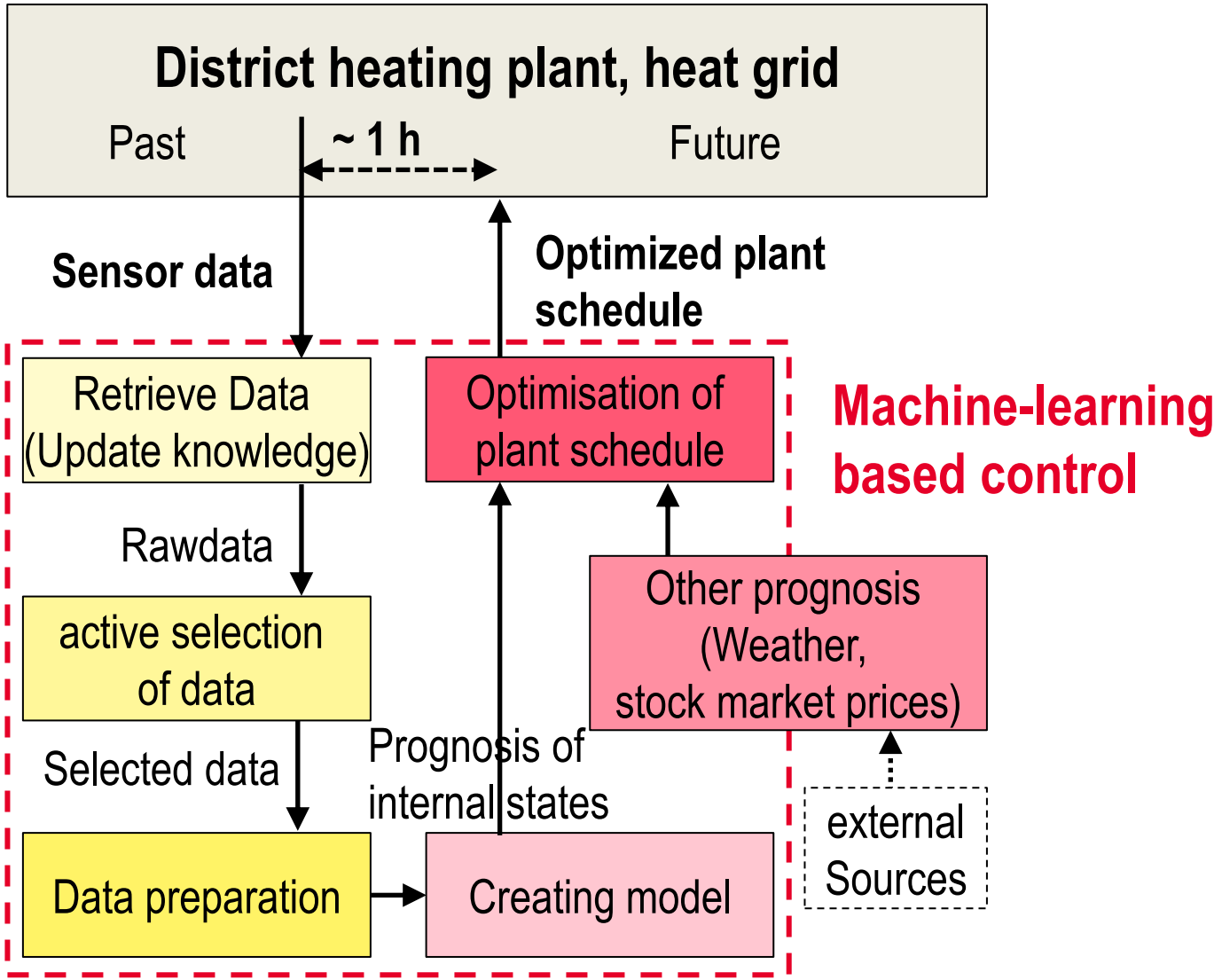
- Development of a **fast, predictive** and **flexible** control (based on methods of machine learning), plant operation based on extended boundary conditions (hourly updated)



➢ Plant operation will adapt according to hourly updated boundary conditions + historical data of plant operation & heat demand (heat grid)

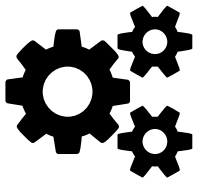
PROJECT MAIN GOAL: INNOVATIVE PLANT CONTROL

How it works:



WHY GENERATING A DIGITAL TWIN?

- **Training / testing / improving** the machine learning based control algorythm before going „live“ -> saving time + preventing potential damage / reliability issues for the heating grid



- **Benchmark platform**: Innovative control algorythm VS „conventional“ automation

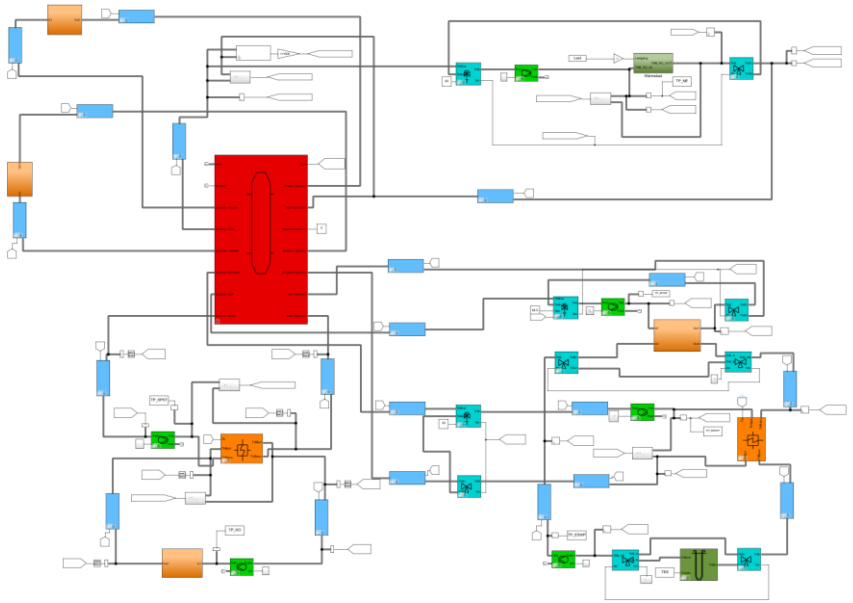
- **Optimization of the real heating plant**

- Developing / improving (classic) control concepts
- In case hardware has to be changed / added, the new systembehaviour can be simulated beforehand

DIGITAL TWIN GENERATED WITH MATLAB SIMULINK

Used software: Matlab (2019a) Simulink, Carnot 7.1

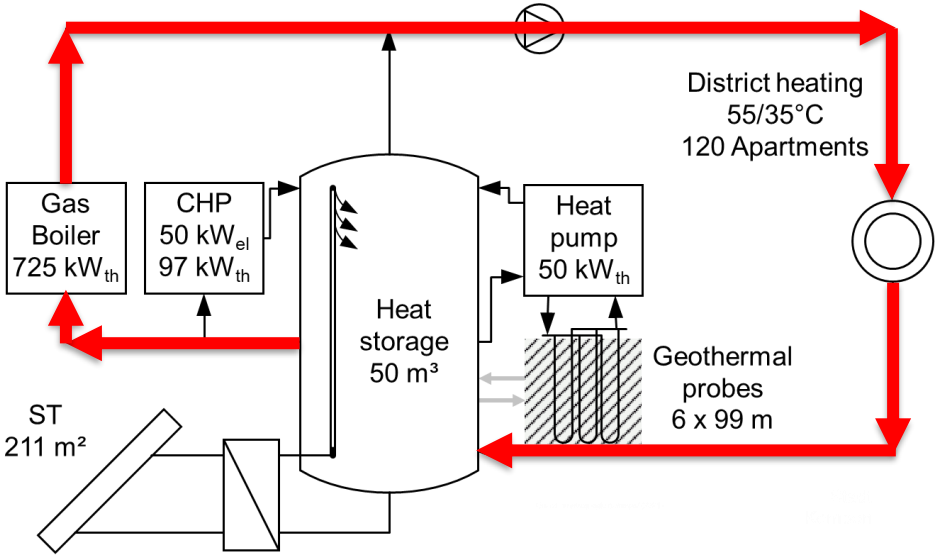
- **Thermal model of the main components:** Bufferstorage, heatpump + geothermal probes, solar thermal collectors, CHP, gas boiler, basic piping, power to heat resistor, heat load
- Weatherdata: DWD for Düsseldorf 2018
- Aggregate controls and automatation (Stateflow)

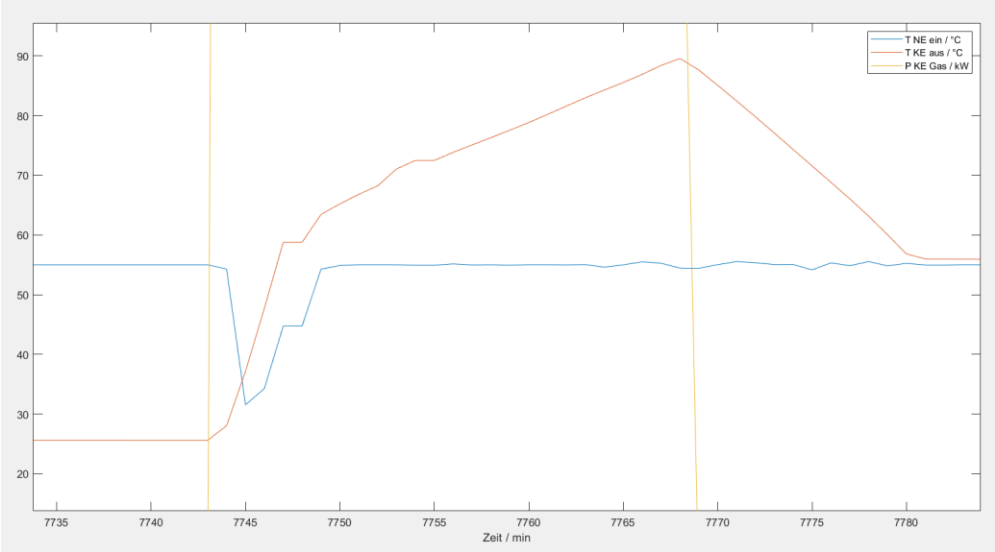


TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

Gas boiler:

- Planning idea: Maximize heat in storage generated by eficcient heat generators
- Therefore: no storage connection and check flap at the storage outlet
- Reality: cooldown of grid during start up + overheating due to throttled volume flow (heat grid pump)
- Modulation problems: large minimum power: 250kW

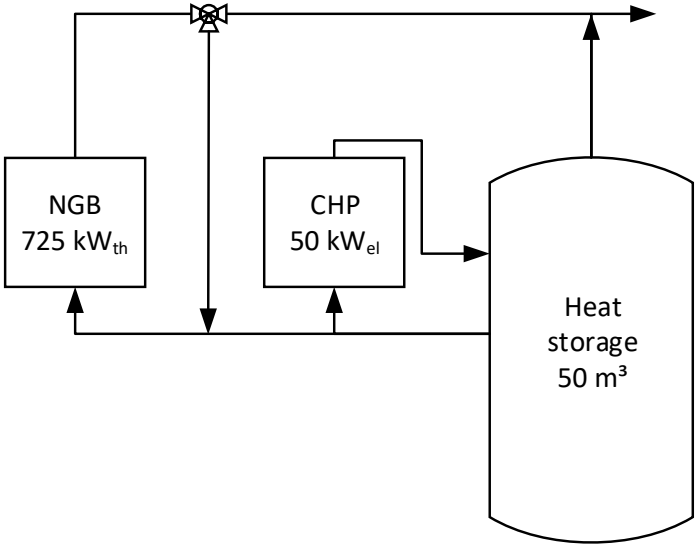


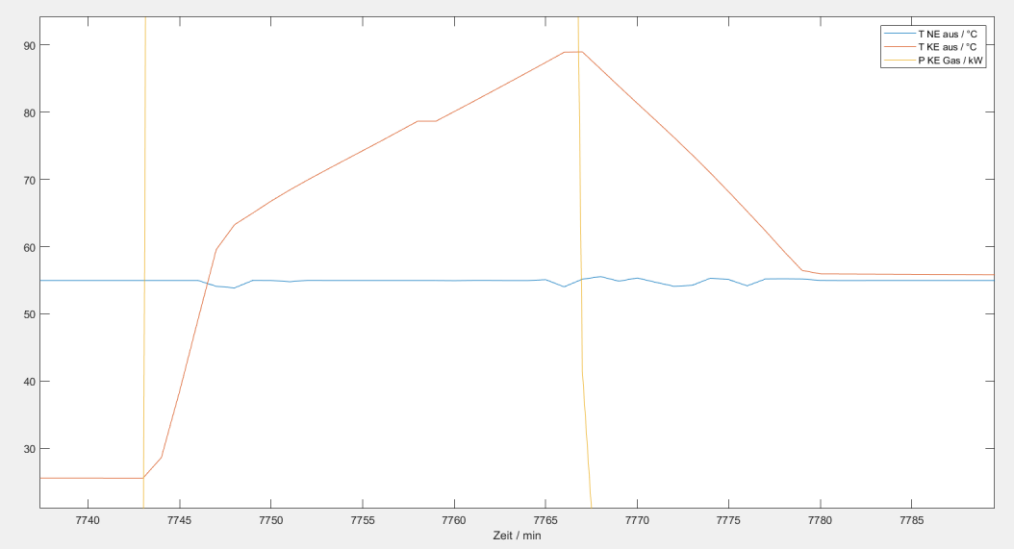


TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

Solution 1:

- Mixing valve against cooldown of grid
- Simulations showed improvements
- Cooldown effect could be reduced
- Overheating of gas boiler + forced shutdown still present

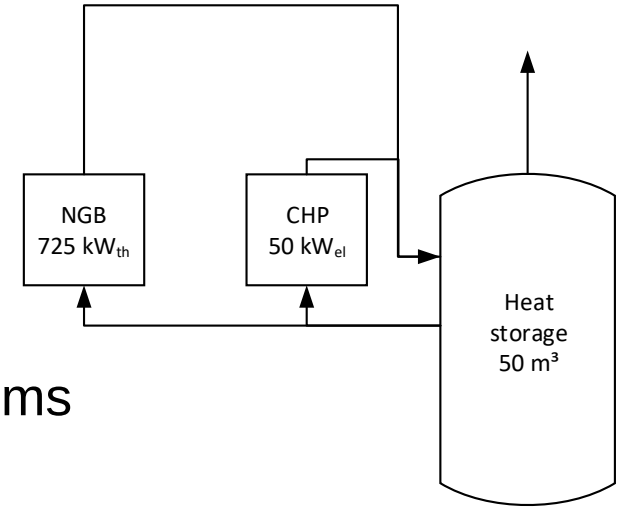


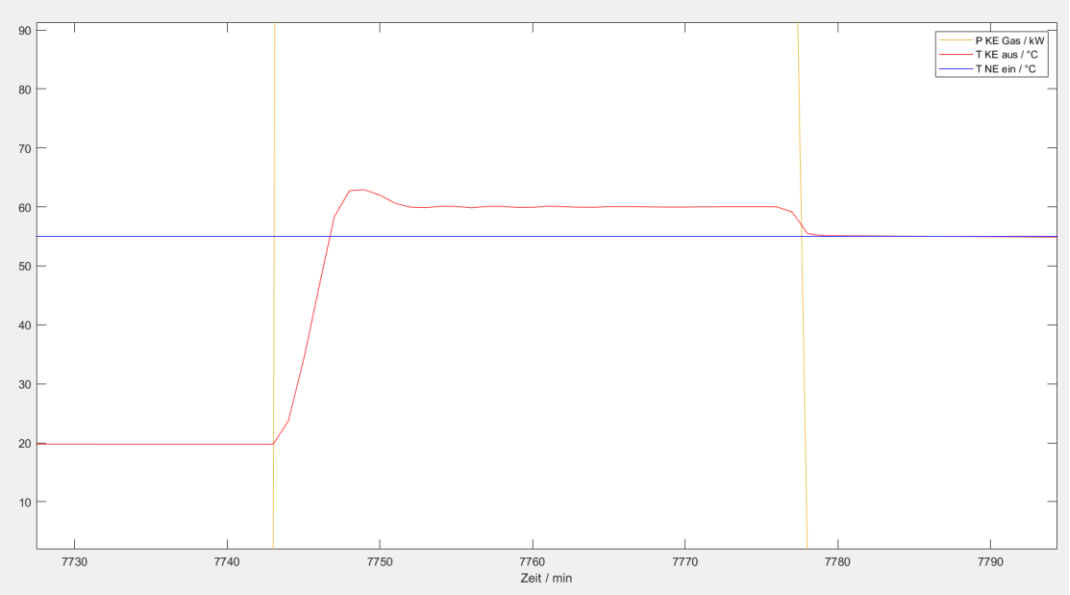


TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

Solution 2:

- Connecting the gas boiler to the heat storage via CHP
- Simulations show that both problems can be adressed with connecting the gas boiler to the heat-storage
- has been sucessfully realized

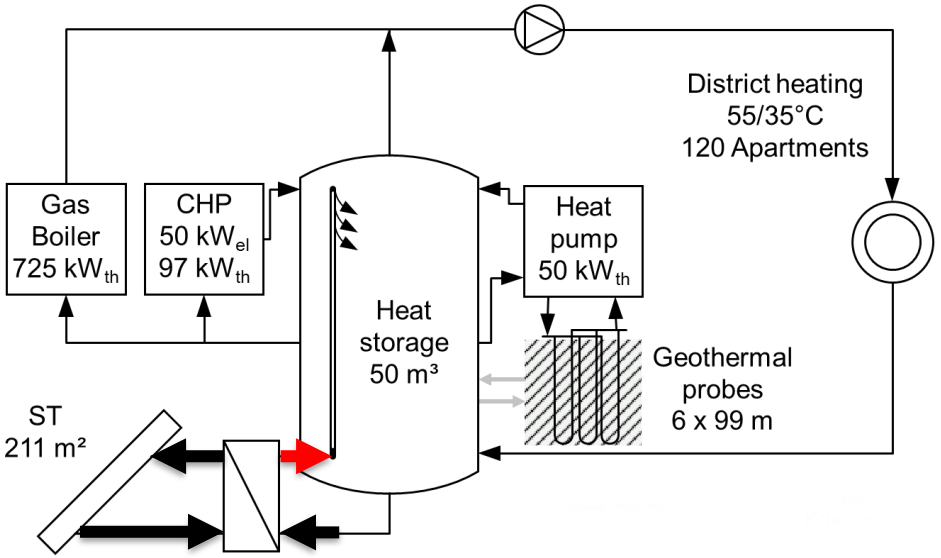


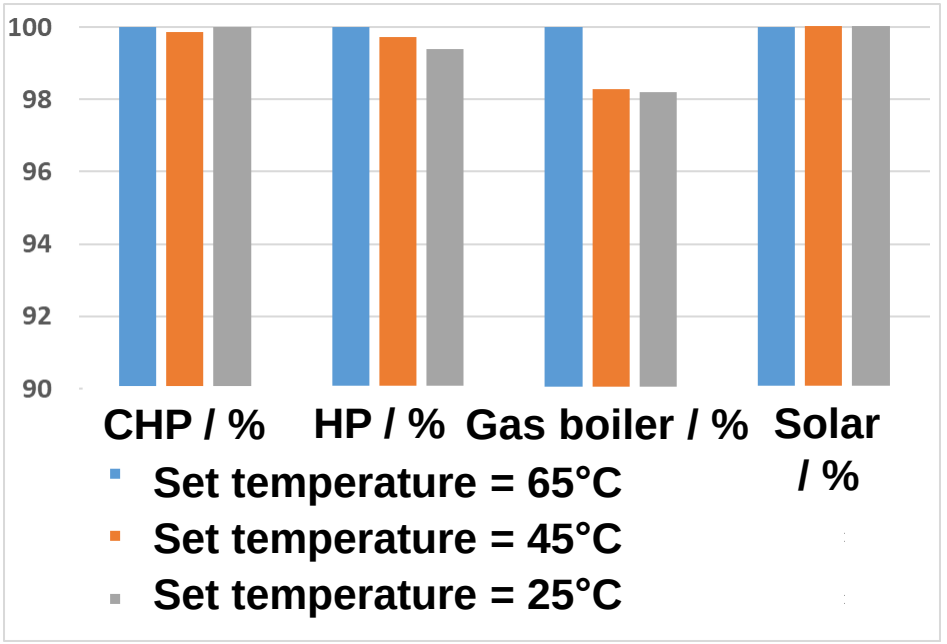


TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

Optimization of solar thermal control set values:

- Detailed information was available from vendor -> control could be implemented in simulation
- Optimization of set flow temperature via annual simulations.
- Result: annual cost reduction of up to 2%, reduction of CO2 emissions up to 8%
- Optimal settings realized in the heating plant

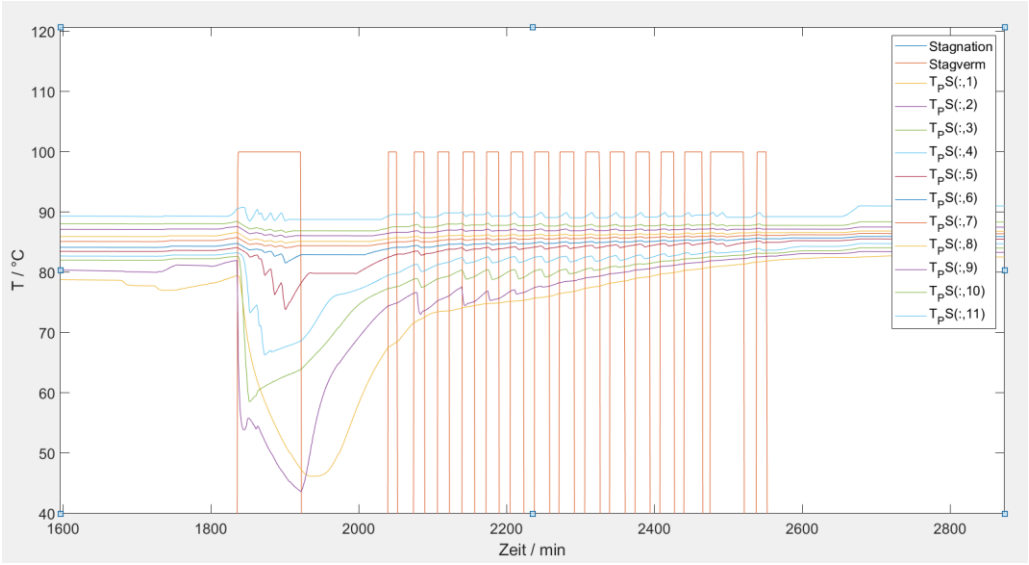




TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

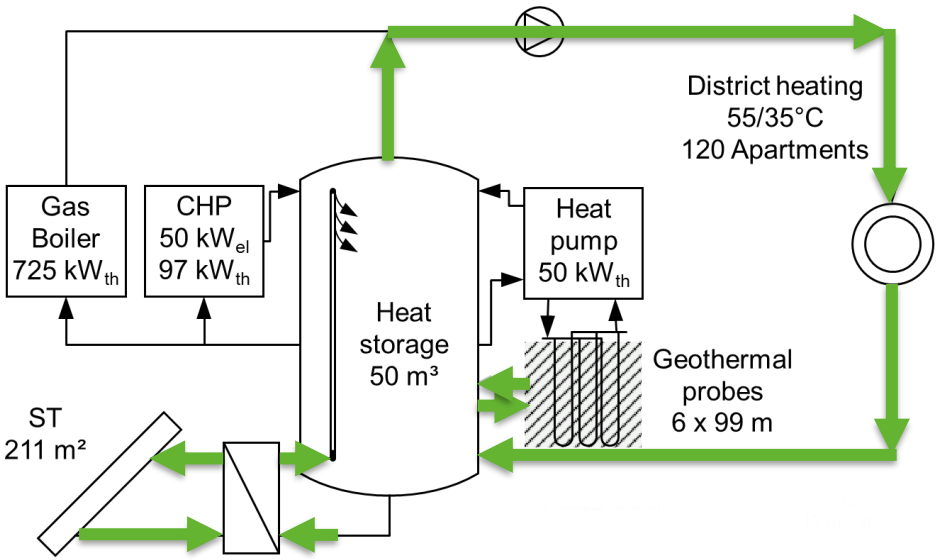
Missing control concept to prevent solar stagnation:

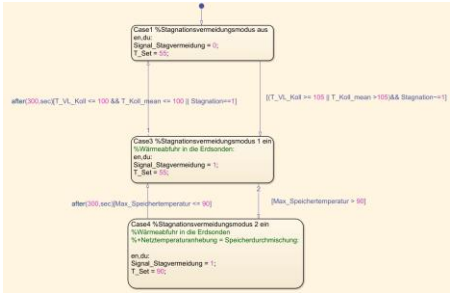
- Only stagnation control within the solar thermal system
- Heat storage hydraulically connected with geothermal probes, -> potential heatsink available
- Analysis were done with the digital twin to find a concept to prevent stagnation



TECHNICAL REALWORLD CHALLENGES APPROACHED WITH THE DIGITAL TWIN

- A concept could be developed, tested and optimized
- In case collectors or heat storage get too hot, the thermal layers of the heat storage will be mixed + cooling via ground probes
- Later: Implementation into sps system





CONCLUSION

Digital twin created with Simulink Carnot toolbox was used to / for:

- simulate thermal behaviour of real heating plant + controls
- early detection of concept problems
- annual simulations (analysis of energy, cost and ecology)
- develop and test missing controls / improvements
- speed up development, training and testing the machine learning concept

Thank you for your attention

Dennis Götzelmann (MSc.)

University of Applied Sciences Düsseldorf

Centre of Innovative Energy Systems (ZIES)