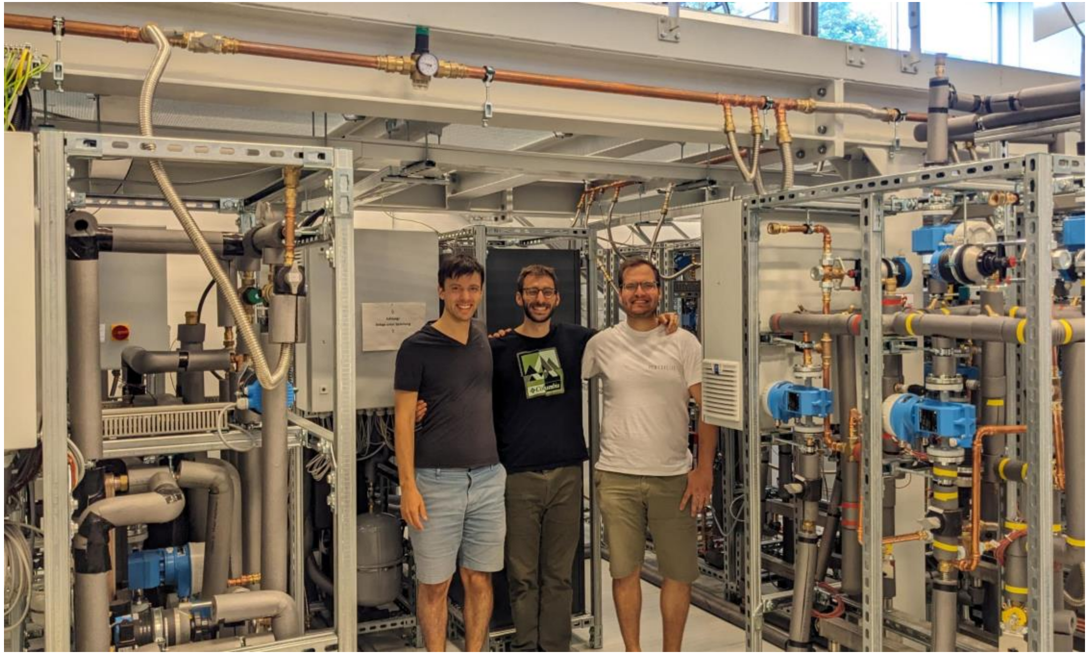
5^{th} Generation District Heating and Cooling

Daniel Zinsmeister, Orestis Angelidis, Ulrich Ganslmeier



Agenda

1. Indroduction of the CoSES laboratory and the district heating and cooling experiment
   Ulrich Ganslmeier

2. Operational designs for District Heating and Cooling Networks with Decentralized Energy Substations: Development and Validation
   Orestis Angelidis

3. Flow direction in district heating and cooling grids with booster heat pumps: Does it make sense to have unidirectional flow?
   Daniel Zinsmeister

4. Open discussion

The Laboratory for
Combined Smart Energy Systems (CoSES)

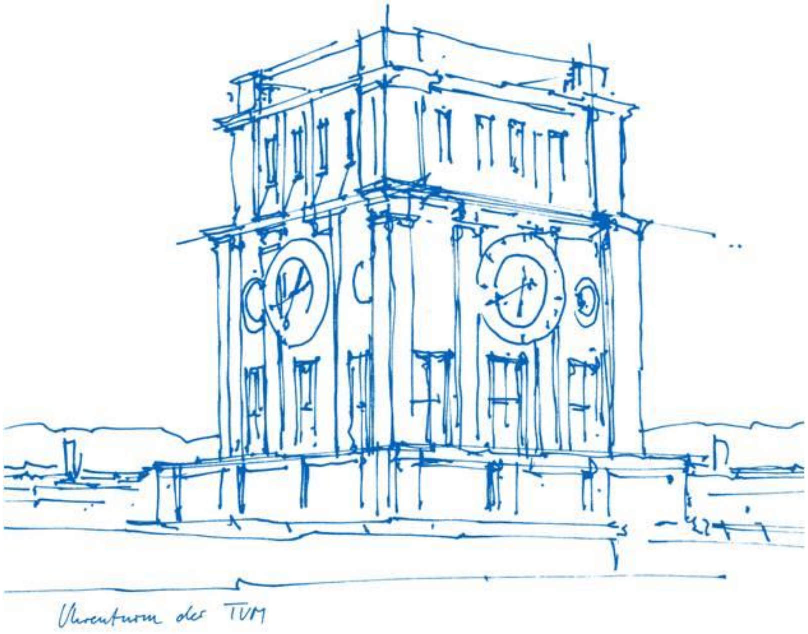
Ulrich Ganslmeier

Technical University of Munich

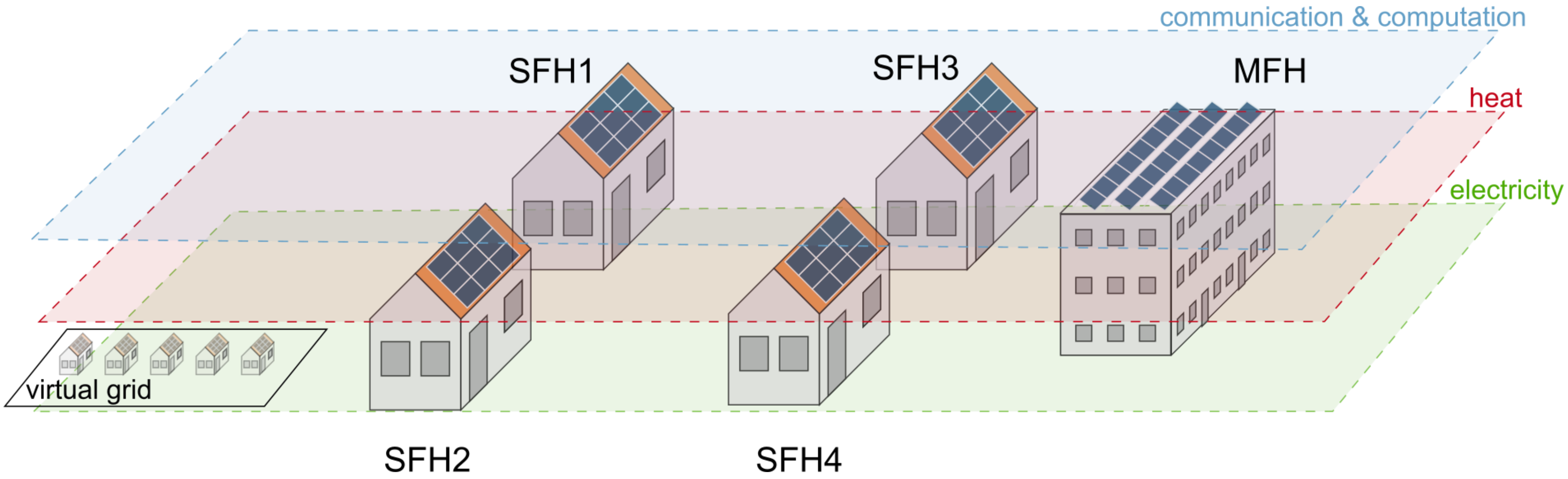
TUM School of Engineering and Design

Institute of Integrated Materials, Energy and Process Engineering (MEP)

Munich, 23.08.2023

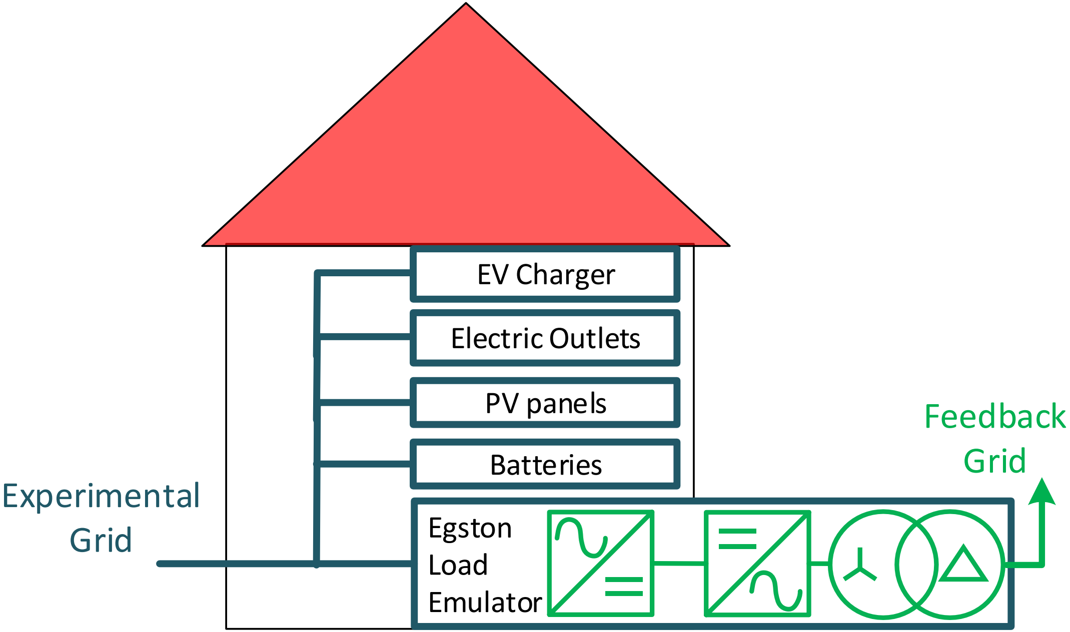


Smart Energy System with 5 Buildings

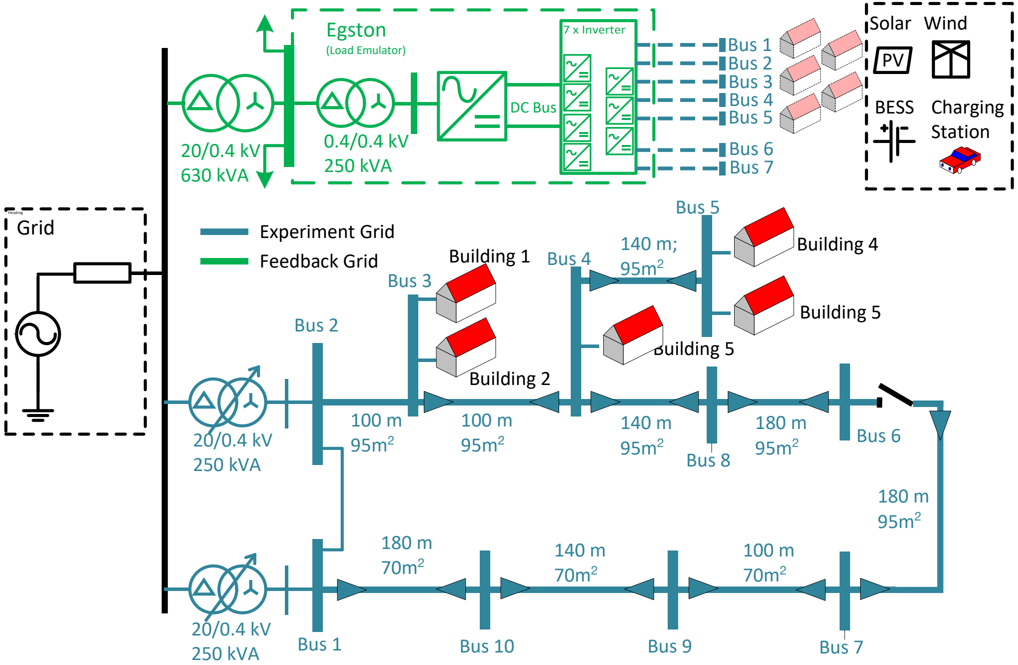


V. S. Perić et al., "CoSES Laboratory for Combined Energy Systems At TU Munich“
2020 IEEE PES General Meeting

Electrical House Emulator



Electrical Grid

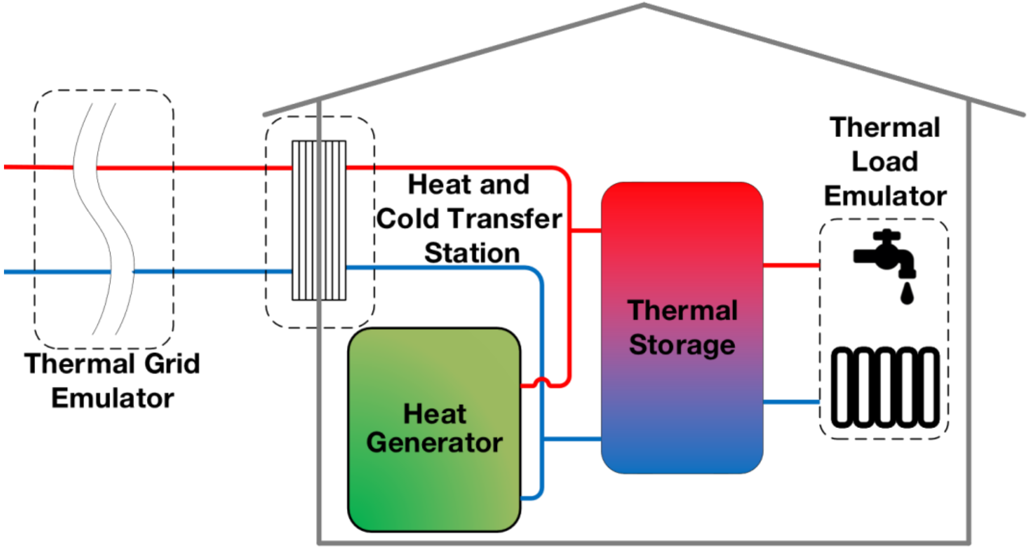


V. S. Perić et al., "CoSES Laboratory for Combined Energy Systems At TU Munich“ 2020 IEEE PES General Meeting

Thermal House Emulator

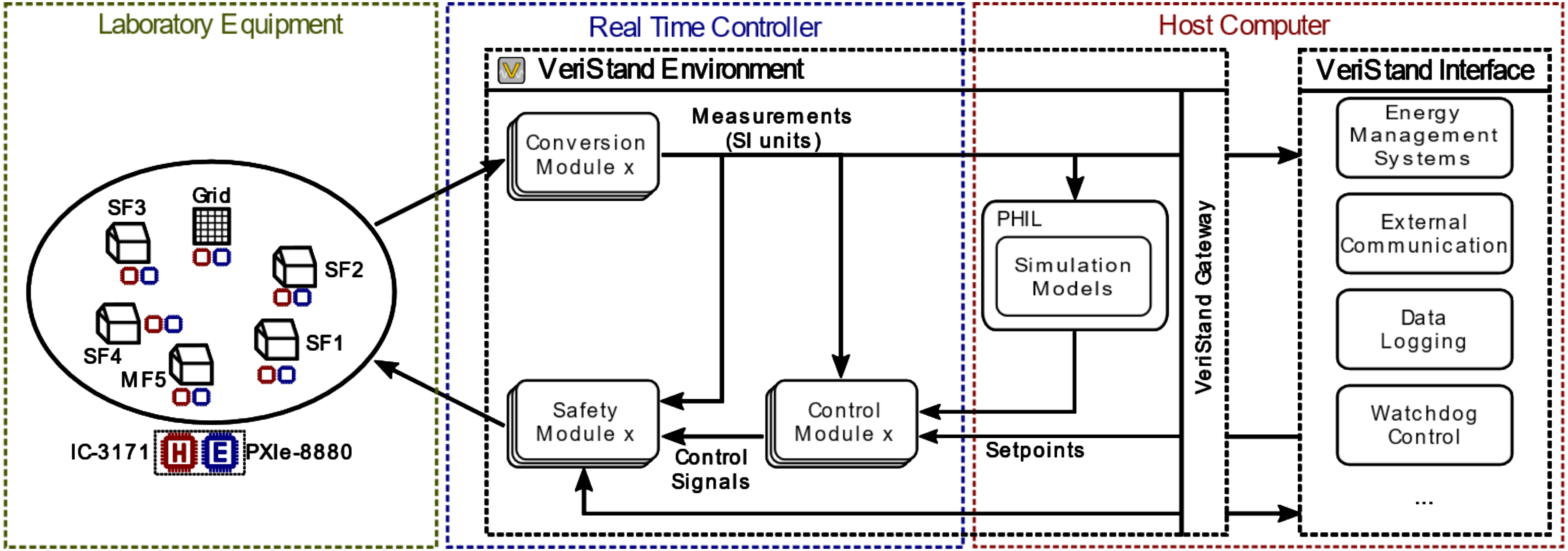

Air Source Heat Pump


Ground Source Heat Pump

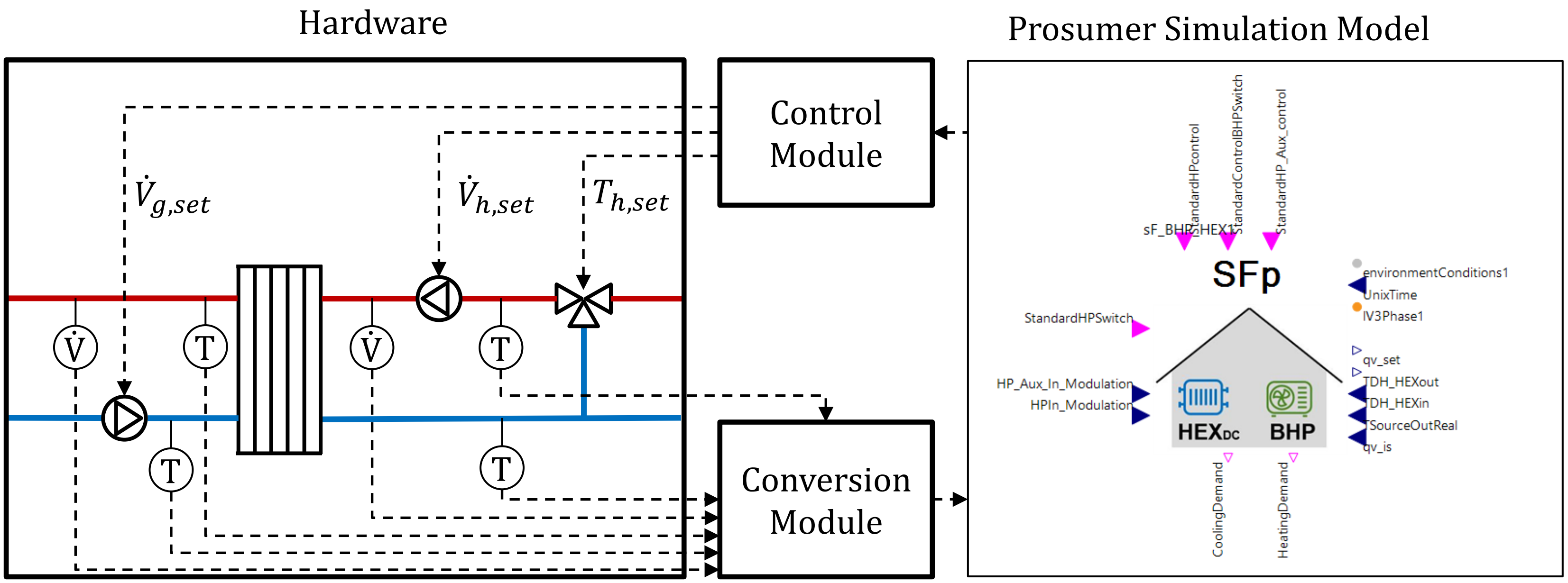



Booster Heat Pump Transfer Station

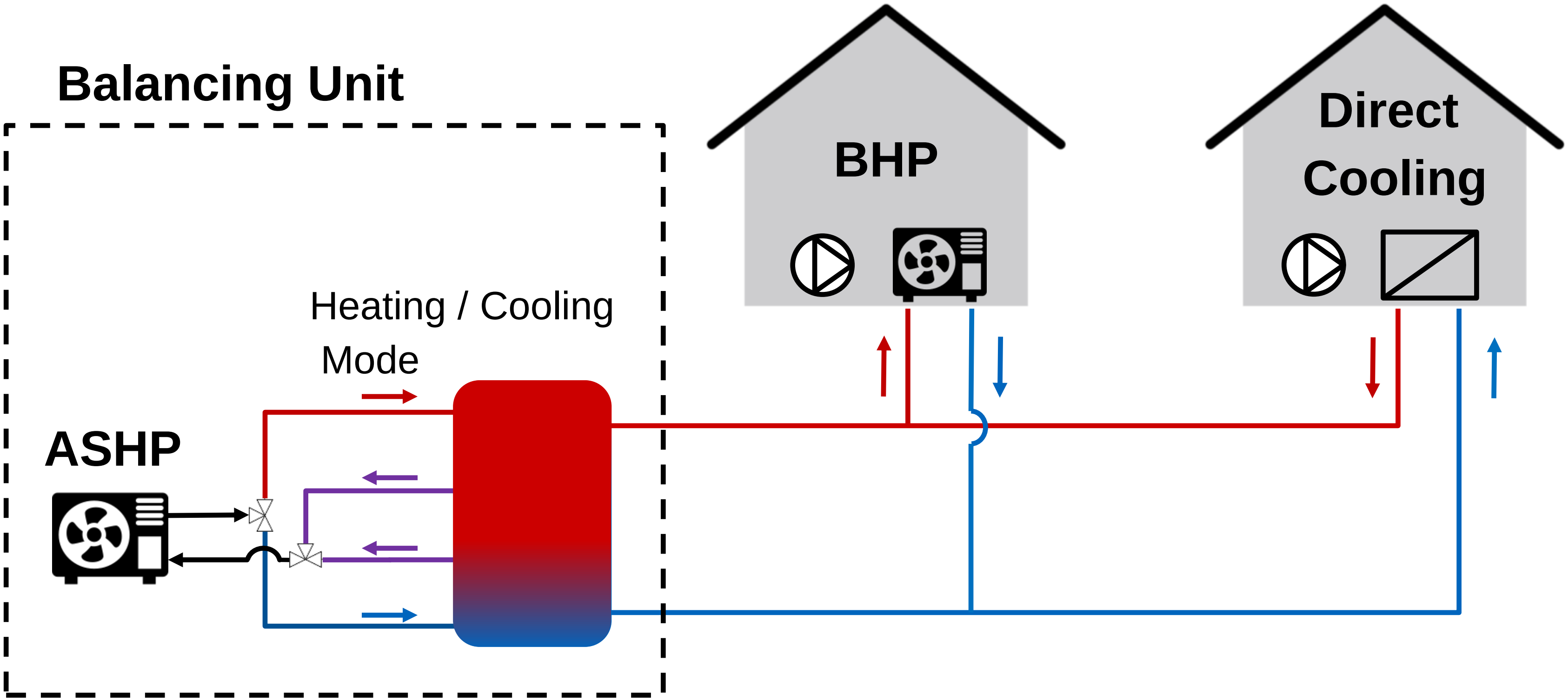
Control Structure

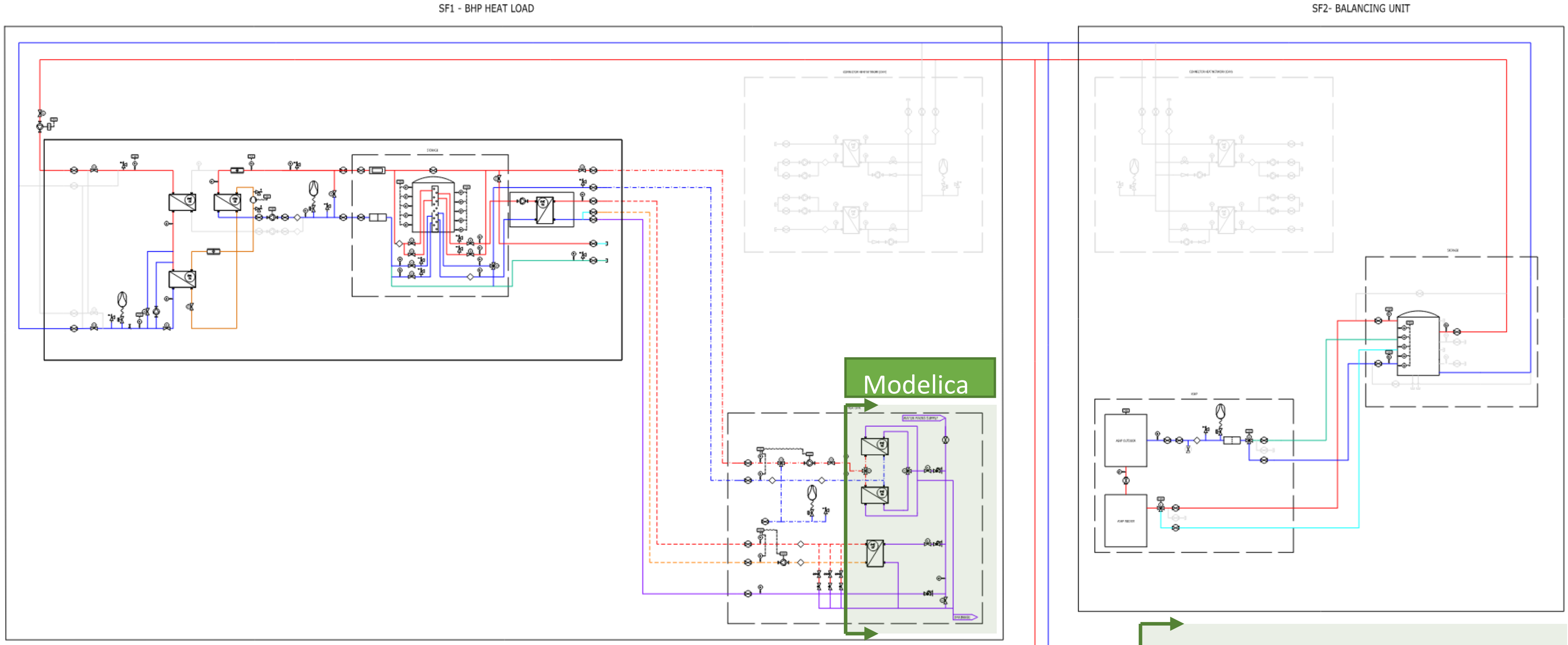


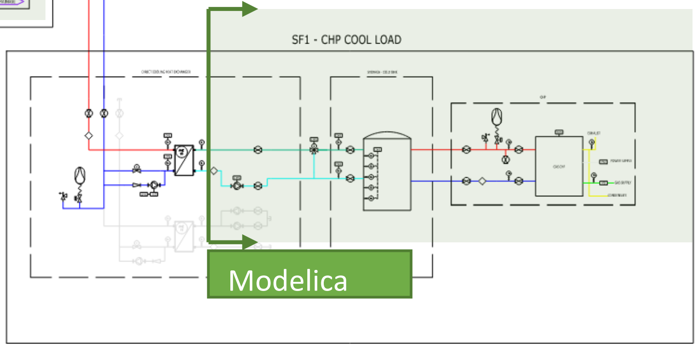
PHIL Setup of a CHN



Prosumer Experiment Hardware Setup







PHIL Setup - Modelica

Modelica models for buildings give back the **return temperature** from the buildings for both heating and cooling. They also provide a **reference flowrate** to meet the power demand based on the flow temperature.

Key message

Experimental and simulative infrastructure for the study of new concepts of 4th and 5th generation district heating and cooling systems and individual heating systems

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Thermal Devices

	House 1	House 2	House 3	House 4	House 5
Heat Generator	CHP (2 kW_{el}, 5,2 kW_{th}) Condensing Boiler (20 kW_{th}) Solar Thermal (9 kW_{th})	Condensing Boiler (20 kW_{th}) Air source heat pump (19 kW_{heat}, 9 kW_{cold}) Solar Thermal (9 kW_{th})	Ground source heat pump (19 kW_{heat}) Solar Thermal (9 kW_{th})	Stirling Engine (1 kW_{el}, 6 kW_{th}) Integrated auxiliary boiler (20 kW_{th})	CHP (5 kW_{el}, 11,9 kW_{th}) CHP (18 kW_{el}, 34 kW_{th}) Condensing Boiler (50 kW_{th})
Thermal Storage	800 l	785 l	1000 l	1000 l	2000 l
Domestic Hot Water	Fresh water storage (500 l)	Fresh water station	Fresh water station	Internal heat exchanger	Fresh water station
Transfer Station	Bidirectional Transfer Station (30 kW_{th}) Booster heat pump (19 kW_{heat}, 14 kW_{cold})	Bidirectional Transfer Station (30 kW_{th})	Bidirectional Transfer Station (30 kW_{th})	Bidirectional Transfer Station (30 kW_{th})	Bidirectional Transfer Station (60 kW_{th})
Thermal Load Emulator	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}, 9 kW_{cold}	30 kW_{heat}	60 kW_{heat}

Source: [1]

OPERATIONAL DESIGNS FOR DISTRICT HEATING AND COOLING NETWORKS WITH DECENTRALIZED ENERGY SUBSTATIONS: DEVELOPMENT AND VALIDATION

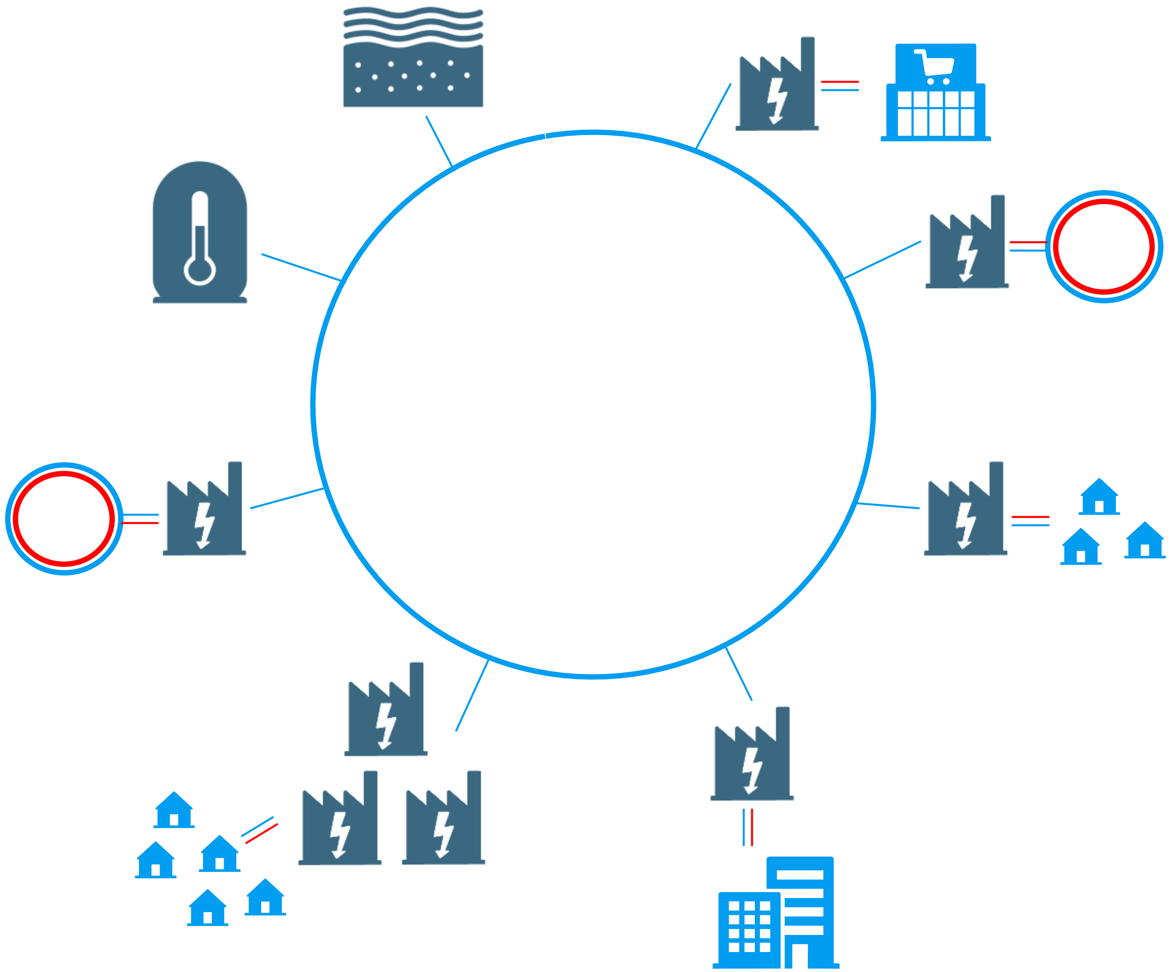
Date: Aug 2023

Orestis Angelidis, Daniel Zinsmeister, Ganslmeier Ulrich, Alan Thomson, Anastasia Ioannou, Daniel Friedrich, Gioia Falcone

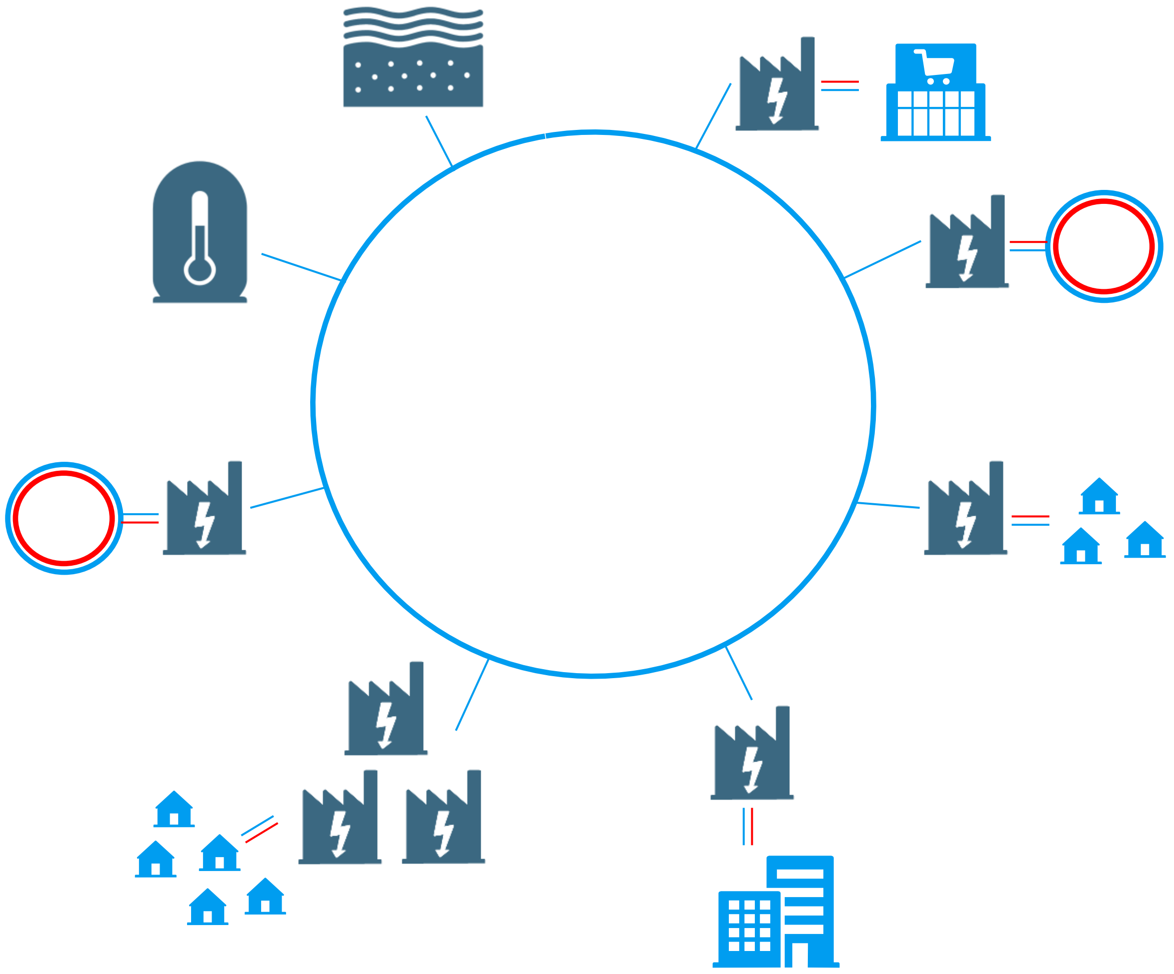
AGENDA

- Background and project aim
- Operational designs
- Experimental Validation
- Results and Discussion
- Conclusion

DISTRICT HEATING AND COOLING NETWORKS WITH DECENTRALIZED ENERGY SUBSTATIONS



DISTRICT HEATING AND COOLING NETWORKS WITH DECENTRALIZED ENERGY SUBSTATIONS



No validated system with controls and detailed operational philosophy is present.

This work, explores a complete thermofluid operational philosophy for and presents its experimental validation.

Prosumer interaction, thermofluid behaviour and control regime are included.

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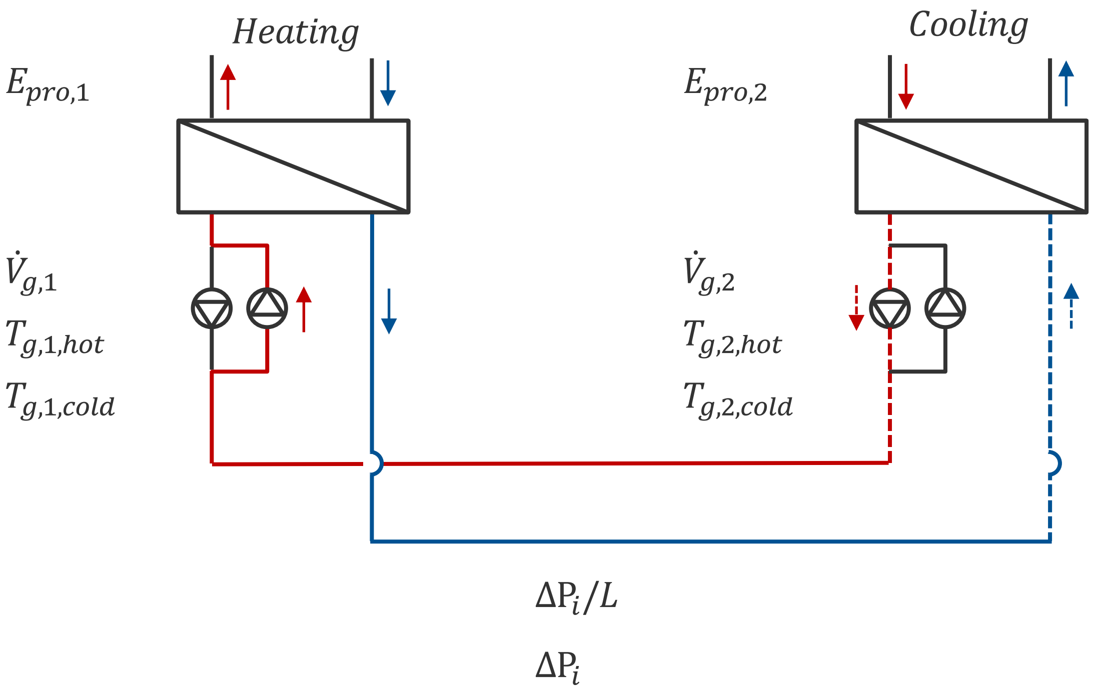
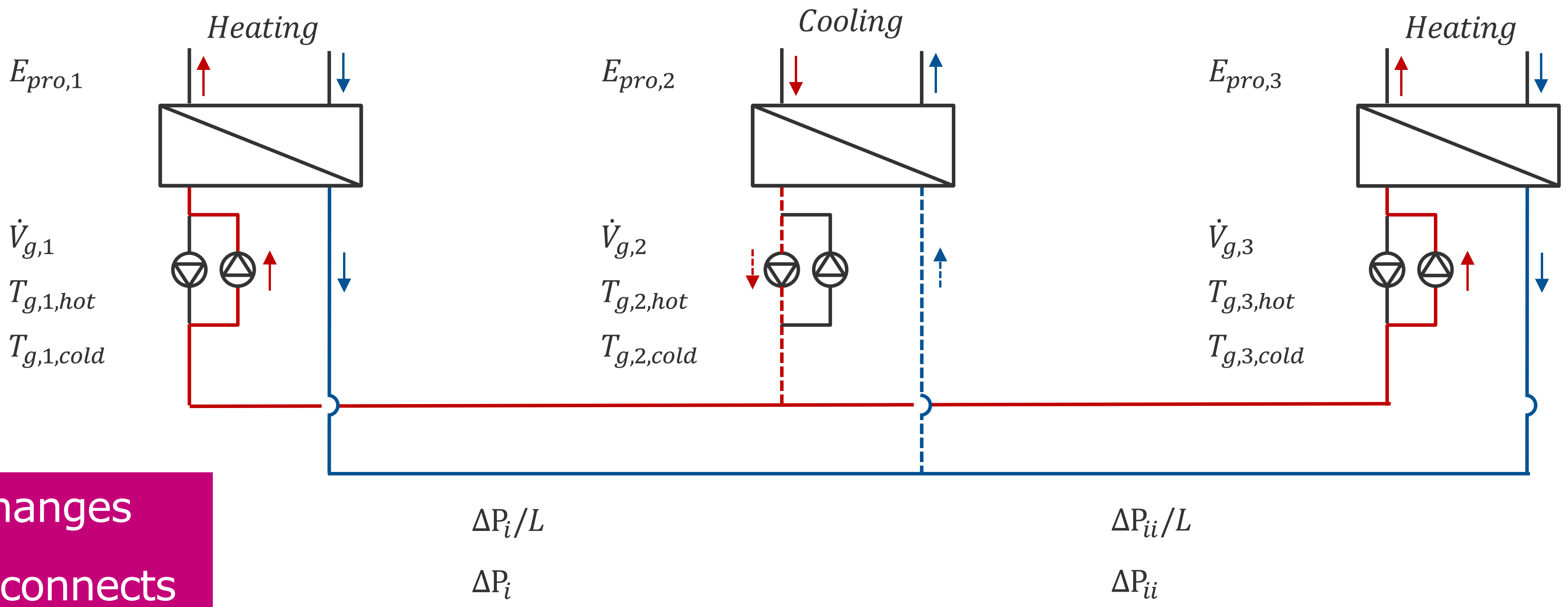
OPERATIONAL DESIGN DEVELOPMENT

HYDRAULIC SETUP – THE IDEAL WORLD



HYDRAULIC SETUP – THE IDEAL WORLD

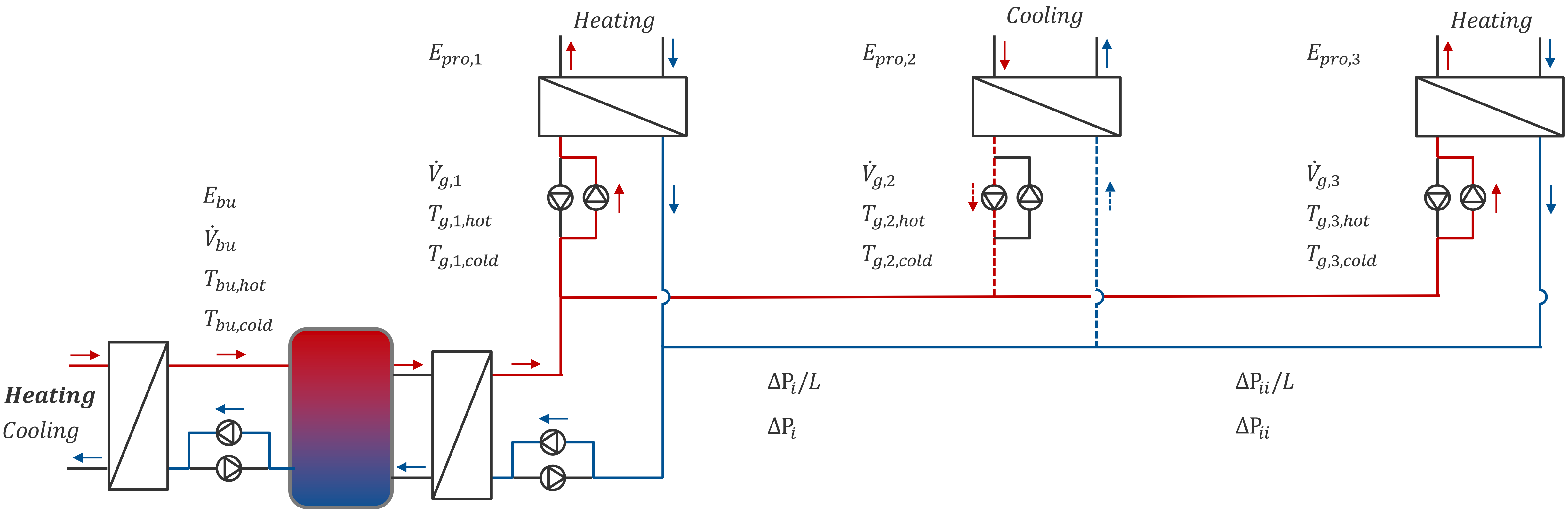


Demand changes

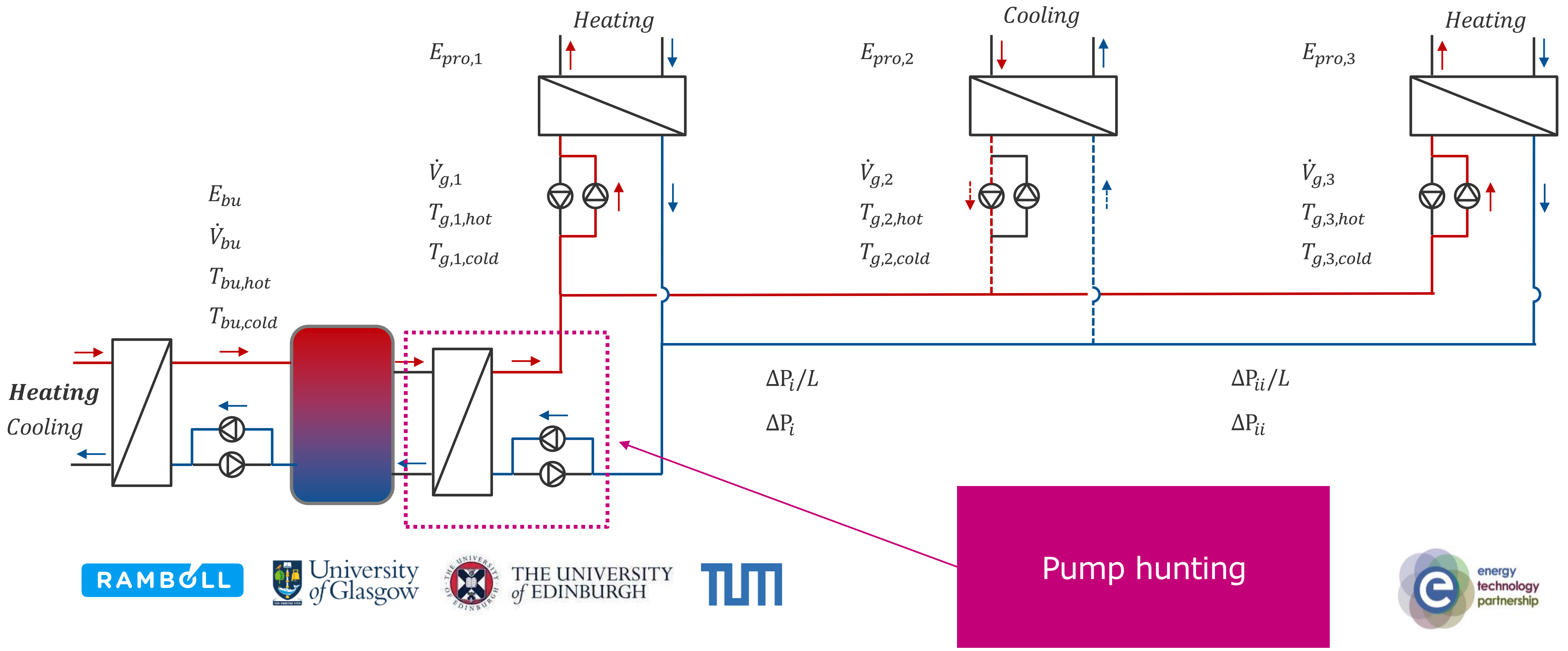
Prosumer disconnects

Controller errors

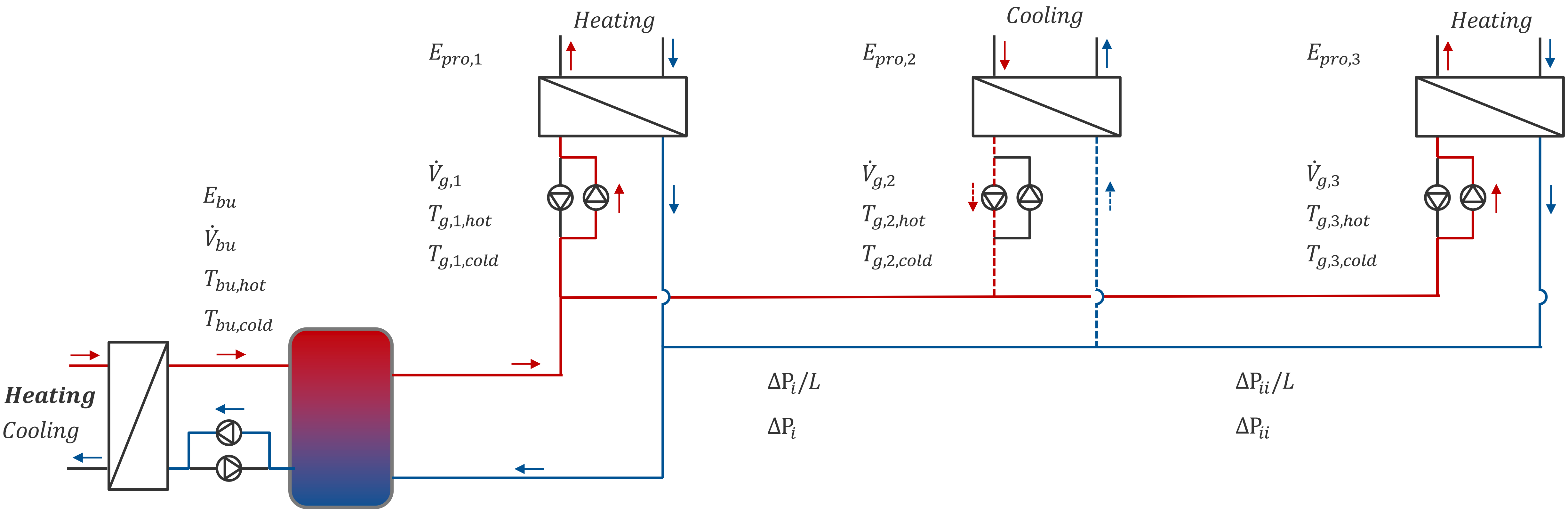
HYDRAULIC SETUP – BALANCING UNIT



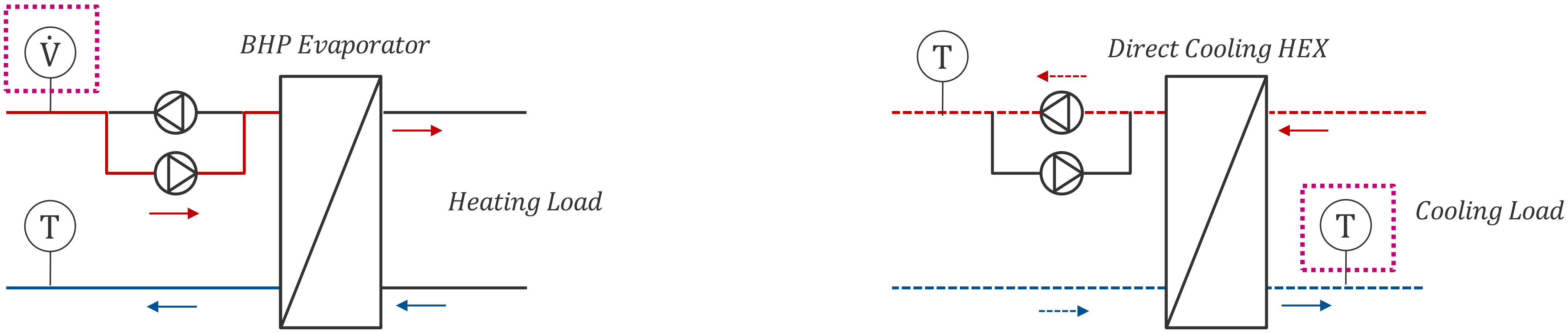
HYDRAULIC SETUP – BALANCING UNIT



HYDRAULIC SETUP – PASSIVE BALANCING UNIT



GRID PUMP CONTROLS: FLEXIBLE GRID ΔT



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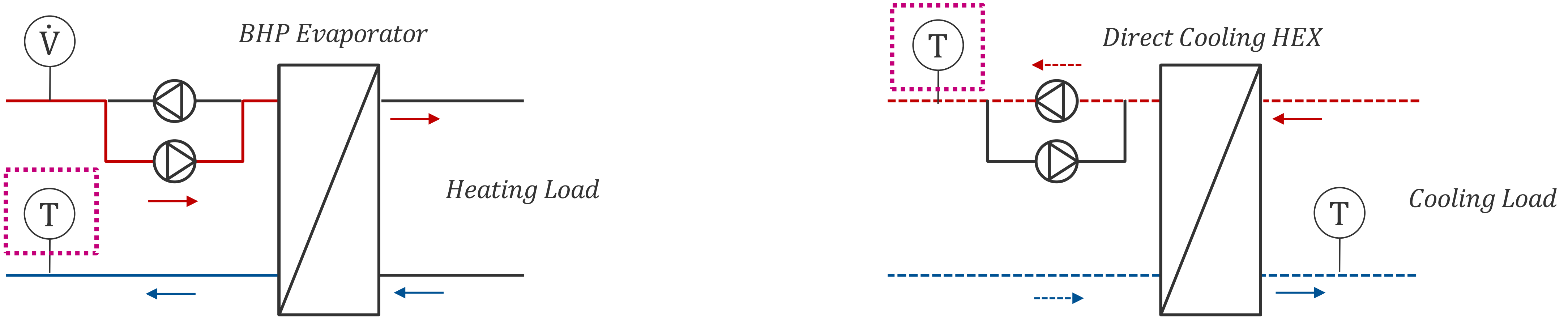
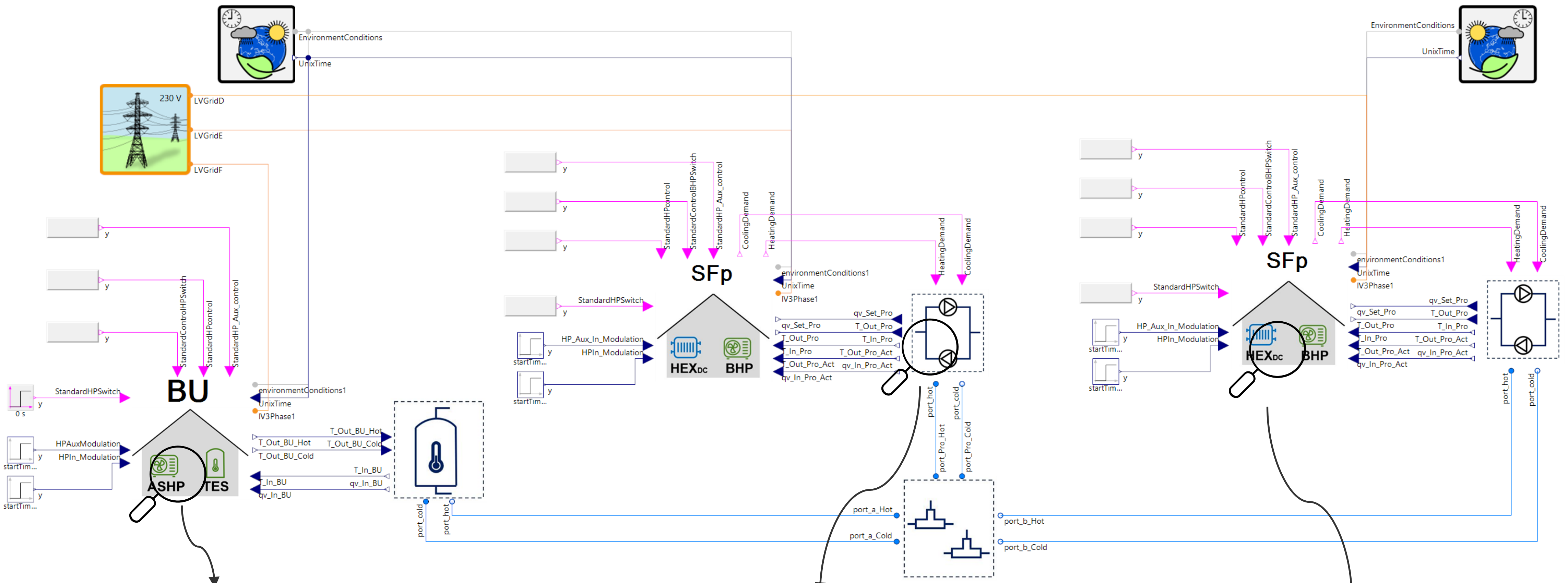
GRID PUMP CONTROLS: CONTROLLED GRID ΔT



PROPOSED DESIGN AND ITS KEY ELEMENTS

- Large passive balancing unit for thermodynamic and hydraulic balance.
- Low hydraulic resistance of the network to not oversize pumps.
- Controller setup to allow for decentralised controls without overarching controllers.

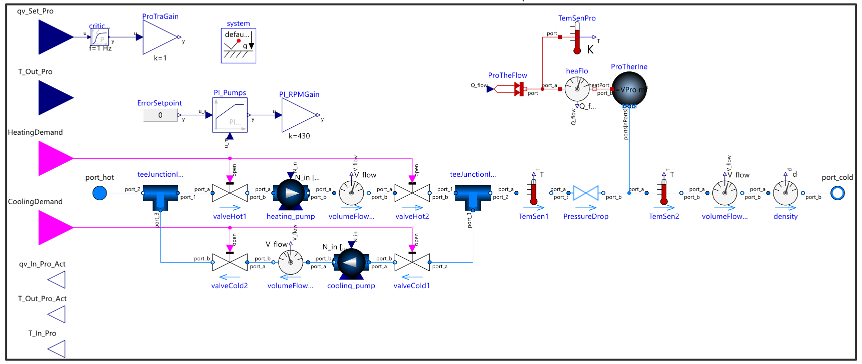
SIMULATION MODELS IN MODELICA



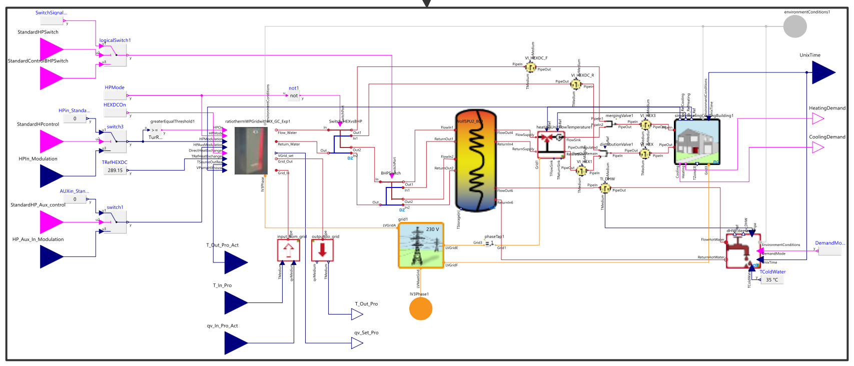

```
// Standard Control
//Control for BHP
when simpleHeatingCoolingBuilding1.Heating then
    HPMode_Switch=true;
    HEXDCOn_Switch=false;
    DemandModeSwitch=true;
elsewhen simpleHeatingCoolingBuilding1.Cooling then
    HPMode_Switch=false;
    HEXDCOn_Switch=true;
    DemandModeSwitch=false;
end when;

//HP 3way valve
when (TS_S_TM_BT_9 < TStartHPhigh) and UseHP then
    HP3WVinStandardControl = true;
```

Operational and control philosophy



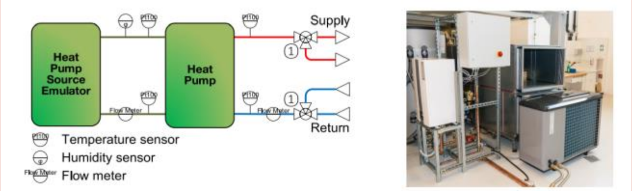
Hydraulic interface



Digital twins of CoSES prosumers

EXPERIMENTAL VALIDATION

EXPERIMENTAL SETUP – MAIN IDEA



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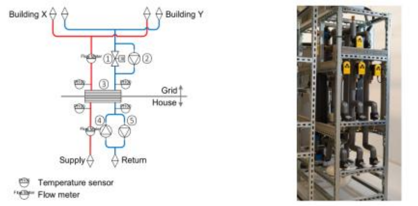

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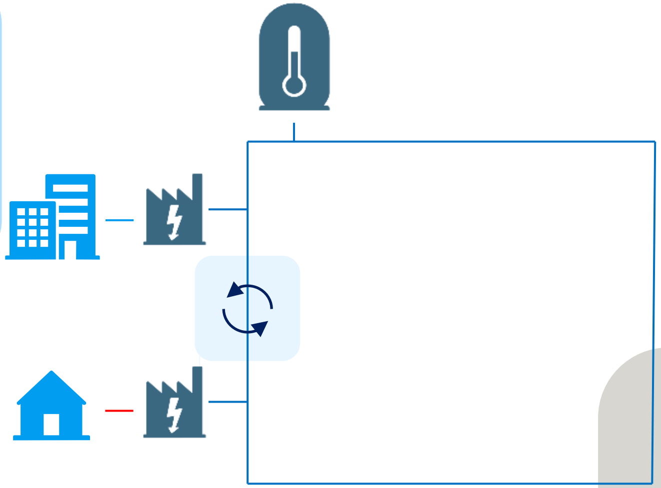
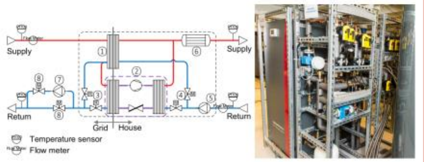
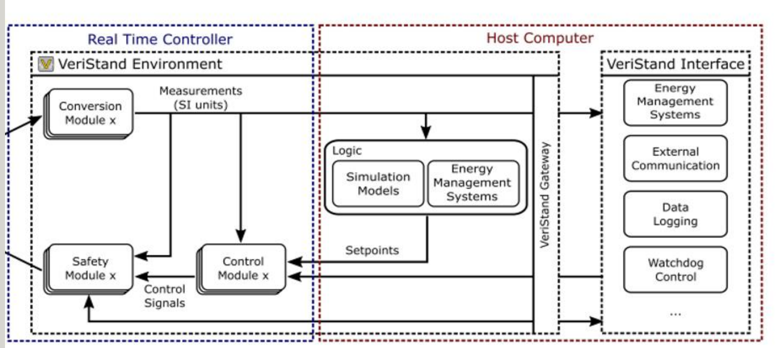




1

1. Booster heat pump (WSHP) for heating
2. HEX for free cooling (Cooling load by resistor)
3. Active balancing unit (ASHP)
4. Power Hardware in the Loop arrangement
5. VeriStand + LabView + IC for control, monitoring and logging.



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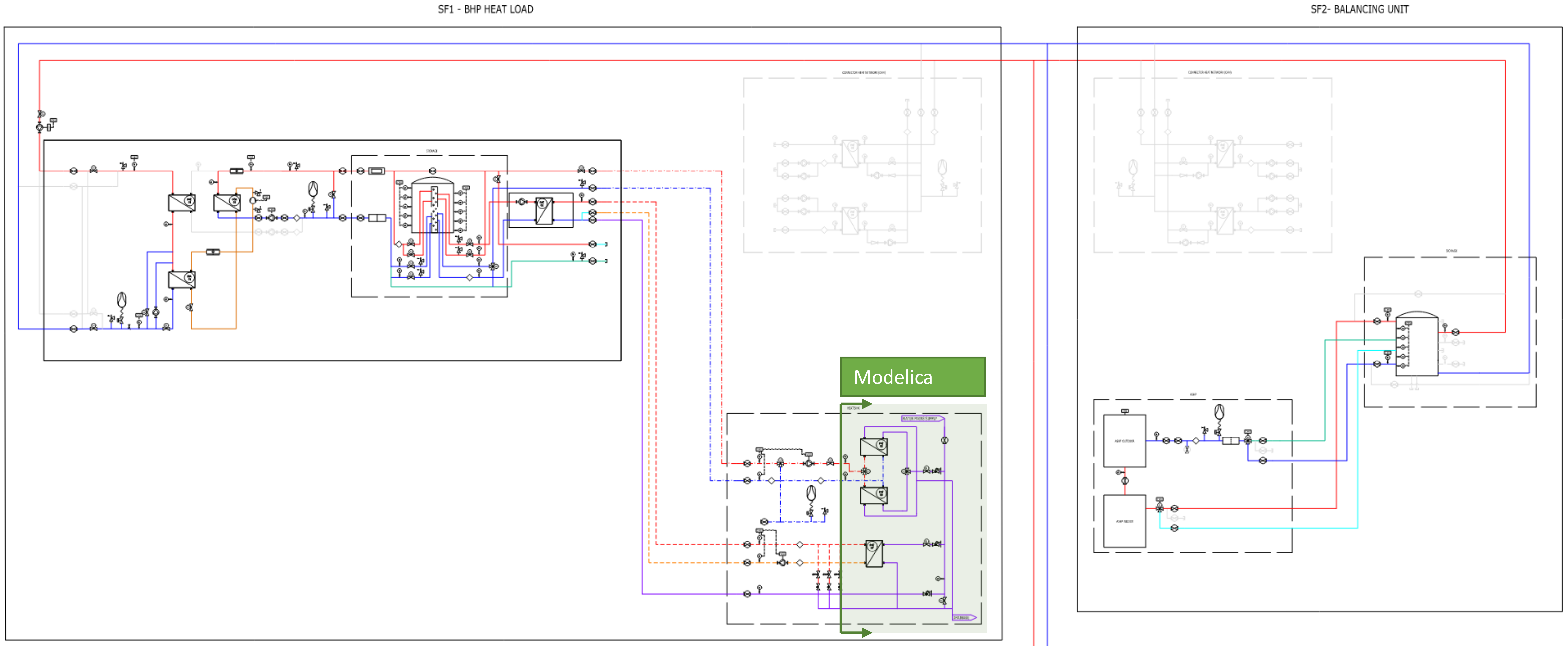
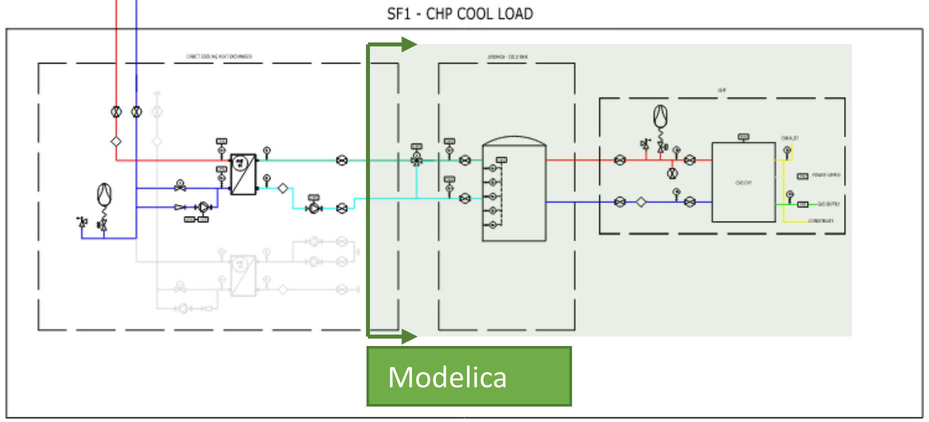
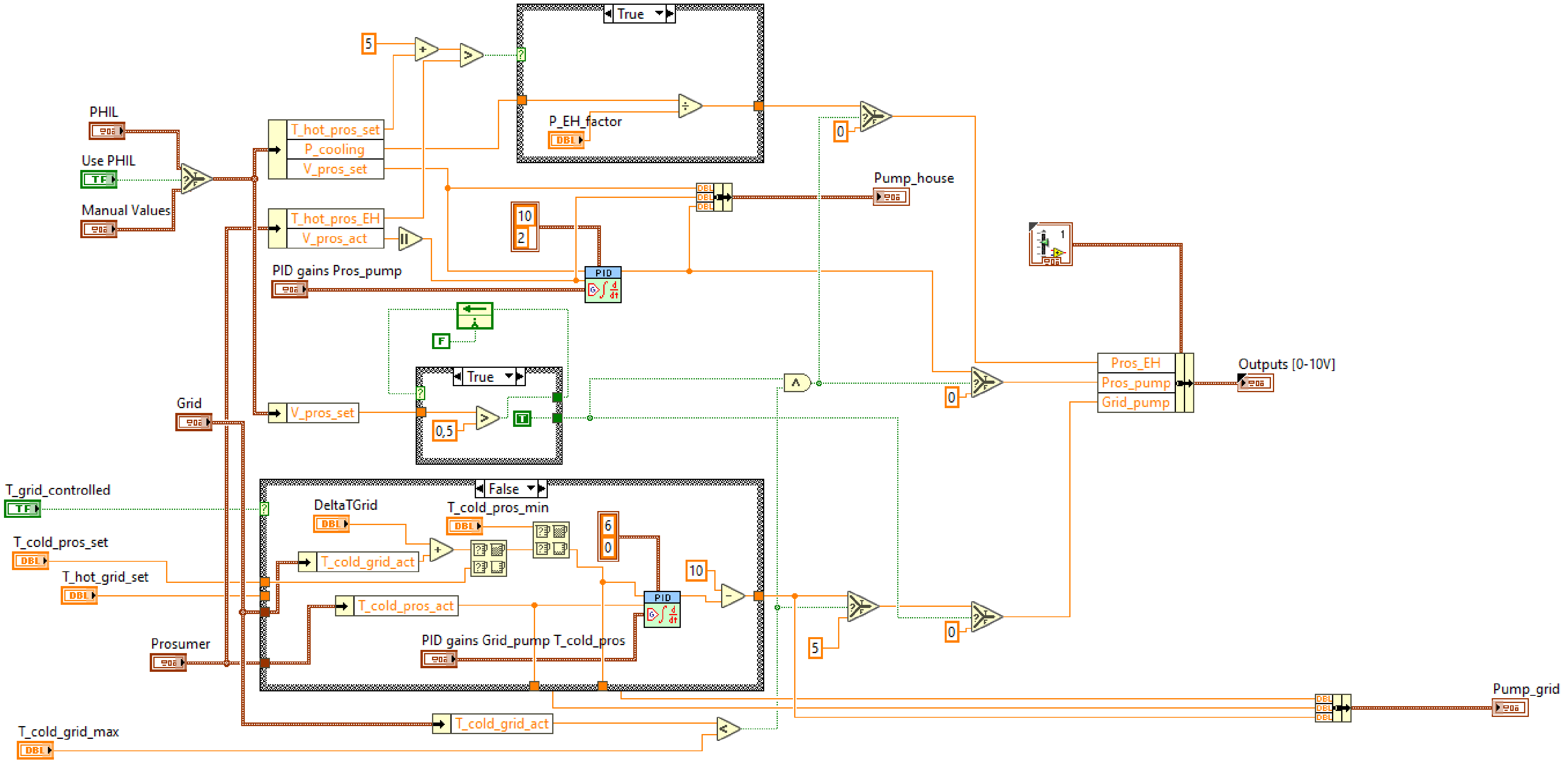




PHIL Setup - Modelica

Modelica models for buildings give back the **return temperature** from the buildings for both heating and cooling. They also provide a **reference flowrate** to meet the power demand based on the flow temperature.

CONTROLS IN LAB VIEW



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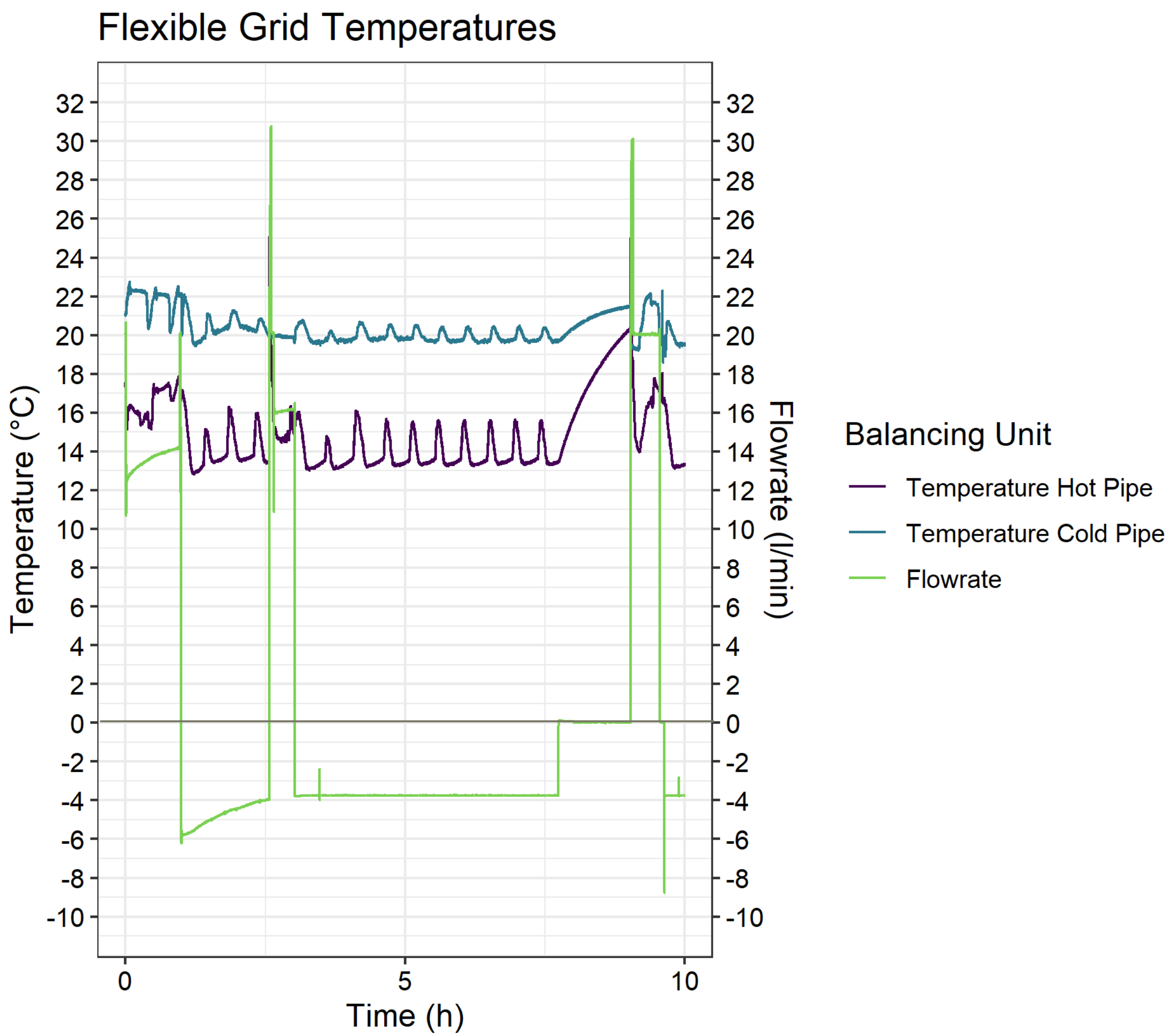
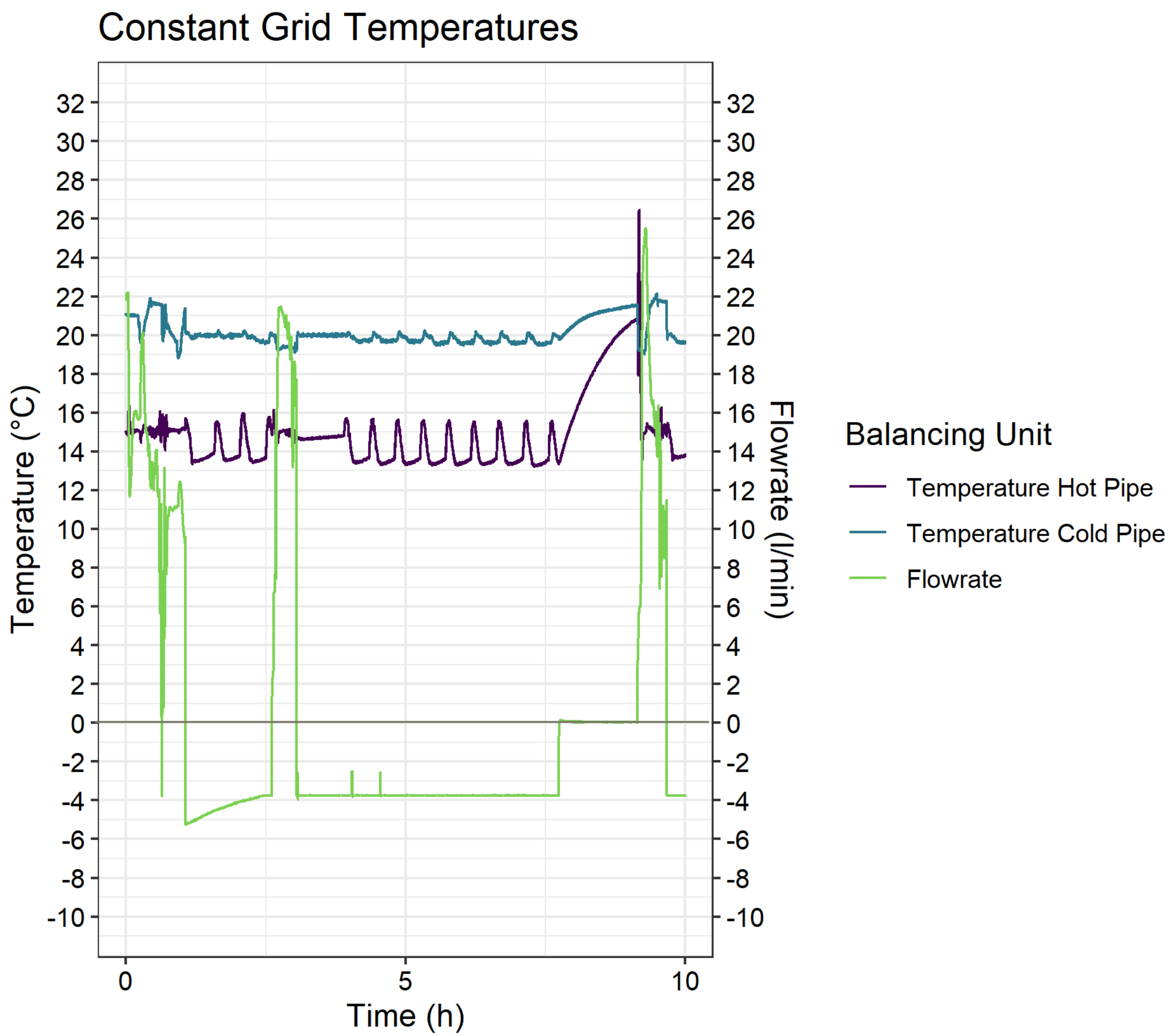
RESULTS AND DISCUSSION

RESULTS





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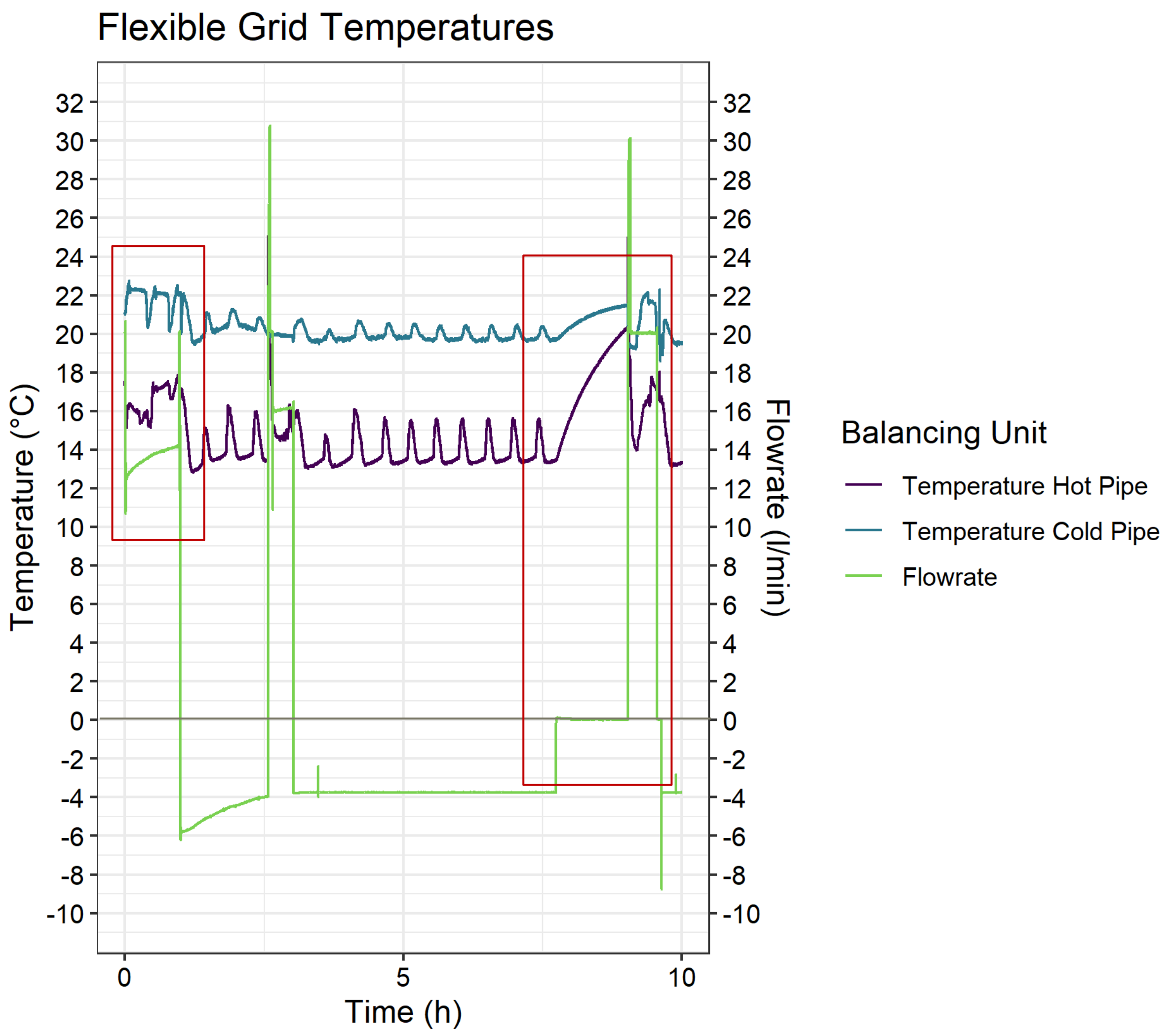
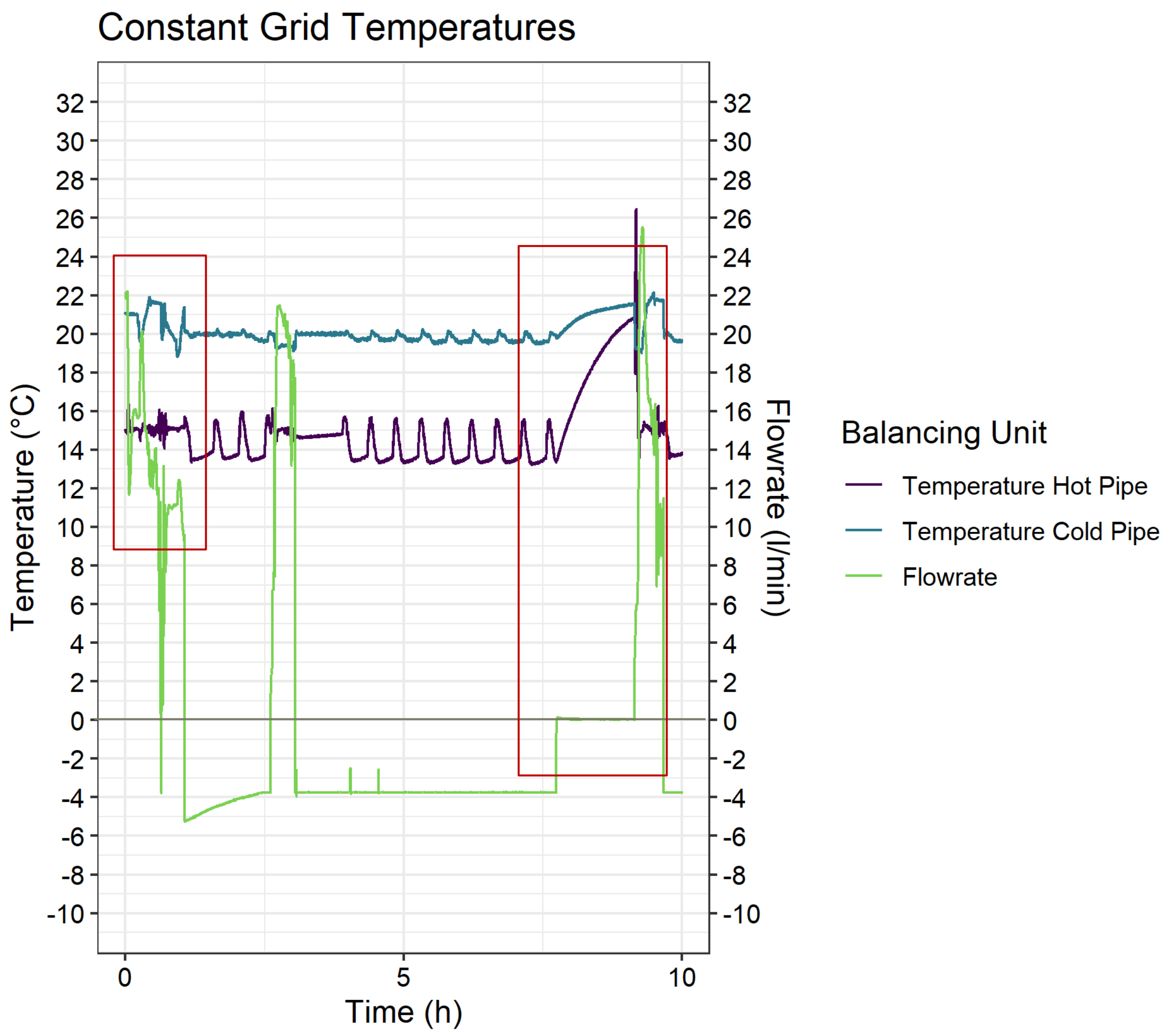
RESULTS





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COMPARISON OF OPERATIONAL STRATEGIES

- Flexible grid ΔT - harder to control & prosumers units' efficiency varies.
- Controlled ΔT - BHP operation with varying flowrate.
- None is designed to have both heating and cooling at the same time.
- Multiple starts and stops of BU.
- Hydraulic basis for future bespoke solutions.

CONCLUSION

- This work presented two operational strategies for the operation of district heating and cooling grids with decentralised energy substations that could allow for energy trading.
- Both operational strategies can facilitate the most common hydraulic and thermodynamic issues that arise in bidirectional grids by utilising novel control approaches.
- More details on the exact setups, a thorough discussion of the results and an analysis of different scenarios with the validated Modelica models is to follow.
- Information about the develop simulation models and the Power Hardware in the Loop methodology will be presented at the 15th International Modelica conference and published as a conference paper. The preprint is available on ResearchGate.

Preprint

THANK YOU FOR YOUR TIME.

QUESTIONS?

Flow direction in district heating and cooling grids with booster heat pumps: Does it make sense to have unidirectional flow?

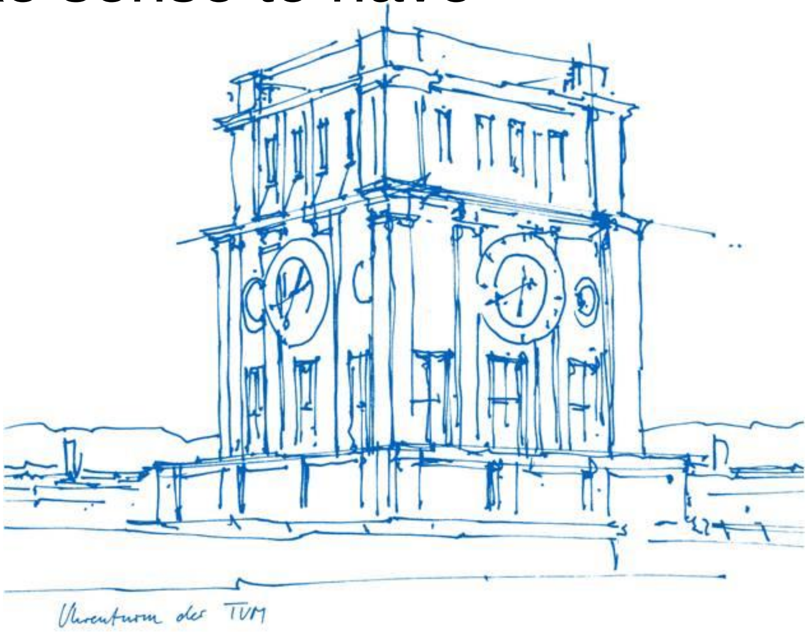
Daniel Zinsmeister, Orestis Angelidis, Thomas Licklederer,

Peter Tzscheutschler, Vedran Perić, Christoph Goebel

Technische Universität München

TUM School of Engineering and Design

Professur für Energy Management Technologien



Motivation

Contents lists available at ScienceDirect
Energy & Buildings
journal homepage: www.elsevier.com/locate/enb

Quantifying Demand Balancing in Bidirectional Low
Networks

Marco Wirtz*, Lukas Kivilip, Peter Remmen, Dirk Müller
[a] RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Cli

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Energy Conversion and Management
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Energy
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bidirectional district heating and

, 1 Cyclotron Road, Berkeley, CA 94720, USA

Common assumption: Bidirectional flow with decentral pumps

Is bidirectional flow always an advantage?

Contents lists available at ScienceDirect
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5th generation district heating and cooling systems: A revie
cases in Europe

Simone Buffa[a,b,*], Marco Cozzini[a], Matteo D'Antoni[a], Marco Baratieri[b], Roberto Fedrizzi[a]
[a] EURAC Research, Institute for Renewable Energy, Viale Druso 1, 39100 Bolzano, Italy
[b] Faculty of Science and Technology, Free University of Bolzano, Piazza Università

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A simulation model for the design and analysis of district systems with simultaneous heating and cooling demands

Marwan Abugabbara*, Saqib Javed, Dennis Johansson
Department of Building and Environmental Technology, Division of Building Services, Lund University, 221 00 Lund, Sweden

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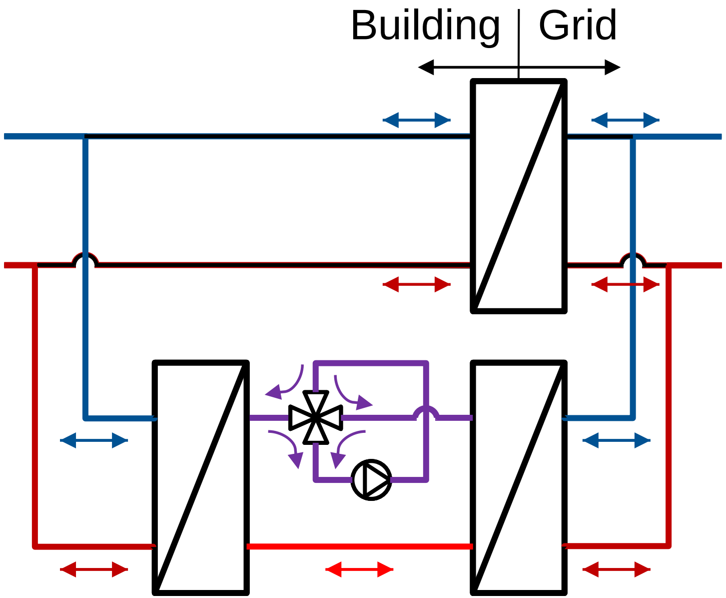
Applied Energy
journal homepage: www.elsevier.com/locate/apenergy

Temperature control in 5th generation district heating and cooling networks: An MILP-based operation optimization

Marco Wirtz[a,*], Lisa Neumaier[a,b], Peter Remmen[a], Dirk Müller[a]
[a] RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Mathieustr. 10, 52074 Aachen, Germany
[b] ETH Zurich, Energy & Process Systems Engineering, Tannenstrasse 3, 8092 Zurich, Switzerland

Booster Heat Pump Transfer Station



Components:

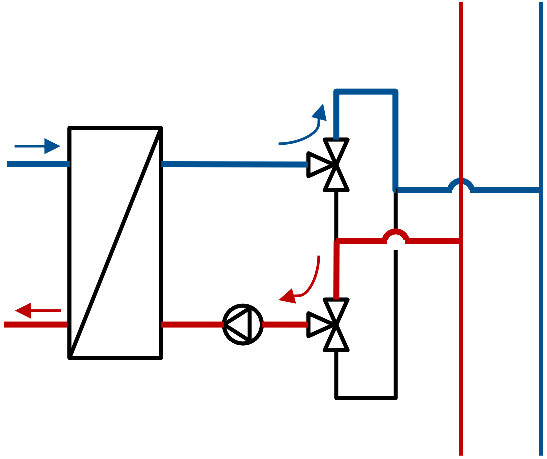
- Booster heat pump
- Direct heat exchanger

Modes:

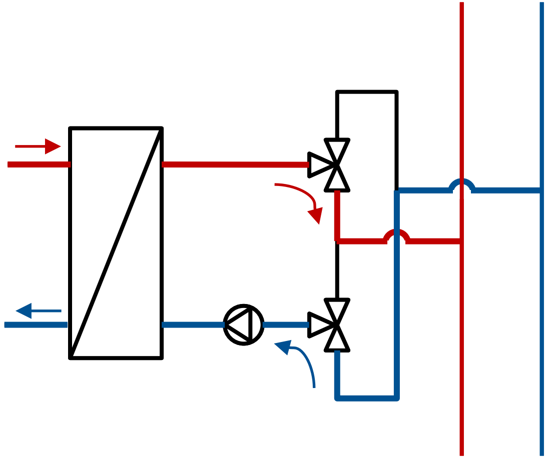
- Active heating (Booster heat pump)
- Active cooling (Booster heat pump)
- Direct cooling (Direct heat exchanger)
- Direct heating (Direct heat exchanger)

Prosumer Integration - No Pressure in DHC grid

Heating



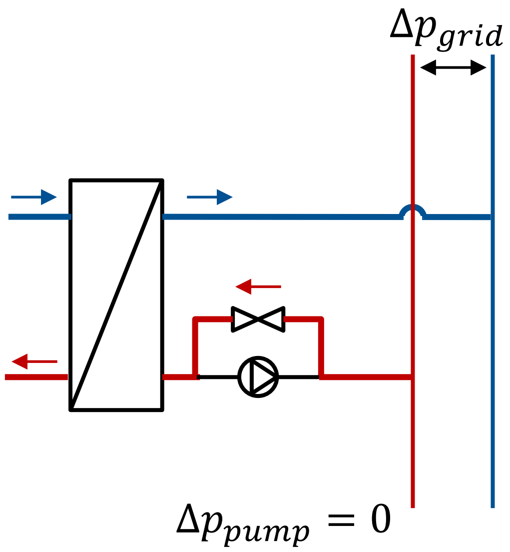
Cooling



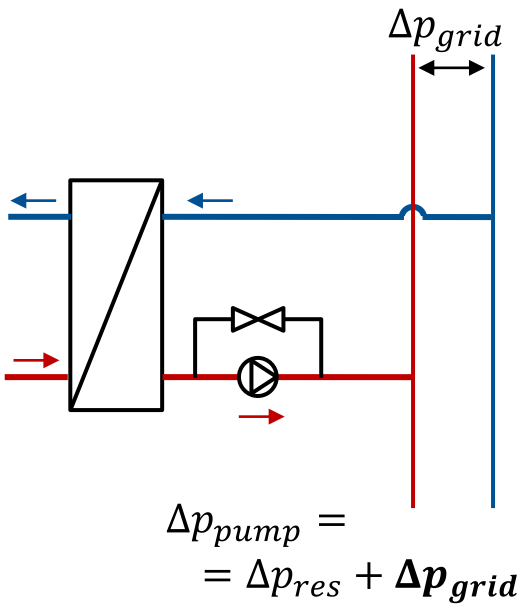
$$\Delta p_{pump} = \Delta p_{res}$$

Prosumer Integration - High Pressure at Supply Line

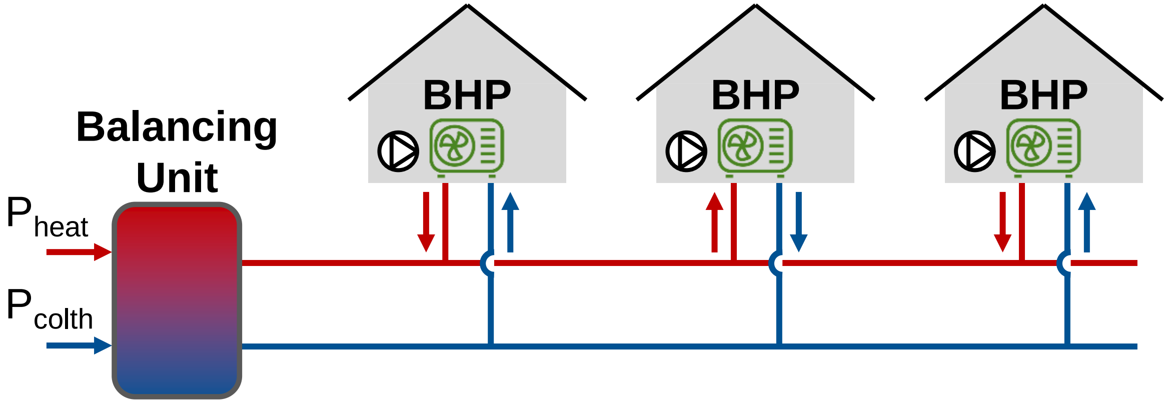
Heating



Cooling



Bidirectional Grid Setup



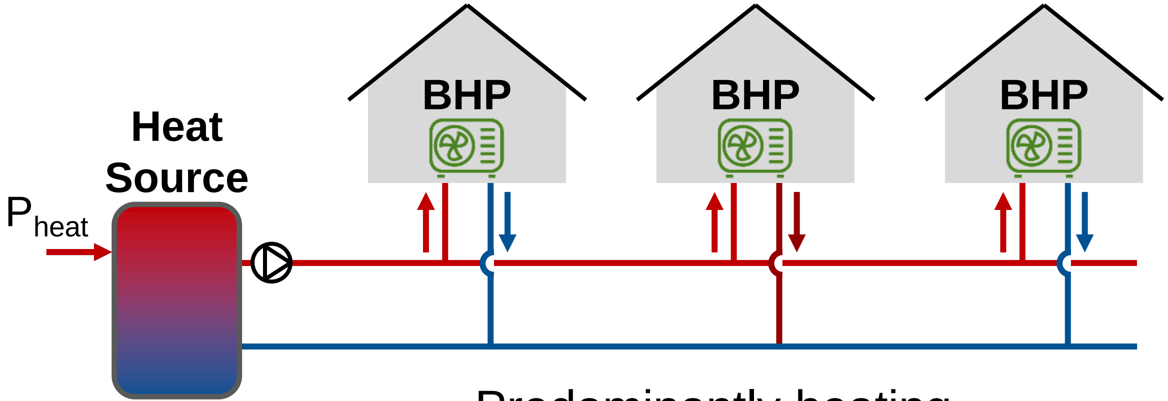
Advantages

- Higher efficiency due to balancing of heating and cooling
- Lower volume flows
- Simpler to extend

Disadvantages

- Grid islands
- Additional grid pump at each house
- More complex control

Unidirectional Grid Setup



Predominantly heating

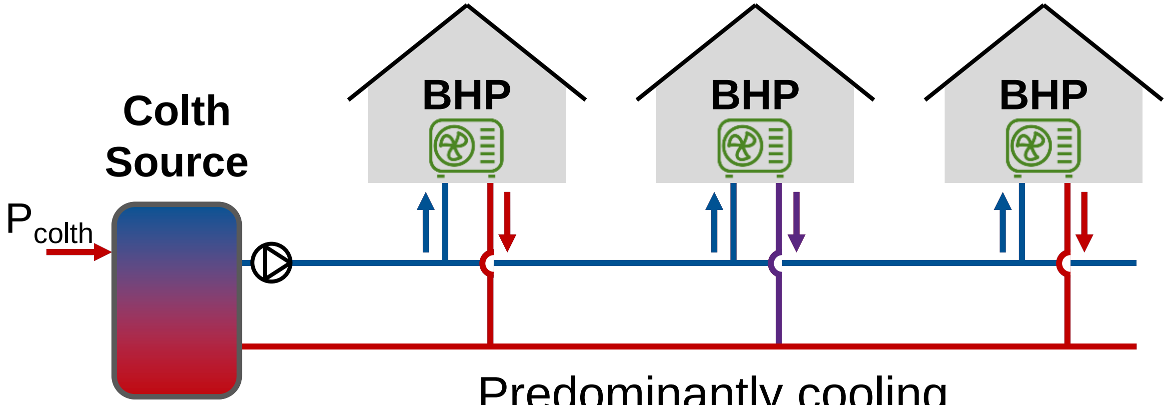
Disadvantages

- Lower efficiency due to no balancing of heating and cooling
- Higher volume flows

Advantages

- Similar to state of the art heat grids
- Central grid pump
- Simple control

Unidirectional Grid Setup



Predominantly cooling

Disadvantages

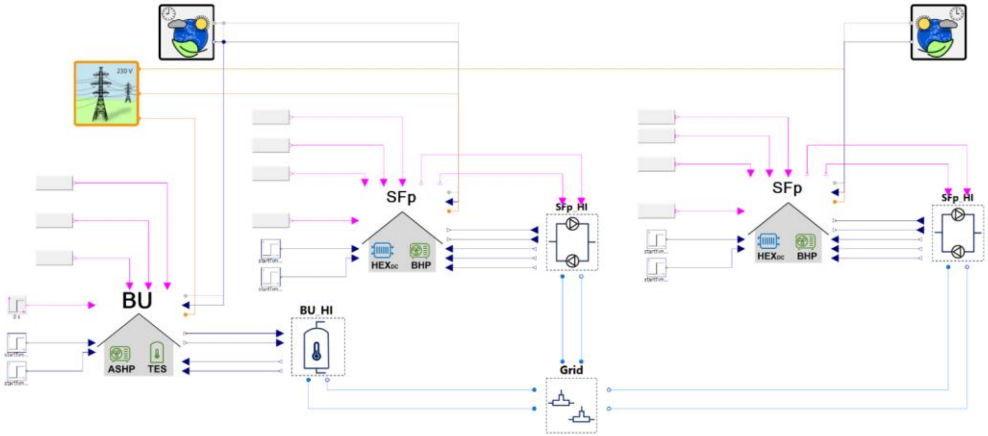
- Lower efficiency due to no balancing of heating and cooling
- Higher volume flows

Advantages

- Similar to state of the art heat grids
- Central grid pump
- Simple control

Simulation Analysis

CoSES ProHMo



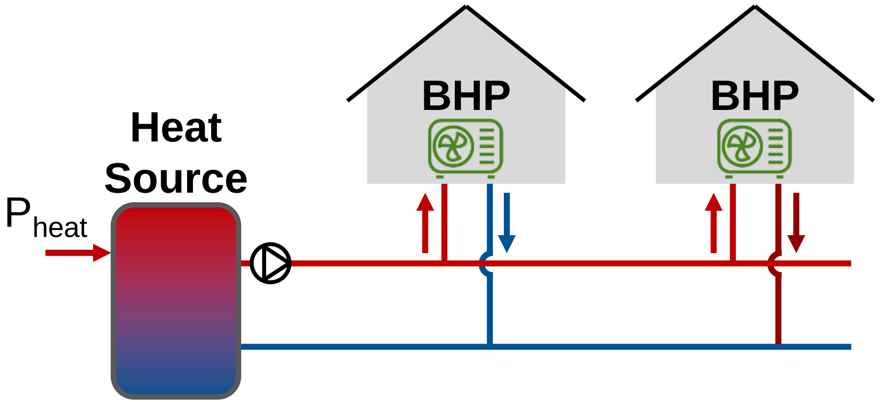
[O. Angelidis et al.: 5th Generation District Heating and Cooling Modelica Models for Prosumer Interaction Analysis, 2023]

Szenarios

- Unidirectional / Bidirectional
- Heating / Cooling Demand:
  - Seasonally balanced
  - Daily balanced
- Number of Prosumer
- Thermal storage size in the balancing unit
- Grid temperature

Key message

- Unidirectional flow for prosumers might be beneficial
- Simulation library is ready – scenario analysis still pending
- Open access FMUs will be provided to allow analysis of individual cases



OSkit
Reference Number: 03EN3032
Grant Period: 01.12.20 – 31.05.24
Projektträger Jülich Forschungszentrum Jülich
Gefördert durch: Bundesministerium für Wirtschaft und Klimaschutz aufgrund eines Beschlusses des Deutschen Bundestages