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AIT AUSTRIAN INSTITUTE OF TECHNOLOGY TOMORROW TODAY

TS3 Webinar on “Hybrid Energy Networks”

Integrating district heating and cooling networks with the electricity and gas grid

Tuesday, 27th April 2021, 9:00 to 17:00 (CET)

A side event of the Mission Innovation Austria Online Conference
https://missioninnovationaustriaweek.at/

Contact: Ralf-Roman Schmidt (AIT); ralf-roman.schmidt@ait.ac.at

This Webinar is held in the framework of the international cooperation program IEA DHC Annex TS3 „Hybrid Energy Networks“. More information at http://www.iea-dhc.org/the-research/annexes/2017-2020-annex-ts3-draft.html The Austrian participation in the IEA DHC Annex TS3 is financed by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

IEA Research Cooperation
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TS3 Webinar on “Hybrid Energy Networks”

Block IV: handling the complexity:

Advanced tools and methods for planning and operation

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Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology

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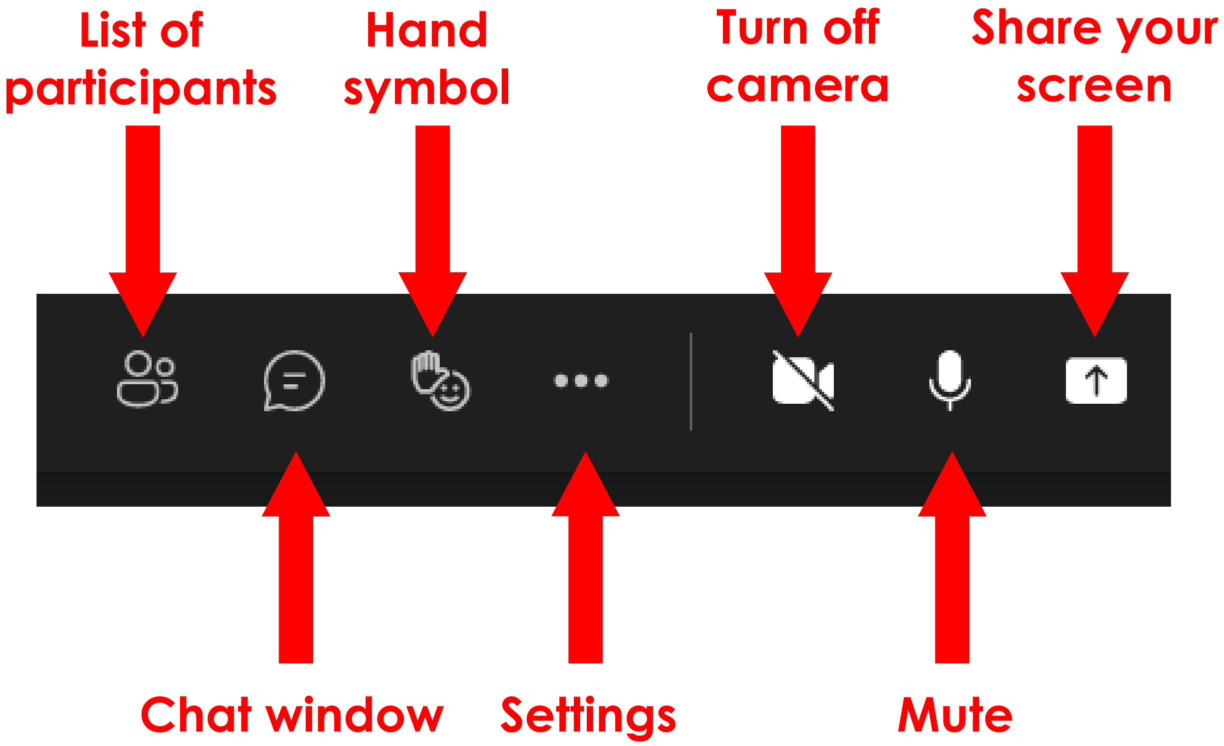
Webinar Etiquette

- The **microphone should be muted** by default
- Requests to speak are reported via the **hand symbol**
- Please **state your name** and institution before you speak
- Please **turn off your webcam**!
  The camera can be used at short notice for spoken contributions.
- We will make a “**group-photo**” at the end of each block



IEA DHC Annex TS3: Hybrid Energy Networks

- **Aim: To promote the opportunities and to overcome the challenges for district heating and cooling networks in an integrated energy system context**
- **Funded** through a task-sharing approach (the participants contribute resources in-kind for connecting existing national and international projects)
- **coordination:** Ralf-Roman Schmidt (AIT); ralf-roman.schmidt@ait.ac.at
- **Runtime**: Fall 2017 – March 2022
- **Expected results**: An assessment of suitable technologies and concepts; country reports; collection and assessment of international case studies; a review of existing methods and tools; best practice guidelines; a final guidebook
- **More information** at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3-draft

Agenda

Time	Item
09:15 – 11:00 CET	**Block I** – Integrated district heating and cooling networks: introduction and best practices
11:15 – 12:45 CET	**Block II** – Barriers, trends and solutions for the creation of an integrated energy market
13:30 – 15:00 CET	**Block III** – country-based constraints and synergies on a national level
15:30 – 17:00 CET	**Block IV** – handling the complexity: Advanced tools and methods for planning and operation

Agenda *Block IV - handling the complexity: Advanced tools and methods for planning and operation*

15:15	***Testing of technical connections***
15.30	Welcome and introduction into the webinar (Ralf-Roman Schmidt, AIT)
	Preliminary survey results: classification of tools and methods for modelling and simulating hybrid energy networks (Edmund Widl, AIT)
	Presentation of selected tools and methods • **EnergyPLAN**: analysing the energy, environmental, and economic impact of hybrid energy systems (Peter Sorknæs, Aalborg University) • **EnergyPRO**: combined technical and financial analysis of hybrid energy systems (Leif Holm Tambjerg, EMD International) • **Pandaplan**: quasi-dynamic assessment of hybrid energy network design and operation (Dennis Cronbach, Fraunhofer IEE) • **Fumola & DisHeatLib**: co-simulation-based analysis of the dynamics of hybrid energy network operation (Benedikt Leitner, AIT)
	Interactive session on use cases, strengths, weaknesses, opportunities and threats
17:00	***End of Block IV***

Preliminary survey results: classification of tools and methods for modelling and simulating hybrid energy networks

(Edmund Widl, AIT)

Classification of tools and methods for modelling and simulating hybrid energy networks

Preliminary Results

TS3 Webinar on “Hybrid Energy Networks”

April 27, 2021, online webinar

Edmund Widl
AIT, Austria

Tools and Methods for Hybrid Energy Networks!?!

power
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

heating / cooling
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

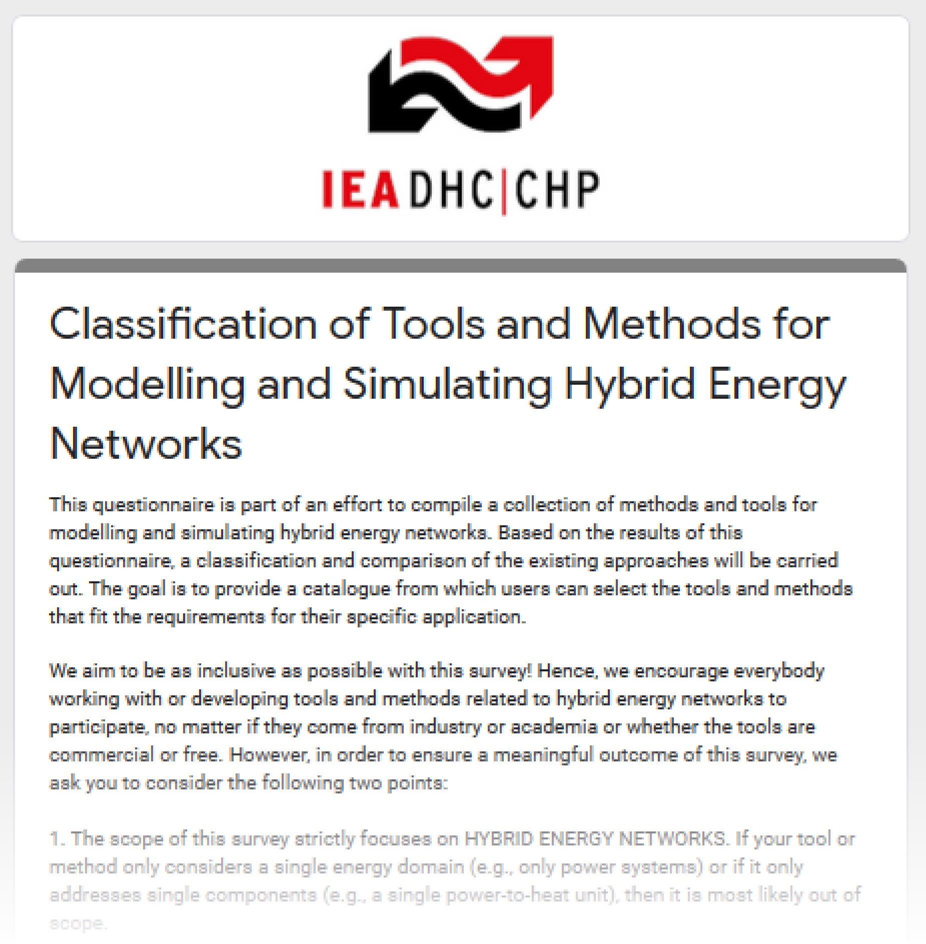
gas
- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Hybrid Energy Networks

???

IEA DHC Annex TS3: Subtask B – Tools and Methods

- **Review of existing methods and tools**
  - compilation of published material through survey of tools and methods for various applications (system planning, design optimization, operation, etc.)
- **Categorization of approaches**
  - identify relevant application areas for tools and methods related to the assessment of hybrid energy networks
  - perform categorization in terms of objectives, requirements and expected results
  - compile a guideline (catalogue of recommended practices)


IEA DHC|CHP

Classification of Tools and Methods for Modelling and Simulating Hybrid Energy Networks

This questionnaire is part of an effort to compile a collection of methods and tools for modelling and simulating hybrid energy networks. Based on the results of this questionnaire, a classification and comparison of the existing approaches will be carried out. The goal is to provide a catalogue from which users can select the tools and methods that fit the requirements for their specific application.

We aim to be as inclusive as possible with this survey! Hence, we encourage everybody working with or developing tools and methods related to hybrid energy networks to participate, no matter if they come from industry or academia or whether the tools are commercial or free. However, in order to ensure a meaningful outcome of this survey, we ask you to consider the following two points:

1. The scope of this survey strictly focuses on HYBRID ENERGY NETWORKS. If your tool or method only considers a single energy domain (e.g., only power systems) or if it only addresses single components (e.g., a single power-to-heat unit), then it is most likely out of scope.

- **Public online survey:** http://bit.ly/iea-dhc-annex-ts3-survey

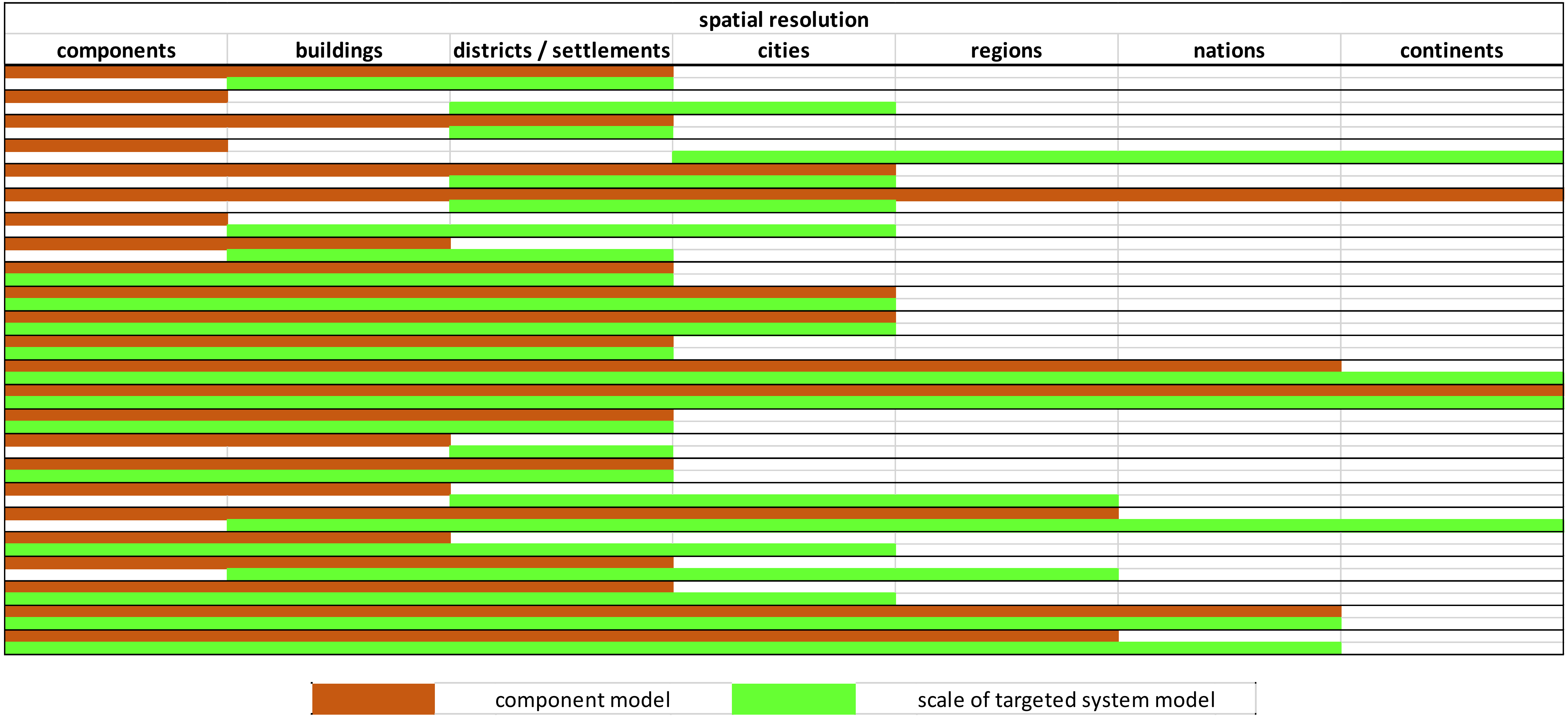
Classification Categories for Tools and Methods

- **Categories related to modelling paradigms**
  - application class, spatial resolution of component models, temporal resolution of component models, targeted scale of system model, targeted time horizon of system model, intended purpose, black / grey / white box models
- **Categories related specifically to the energy domain**
  - included sectors, coupling points, power network model, thermal network model, gas network model, energy storages included, operational control
- **Categories related to implementation features of the tools**
  - monolithic simulations vs. co-simulation, availability of used software, documentation
- **Potential classification aspects**
  - targeted project phase, targeted audience

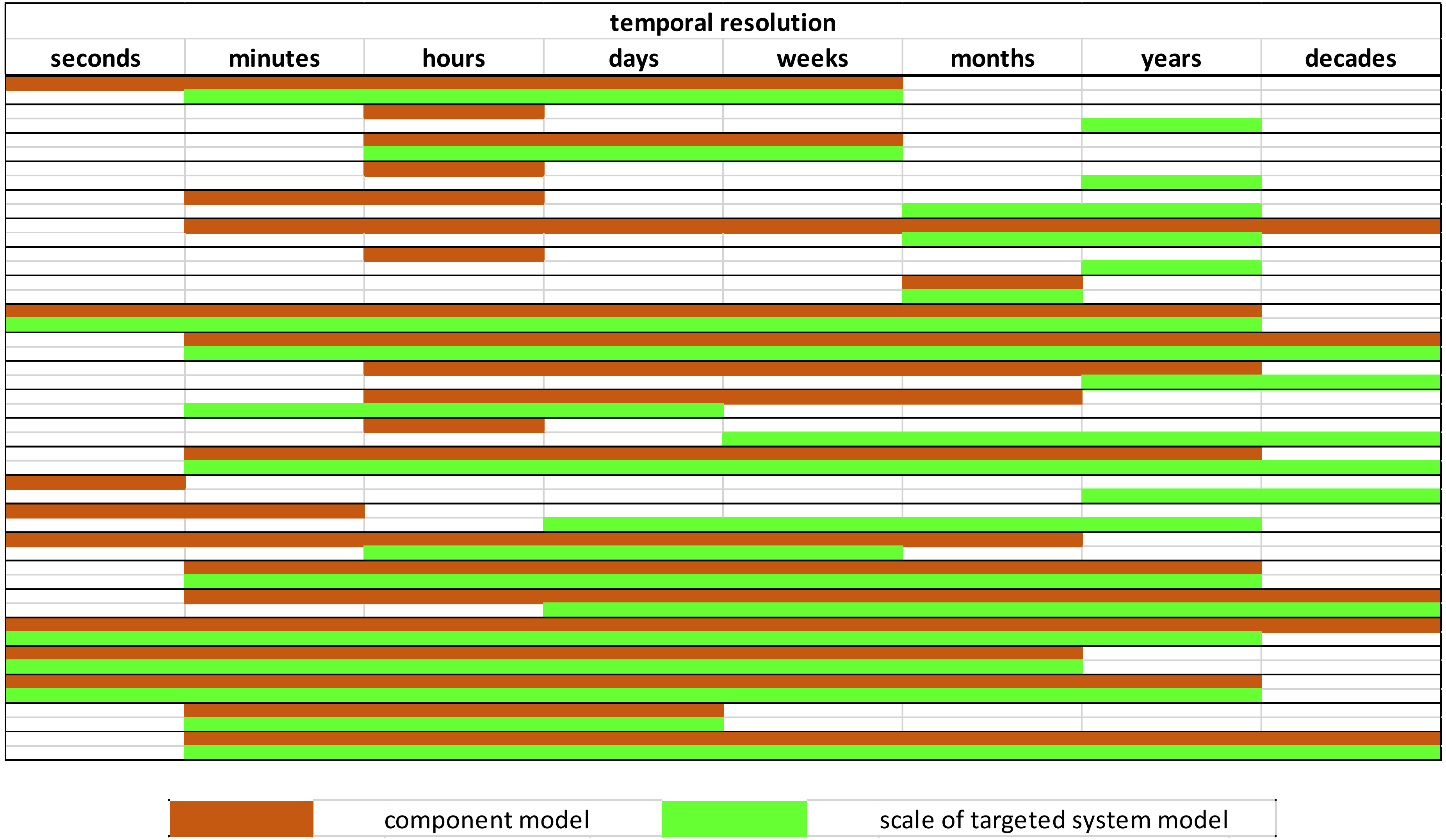
Preliminary Blinded Results – Overview

- **Replies** (so far): **30**
- Tool with focus on **multi-energy**, but not on hybrid networks: **6**
- Tools with special focus on **hybrid networks**:
  - implicit network models only (energy balances): **7**
  - explicit network model for 1 domain (other domains included implicitly): **6**
  - explicit network models for at least 2 domains: **11**

Preliminary Blinded Results – Spatial Resolutions



Preliminary Blinded Results – Temporal Resolutions



Preliminary Blinded Results – and much more …

- explicit modelling of controllers: **15**
- co-simulation approaches: **9**
- licensing:
  - commercial license: **7**
  - free use (but not open source): **3**
  - open source with strict copy-left (GPL): **6**
  - open source without strict copy-left (BSD, Apache, etc.): **7**
  - combination of software packages with different license terms (mix of open-source and commercial licenses): **5**
  - other: **2**
- and more …

If you want to know more ...

- **survey will be extended**
  - add results from literature survey
  - online survey is still open → You are welcome to add your own methods or tools!!!
- **classification will be refined**
  - double-check survey results with available documentation, publications, etc.
- **final analysis with unblinded results will be made public**

  → presentation at TS3 track @ Smart Energy Systems conference

  → open-source publication of results

Thank you for your attention!

Contact:

Edmund Widl

AIT Austrian Institute of Technology GmbH

e-mail: Edmund.widl@ait.ac.at

EnergyPLAN: analysing the energy, environmental, and economic impact of hybrid energy systems (Peter Sorknæs, Aalborg University)

ENERGYPLAN –
ANALYSING THE ENERGY, ENVIRONMENTAL, AND ECONOMIC IMPACT OF HYBRID ENERGY SYSTEMS

PETER SORKNÆS

AALBORG UNIVERSITY
DENMARK

General information

- Created for the study and research of future sustainable energy systems with a special focus on energy systems with high shares of renewable energy sources.
- Developed in 1999 and is continuously being improved by the Sustainable Energy Planning research group at Aalborg University, Denmark.
- Made for Microsoft Windows.
- Coded in Delphi Pascal.
- Current version is 15.2 (next version summer 2021).

- Free to download and use (download from www.energyplan.eu)

Guiding principles for development of EnergyPLAN

- Character of technological change
  - Enable the user to analyse the type of technological change which is required when transitioning to 100% renewable energy systems.

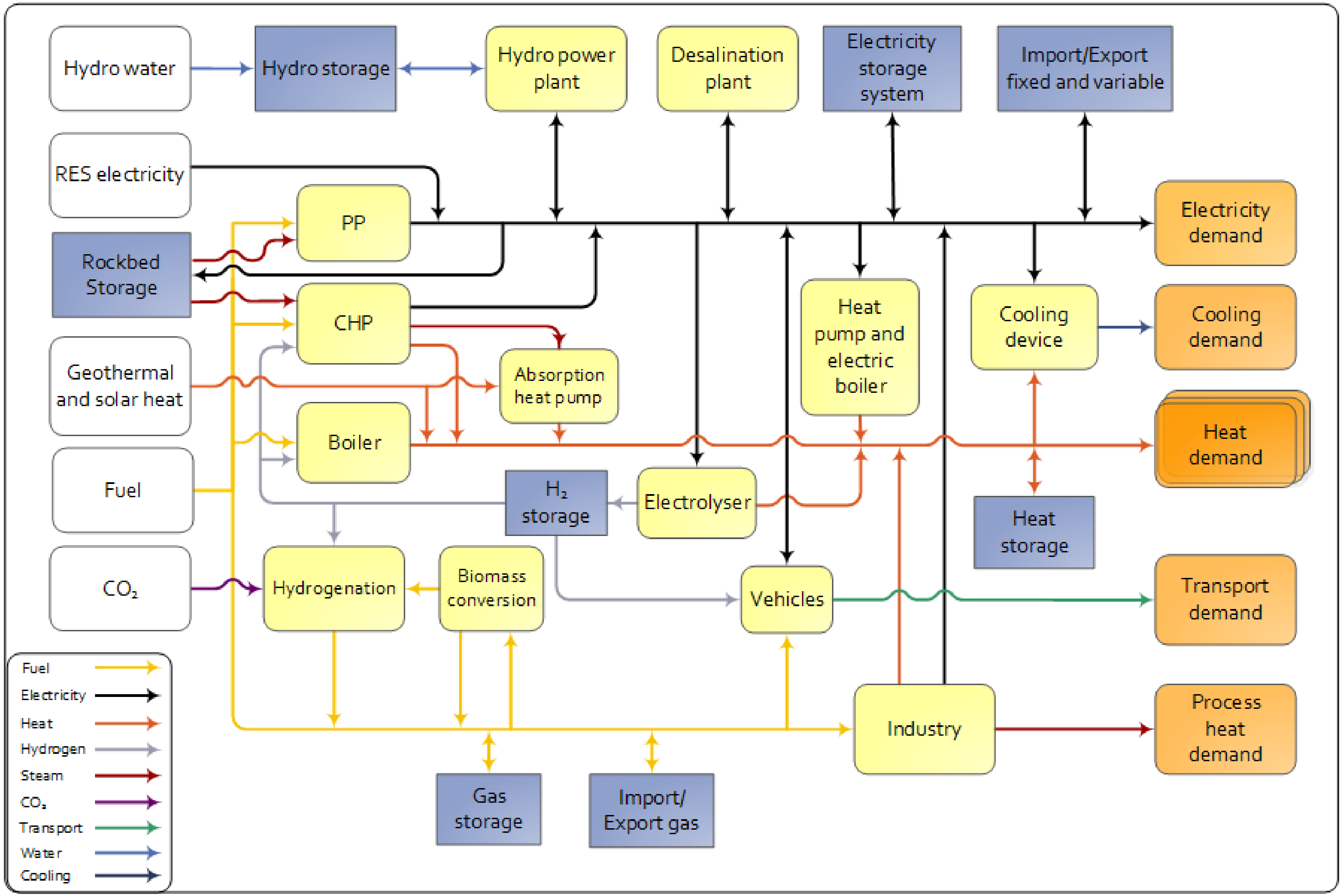
- Multiple alternatives
  - Enable the transparent and consistent comparison of multiple transition alternatives.

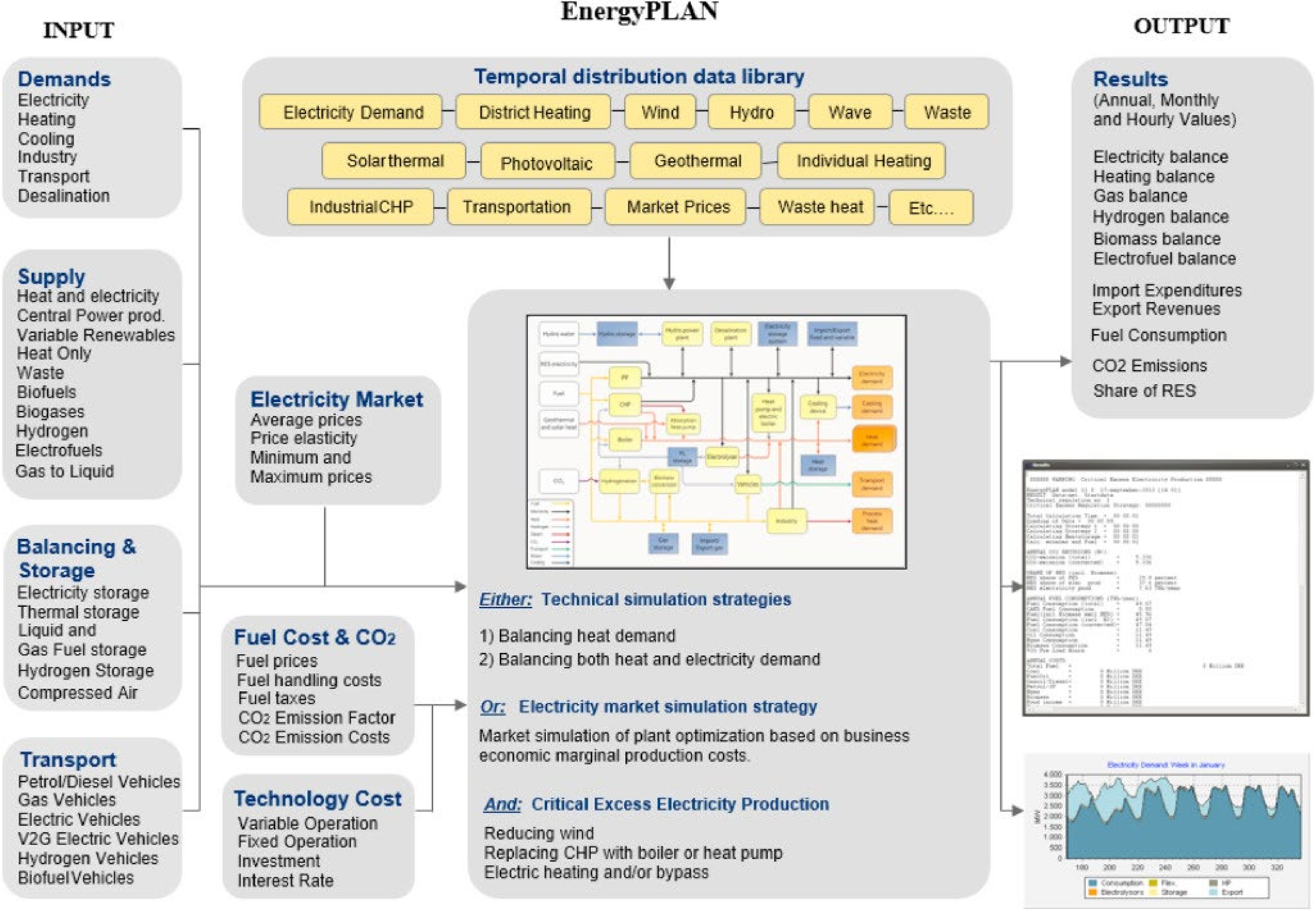
- Free of institutional inertia
  - Alternatives designed and analysed in EnergyPLAN should not be limited by existing institutional and market frameworks.

Overview of principles of EnergyPLAN

- Deterministic simulation tool for energy flows of an entire energy system (electricity, heat, cooling, transport, and industry).
- Chronological simulates the hourly operation of the modelled energy system for a leap year (8,784 hours).
- Especially useful on city, regional, and national scale.
- Inputs and outputs are aggregated into groups of technologies.
- Different simulation strategies are available:
  - Technical <- Aims at reducing fuel consumption.
  - Economic <- Lowest marginal costs (incl. electricity trading).
- Fast simulations (each yearly simulation takes seconds).

Overall structure of the energy system in EnergyPLAN





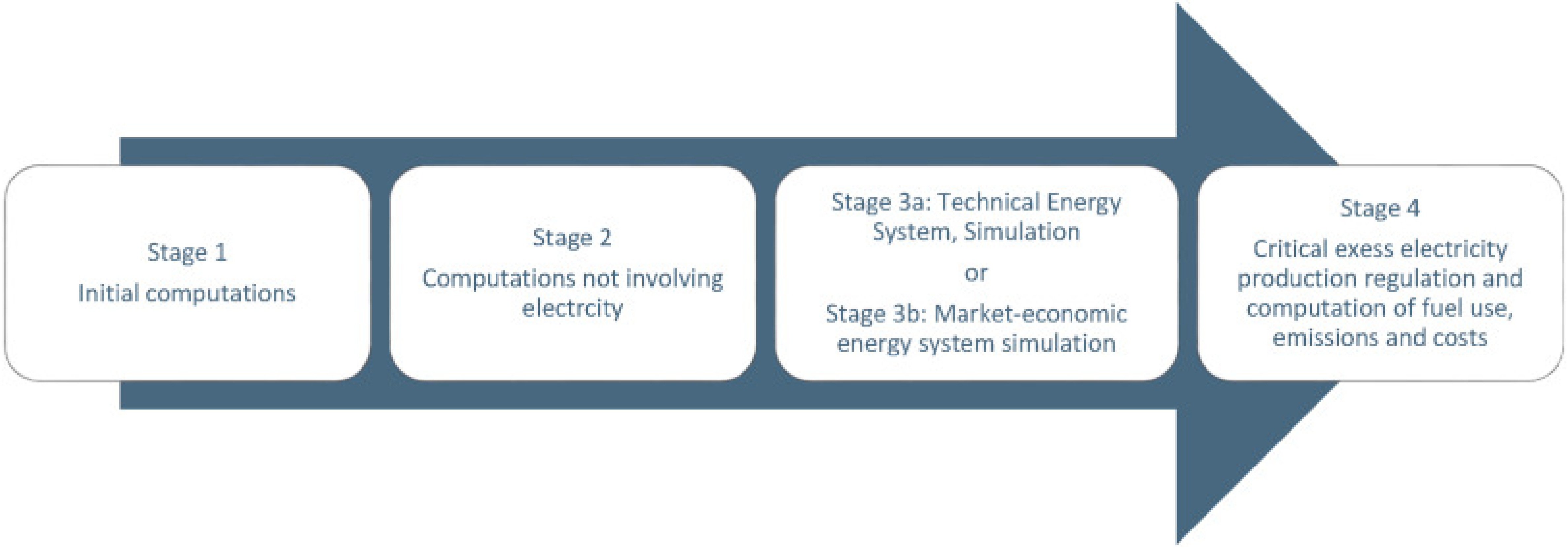
EnergyPLAN
INPUT
OUTPUT
Demands
Electricity
Heating
Cooling
Industry
Transport
Desalination
Supply
Heat and electricity
Central Power prod.
Variable Renewables
Heat Only
Waste
Biofuels
Biogases
Hydrogen
Electrofuels
Gas to Liquid
Balancing & Storage
Electricity storage
Thermal storage
Liquid and
Gas Fuel storage
Hydrogen Storage
Compressed Air
Transport
Petrol/Diesel Vehicles
Gas Vehicles
Electric Vehicles
V2G Electric Vehicles
Hydrogen Vehicles
Biofuel Vehicles
Temporal distribution data library
Electricity Demand
District Heating
Wind
Hydro
Wave
Waste
Solar thermal
Photovoltaic
Geothermal
Individual Heating
Industrial CHP
Transportation
Market Prices
Waste heat
Etc....
Electricity Market
Average prices
Price elasticity
Minimum and
Maximum prices
Fuel Cost & CO2
Fuel prices
Fuel handling costs
Fuel taxes
CO2 Emission Factor
CO2 Emission Costs
Technology Cost
Variable Operation
Fixed Operation
Investment
Interest Rate
Either: Technical simulation strategies
1) Balancing heat demand
2) Balancing both heat and electricity demand
Or: Electricity market simulation strategy
Market simulation of plant optimization based on business economic marginal production costs.
And: Critical Excess Electricity Production
Reducing wind
Replacing CHP with boiler or heat pump
Electric heating and/or bypass
Results
(Annual, Monthly and Hourly Values)
Electricity balance
Heating balance
Gas balance
Hydrogen balance
Biomass balance
Electrofuel balance
Import Expenditures
Export Revenues
Fuel Consumption
CO2 Emissions
Share of RES
Electricity Demand: Week in January

Simulation method

- EnergyPLAN uses what the developers denote as “analytical programming”.
- Rather than establishing a series of balance equations that are solved numerically as in optimisation and equilibrium models, EnergyPLAN is based on a series of endogenous priorities within, e.g., power and heat production and pre-defined procedures for simulating the operation of units that are freely dispatchable.
- The approach is purely deterministic with no stochastic elements.

- EnergyPLAN simulates user-defined systems and does not make endogenous system optimisation

Overall simulation approach



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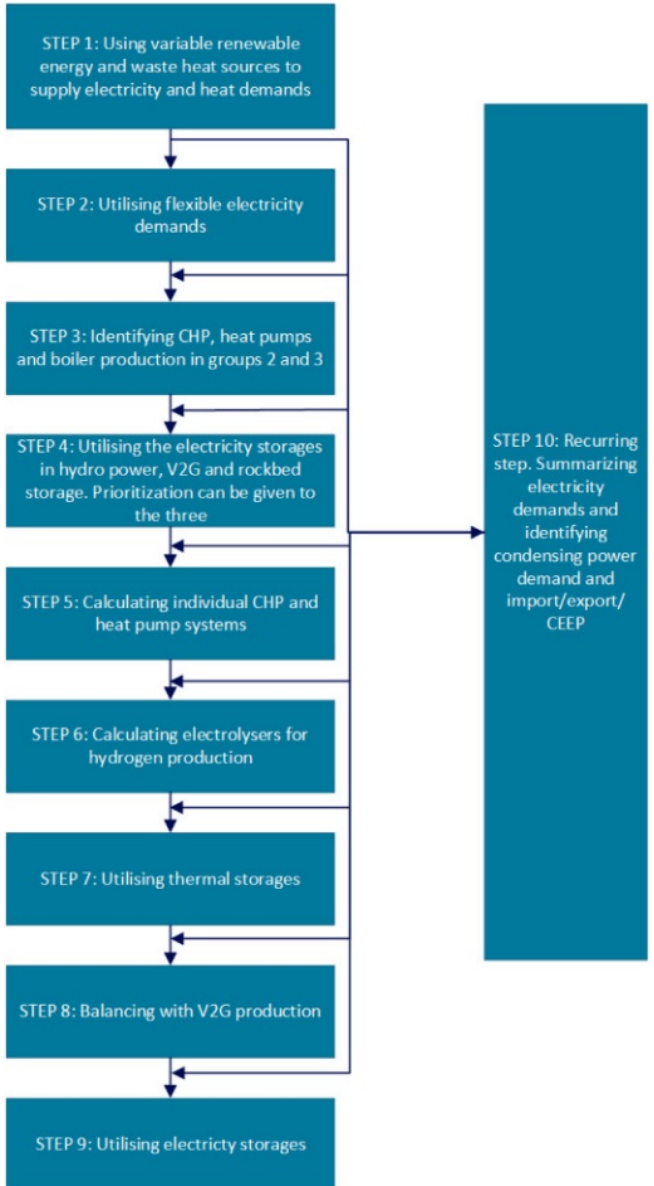
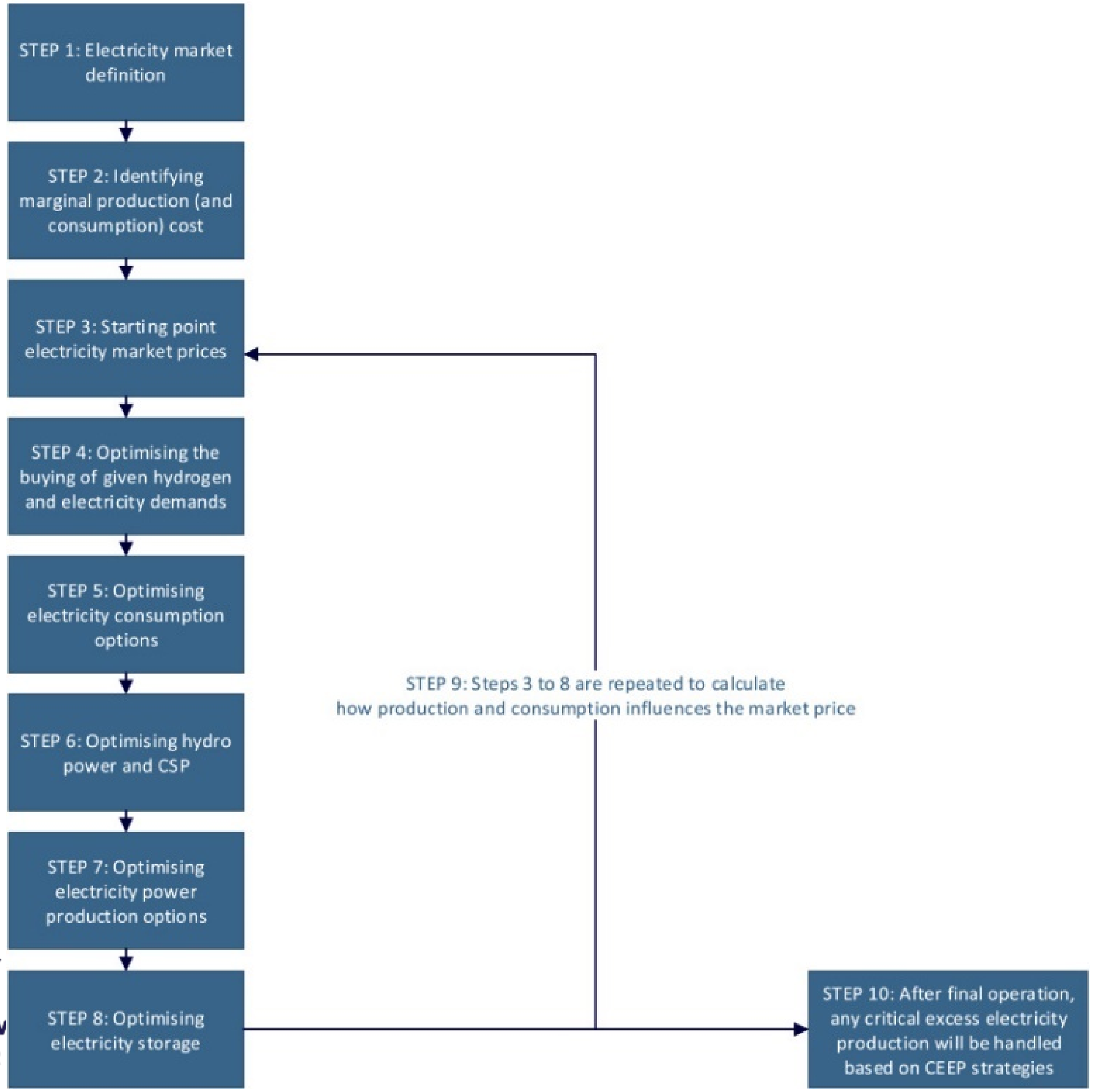
The two simulation strategies

Technical simulation



Economic simulation



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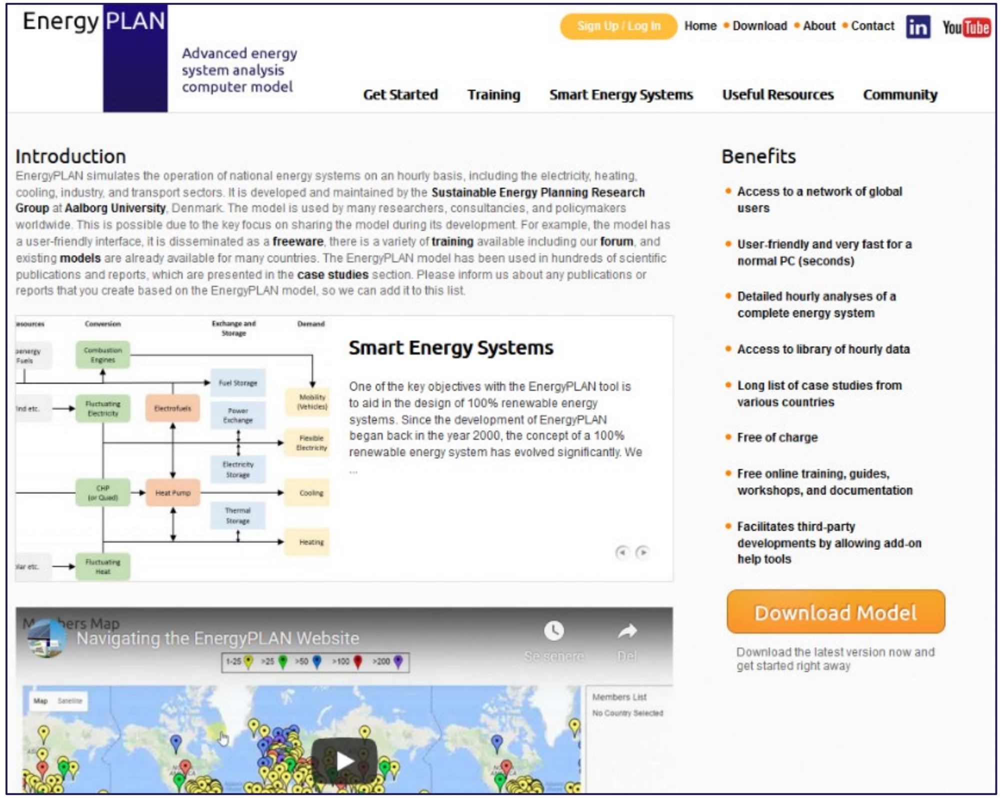
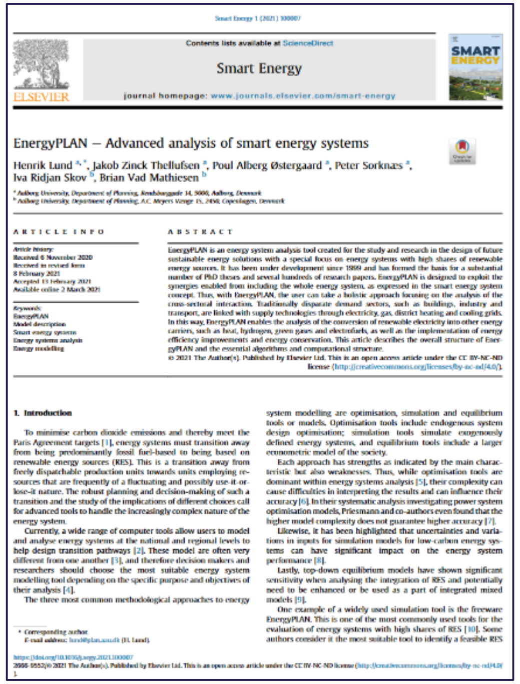
For more on EnergyPLAN

- https://www.energyplan.eu/



- Lund H, Thellufsen JZ, Østergaard PA, Sorknæs P, Skov IR, Mathiesen BV. EnergyPLAN – Advanced analysis of smart energy systems. Smart Energy 2021;1:100007. doi:10.1016/j.segy.2021.100007.


Smart Energy 1 (2021) 100007

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EnergyPLAN – Advanced analysis of smart energy systems

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ABSTRACT

EnergyPLAN is an energy system analysis tool created for the study and research in the design of future sustainable energy solutions with a special focus on energy systems with high shares of renewable energy sources. It has been under development since 1999 and has formed the basis for a substantial number of PhD theses and several hundreds of research papers. EnergyPLAN is designed to exploit the synergies enabled from including the whole energy system, as expressed in the smart energy system concept. Thus, with EnergyPLAN, the user can take a holistic approach focusing on the analysis of the cross-sectoral interaction. Traditionally disparate demand sectors, such as buildings, industry and

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EnergyPRO: combined technical and financial analysis of hybrid energy systems (Leif Holm Tambjerg, EMD International)

EnergyPRO

combined technical and financial analysis of hybrid energy systems

energyPRO

EMD International

Leif Holm Tambjerg, lht@emd.dk

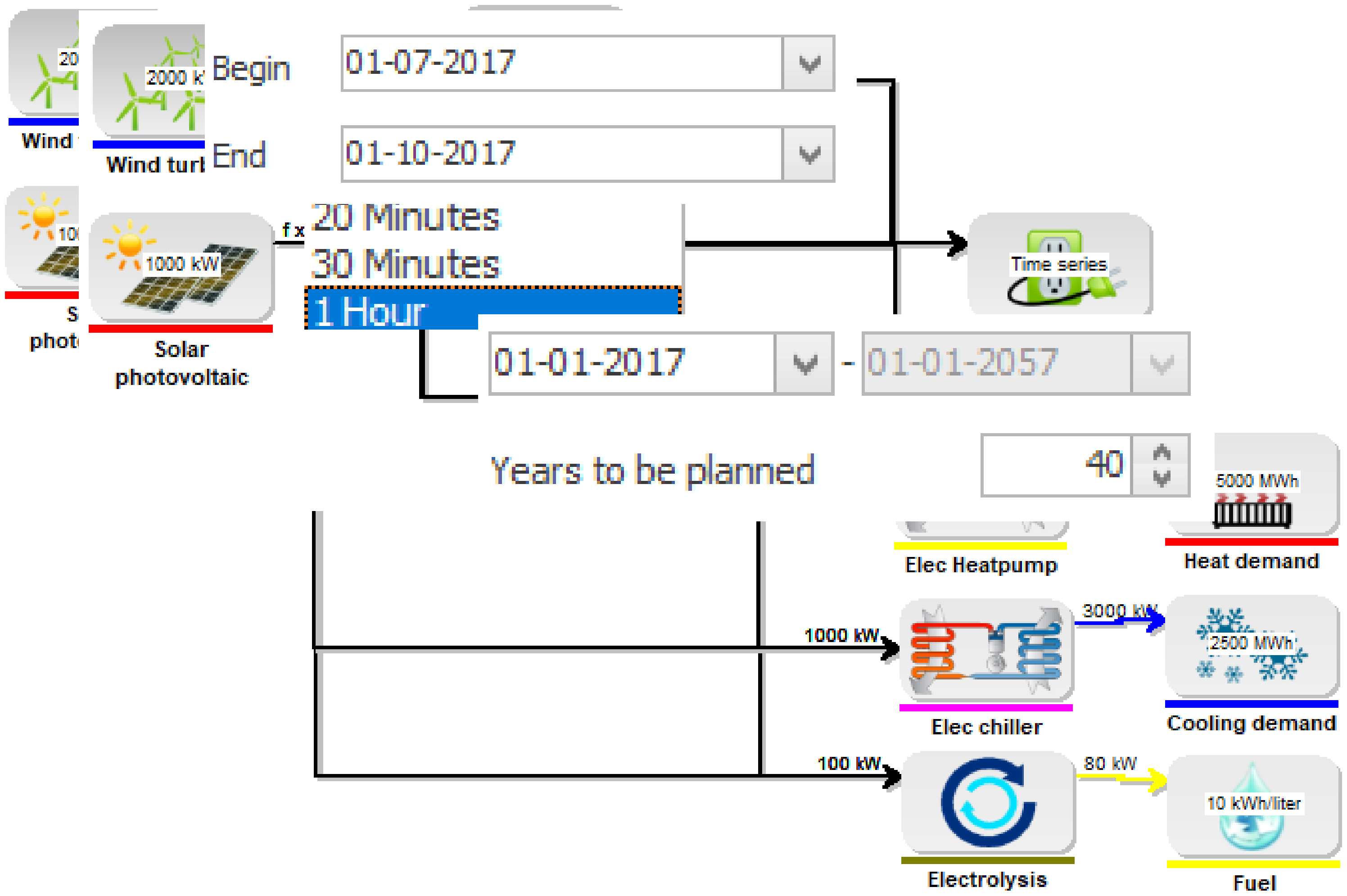
EMD International

- EMD is a global company supplying software and consultancy services for design, planning, documentation and operation of **wind energy projects** as well as **complex distributed energy projects**.
- Regional sales offices in Germany, France, Spain, United Kingdom, Turkey, USA, Brazil and China.
- The company is founded in 1986 and has a staff of app. 30 employees at the Danish office.

What is energyPRO

Techno-economic optimisation

- Energy system modelling
- Across energy sectors
    - Renewable energy
    - Electricity
    - Heating
    - Cooling
    - Fuels
- Hour by hour or less calculati
- 3 days or 40 years

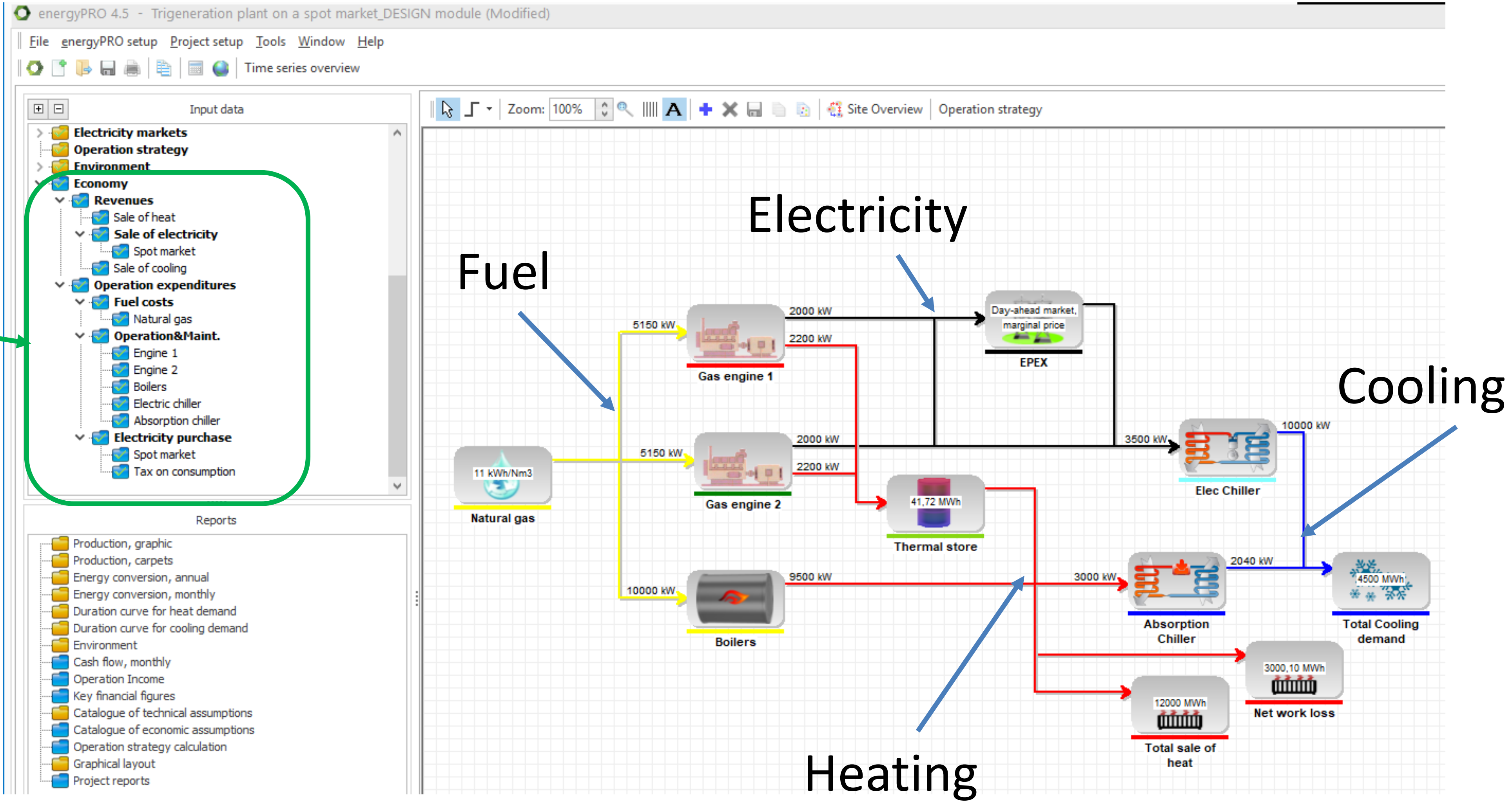


energyPRO in details

Across sectional example

Payments are essential in energyPRO

For calculating economic results, NPV, LCOE and for setting operation strategy

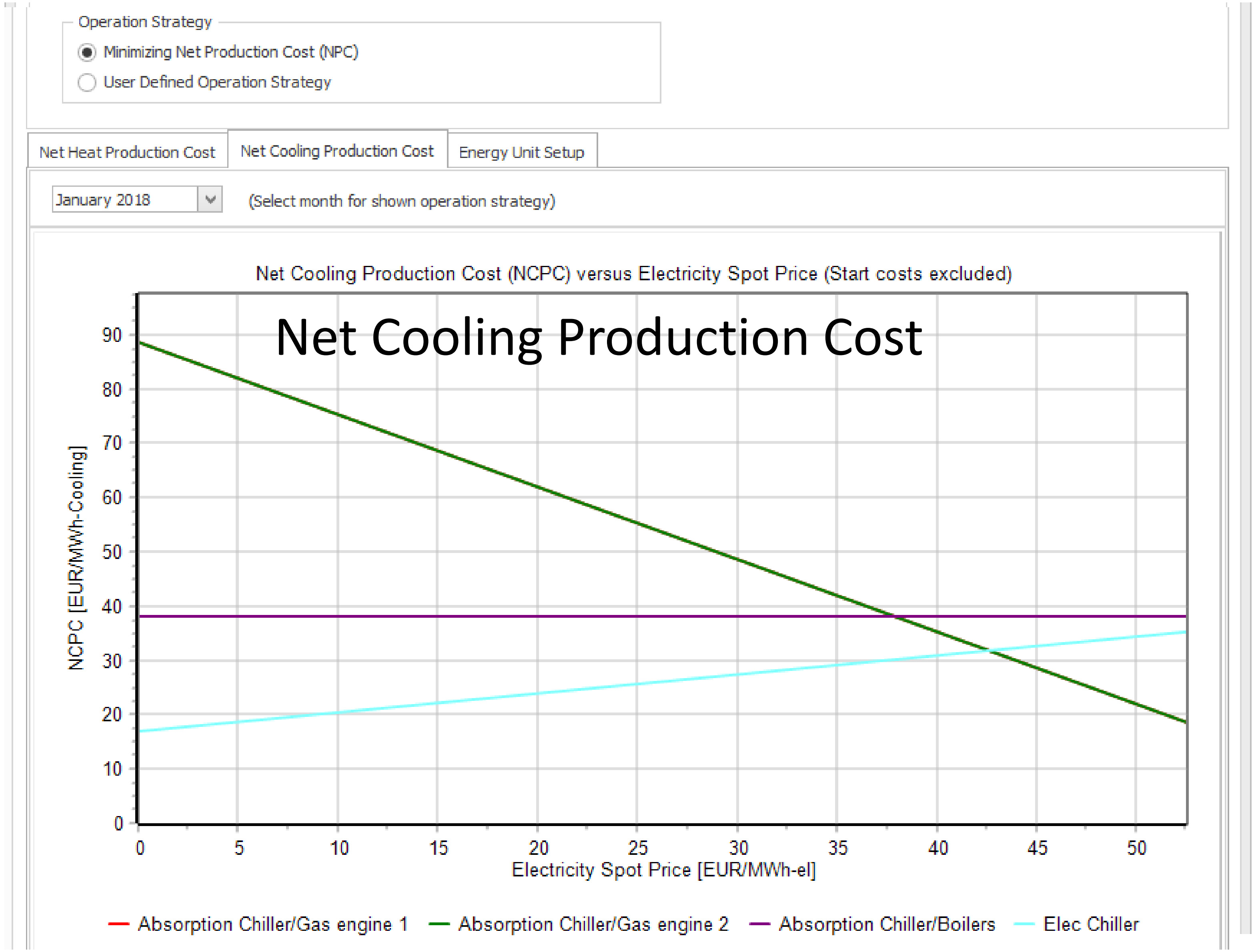


energyPRO in details

Operation strategy

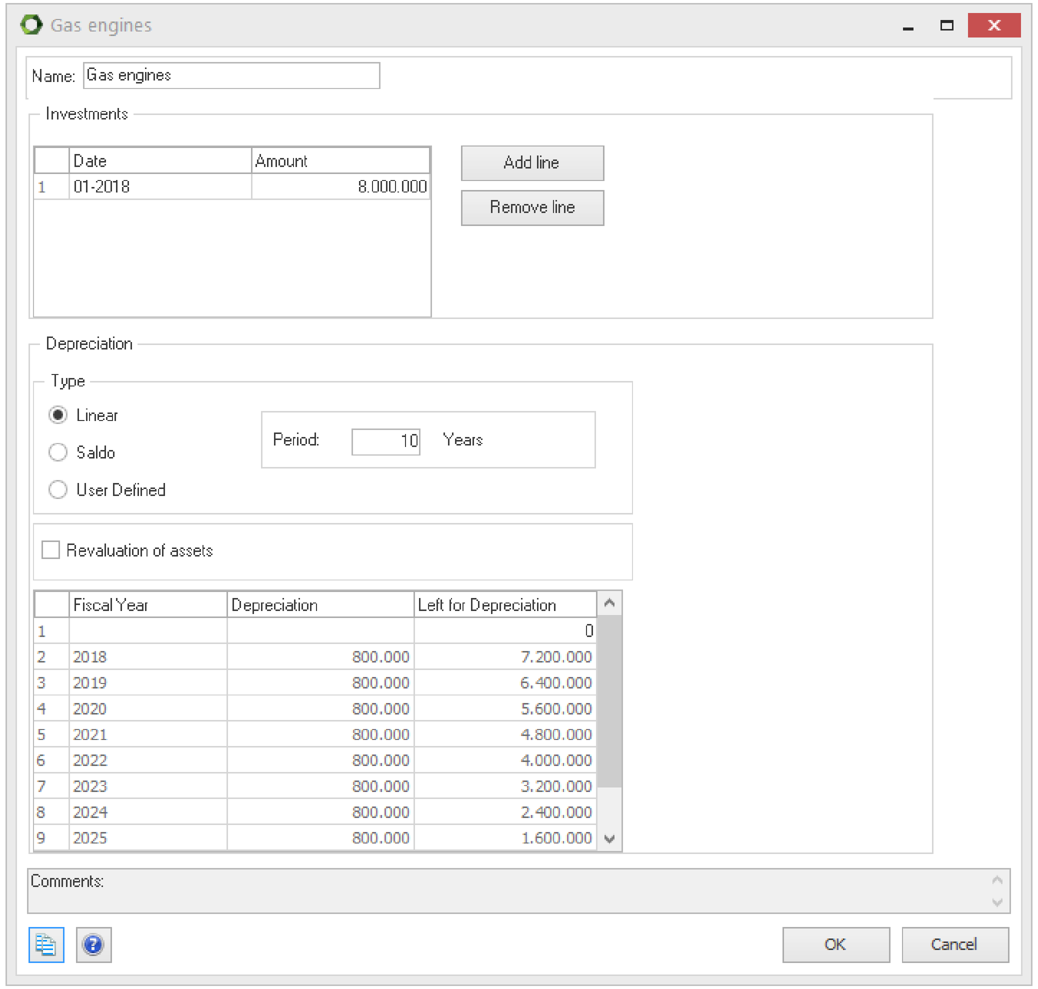
- Setting of energy conversion units and payments defines the operation strategy

- Two calculation methods:
  - Analytic
  - MILP



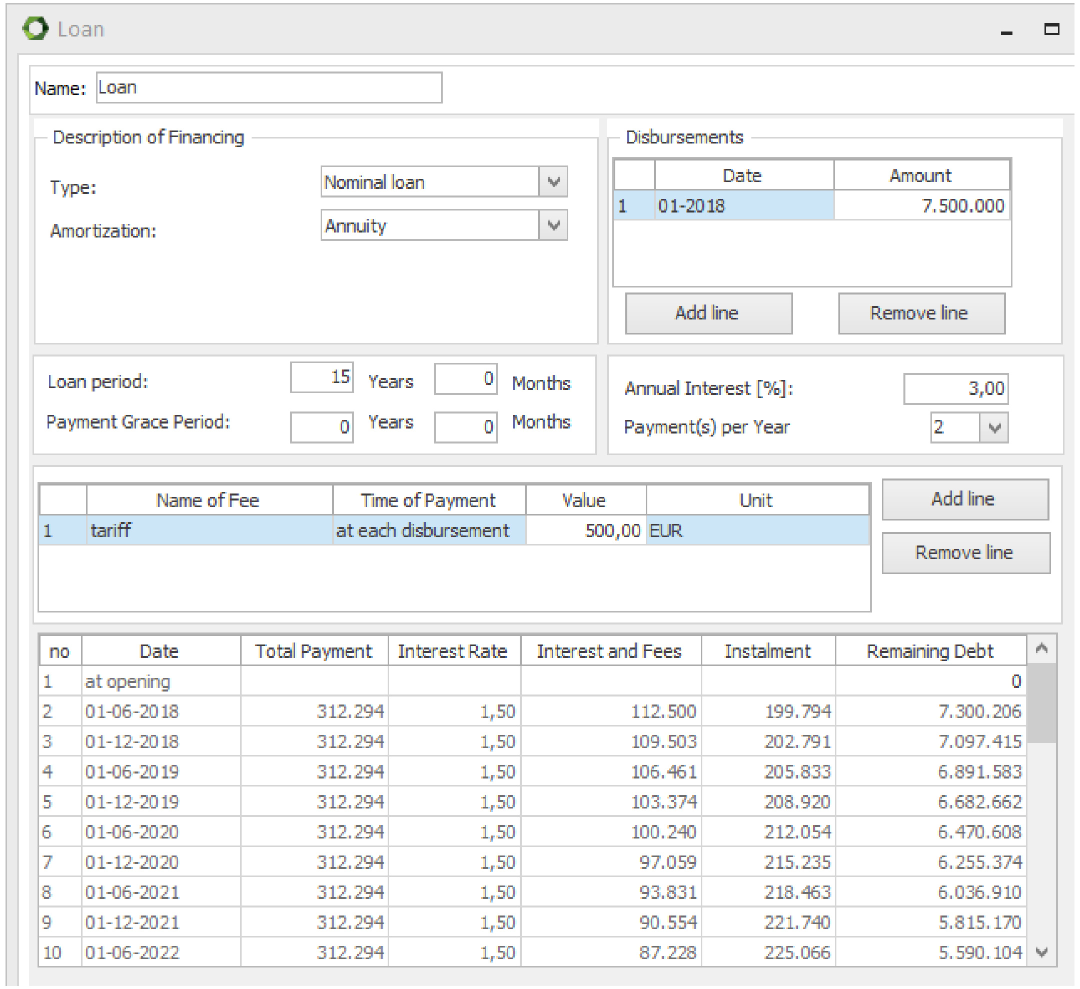
Investment, financing and taxes

Detailed settings of investments and financing



	Date	Amount
1	01-2018	8.000.000

	Fiscal Year	Depreciation	Left for Depreciation
1			0
2	2018	800.000	7.200.000
3	2019	800.000	6.400.000
4	2020	800.000	5.600.000
5	2021	800.000	4.800.000
6	2022	800.000	4.000.000
7	2023	800.000	3.200.000
8	2024	800.000	2.400.000
9	2025	800.000	1.600.000



	Date	Amount
1	01-2018	7.500.000

	Name of Fee	Time of Payment	Value	Unit
1	tariff	at each disbursement	500,00	EUR

no	Date	Total Payment	Interest Rate	Interest and Fees	Instalment	Remaining Debt
1	at opening					0
2	01-06-2018	312.294	1,50	112.500	199.794	7.300.206
3	01-12-2018	312.294	1,50	109.503	202.791	7.097.415
4	01-06-2019	312.294	1,50	106.461	205.833	6.891.583
5	01-12-2019	312.294	1,50	103.374	208.920	6.682.662
6	01-06-2020	312.294	1,50	100.240	212.054	6.470.608
7	01-12-2020	312.294	1,50	97.059	215.235	6.255.374
8	01-06-2021	312.294	1,50	93.831	218.463	6.036.910
9	01-12-2021	312.294	1,50	90.554	221.740	5.815.170
10	01-06-2022	312.294	1,50	87.228	225.066	5.590.104

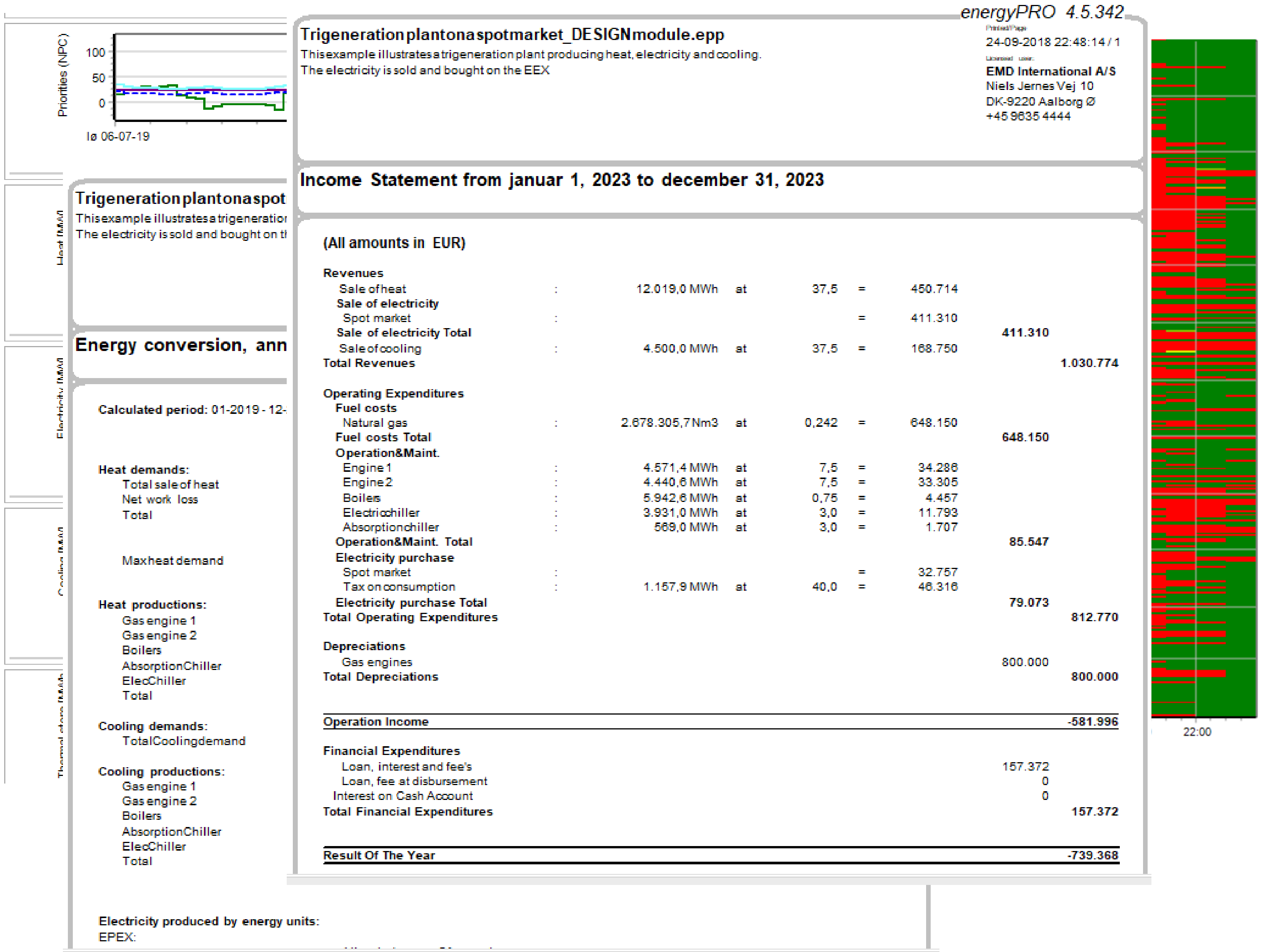
Reports

energyPRO

Numerous reports

Reports

- Production, graphic
  - 2018
  - 2019
  - 2020
  - 2021
  - 2022
  - 2023
  - 2024
  - 2025
  - 2026
  - 2027
- Production, carpets
- Energy conversion, annual
- Energy conversion, monthly
- Energy conversion, summary
- Duration curve for heat demand
- Duration curve for cooling demand
- Environment
- Cash flow, monthly
- Cash flow, summary
- Cash flow, graphic
- Key financial figures
- Income Statement
- Income Statement, summary
- Balance Sheet
- Balance Sheet, summary
- Catalogue of technical assumptions
- Catalogue of economic assumptions
- Operation strategy calculation
- Graphical layout
- Project reports



Trigenerationplantonaspotmarket_DESIGNmodule.epp

Thisexample illustratesatrigeneration plant producing heat, electricity and cooling.
The electricity is sold and bought on the EEX

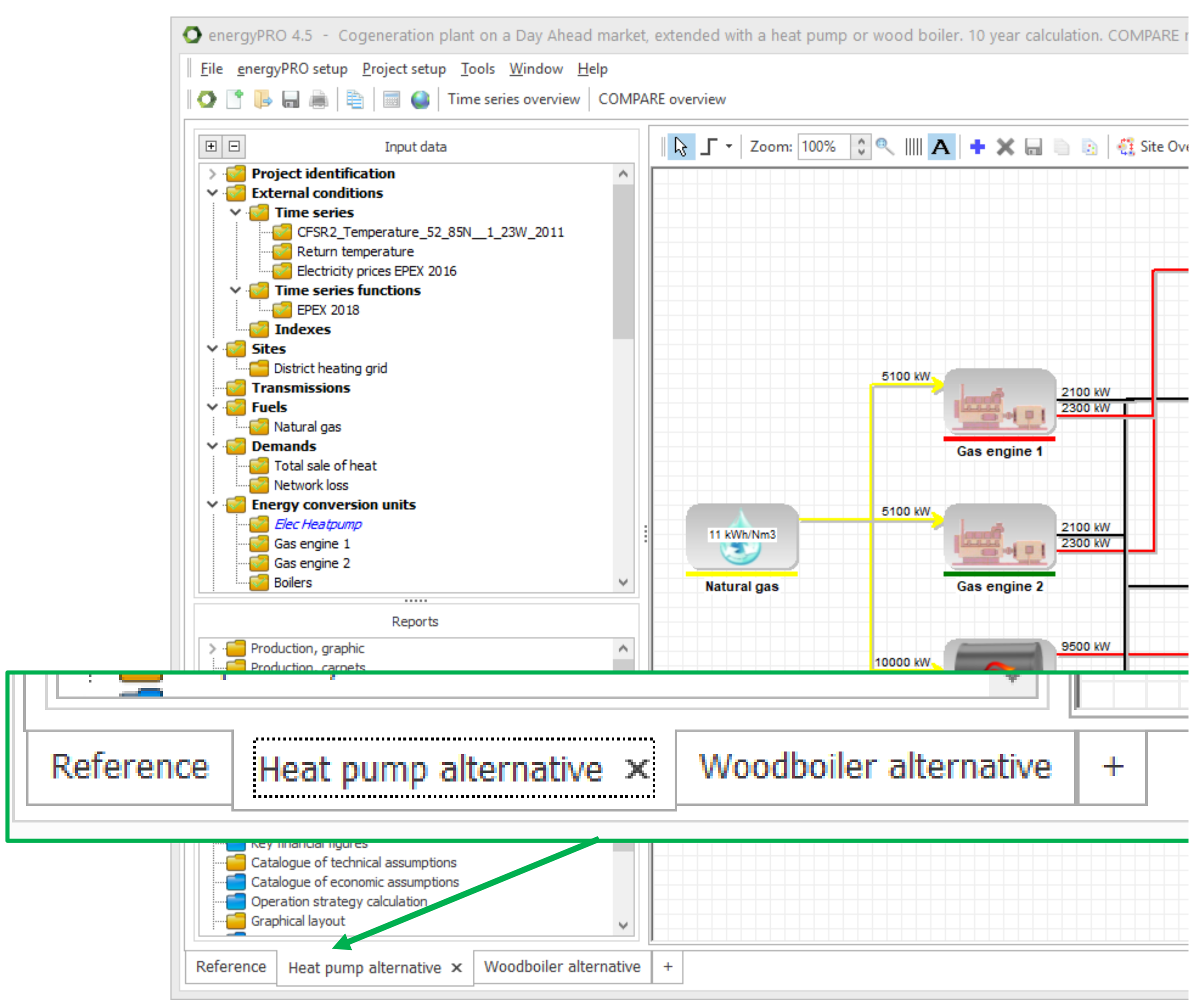
Income Statement from januar 1, 2023 to december 31, 2023

(All amounts in EUR)

Revenues					
Sale of heat	12.019,0 MWh	at 37,5	= 450.714		
Sale of electricity					
Spot market			= 411.310		
Sale of electricity Total				411.310	
Sale of cooling	4.500,0 MWh	at 37,5	= 168.750		
Total Revenues					1.030.774
Operating Expenditures					
Fuel costs					
Natural gas	2.678.305,7 Nm3	at 0,242	= 648.150		
Fuel costs Total				648.150	
Operation&Maint.					
Engine 1	4.571,4 MWh	at 7,5	= 34.286		
Engine 2	4.440,6 MWh	at 7,5	= 33.305		
Boilers	5.942,6 MWh	at 0,75	= 4.457		
Electricchiller	3.931,0 MWh	at 3,0	= 11.793		
Absorptionchiller	569,0 MWh	at 3,0	= 1.707		
Operation&Maint. Total				85.547	
Electricity purchase					
Spot market			= 32.757		
Tax on consumption	1.157,9 MWh	at 40,0	= 46.316		
Electricity purchase Total				79.073	
Total Operating Expenditures					812.770
Depreciations					
Gas engines				800.000	
Total Depreciations					800.000
Operation Income					-581.996
Financial Expenditures					
Loan, interest and fee's				157.372	
Loan, fee at disbursement				0	
Interest on Cash Account				0	
Total Financial Expenditures					157.372
Result Of The Year					-739.368

COMPARE

Use COMPARE to evaluate different alternatives



Compare key financial figures

Net present values of the alternatives relative to the reference scenario

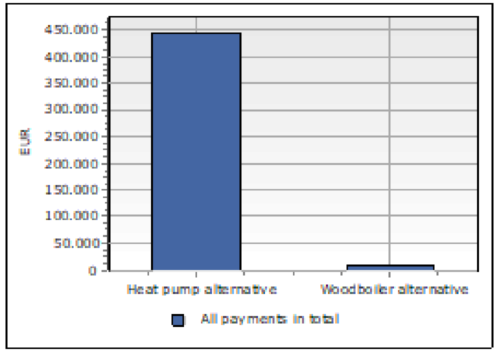
Nominal discountrate: 3,0
Project period : 10 years from januar 2018 to december 2027

Increased net present values of Heat pump alternative relative to reference

Revenues	:	-1.645.030 EUR
OperatingExpenditures	:	-3.590.482 EUR
Operational payments in total	:	**1.945.452 EUR**
Investments	:	1.500.000 EUR
Operational payments and investments in total	:	**445.452 EUR**
Financing	:	0 EUR
All payments in total	:	**445.452 EUR**

Increased net present values of Woodboiler alternative relative to reference

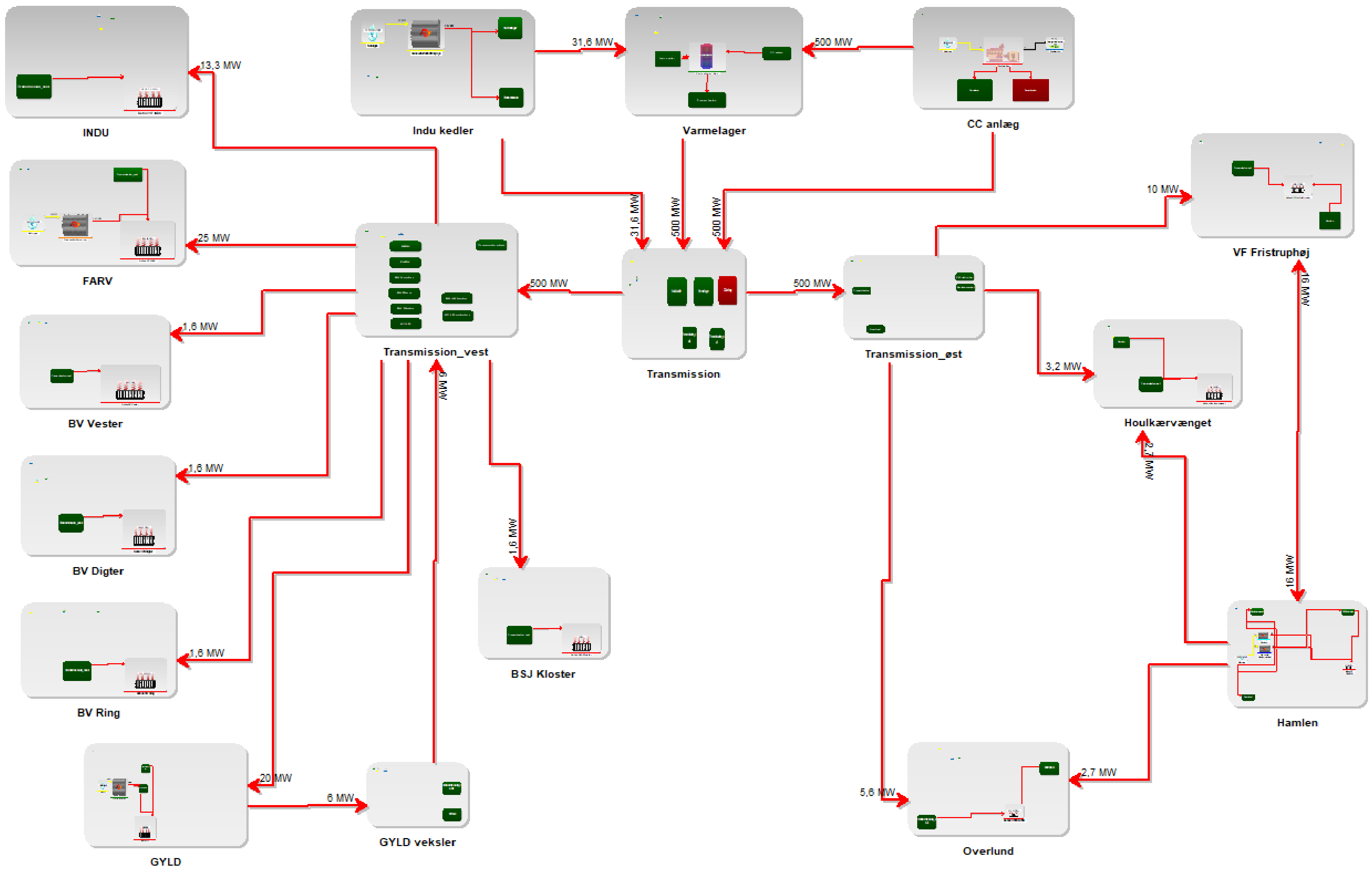
Revenues	:	-1.149.847 EUR
OperatingExpenditures	:	-2.157.534 EUR
Operational payments in total	:	**1.007.687 EUR**
Investments	:	1.000.000 EUR
Operational payments and investments in total	:	**7.687 EUR**
Financing	:	0 EUR
All payments in total	:	**7.687 EUR**



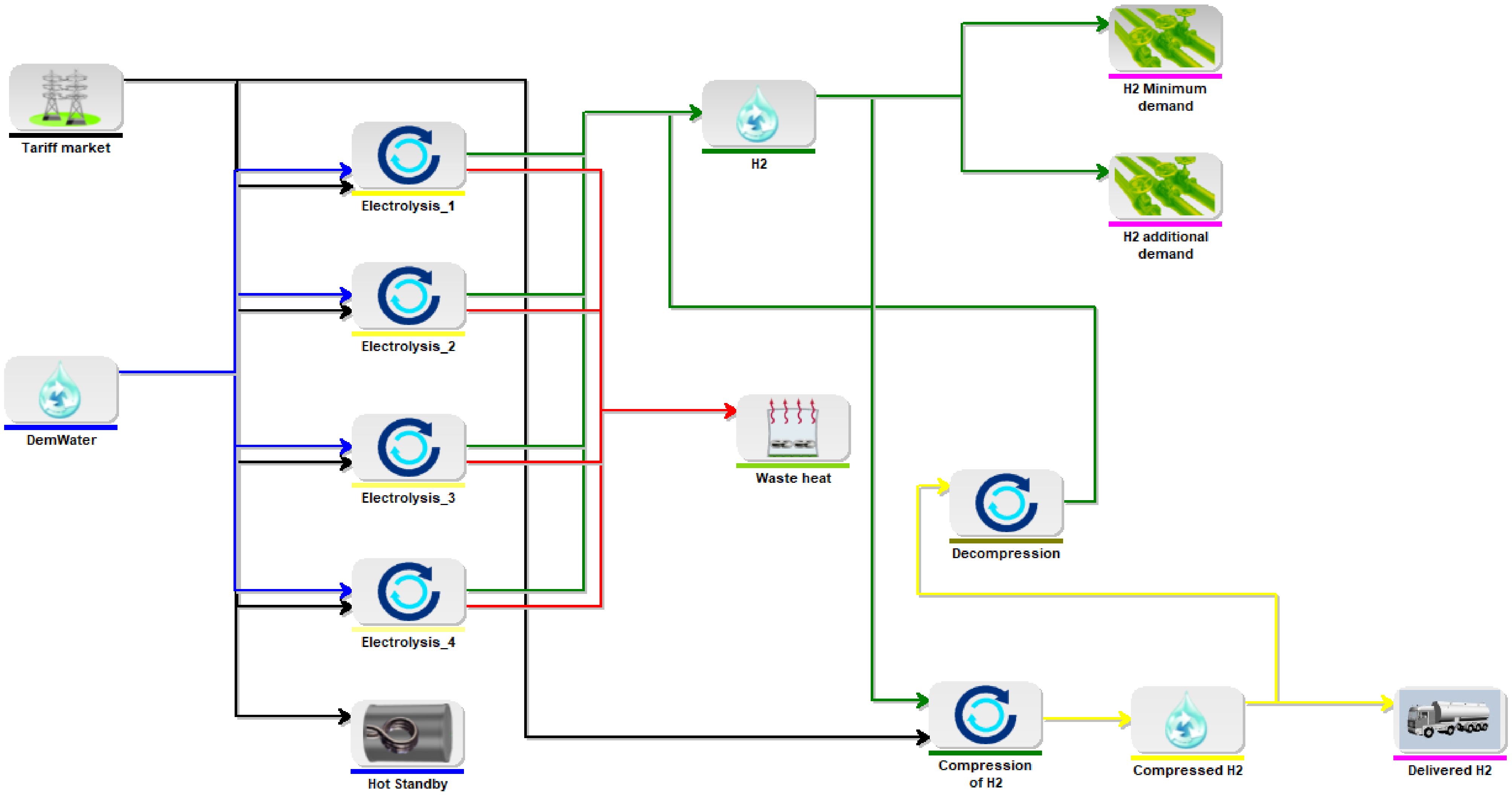
Discounted Payback Period

Heatpump alternative	7,3 years
Woodboiler alternative	9,8 years

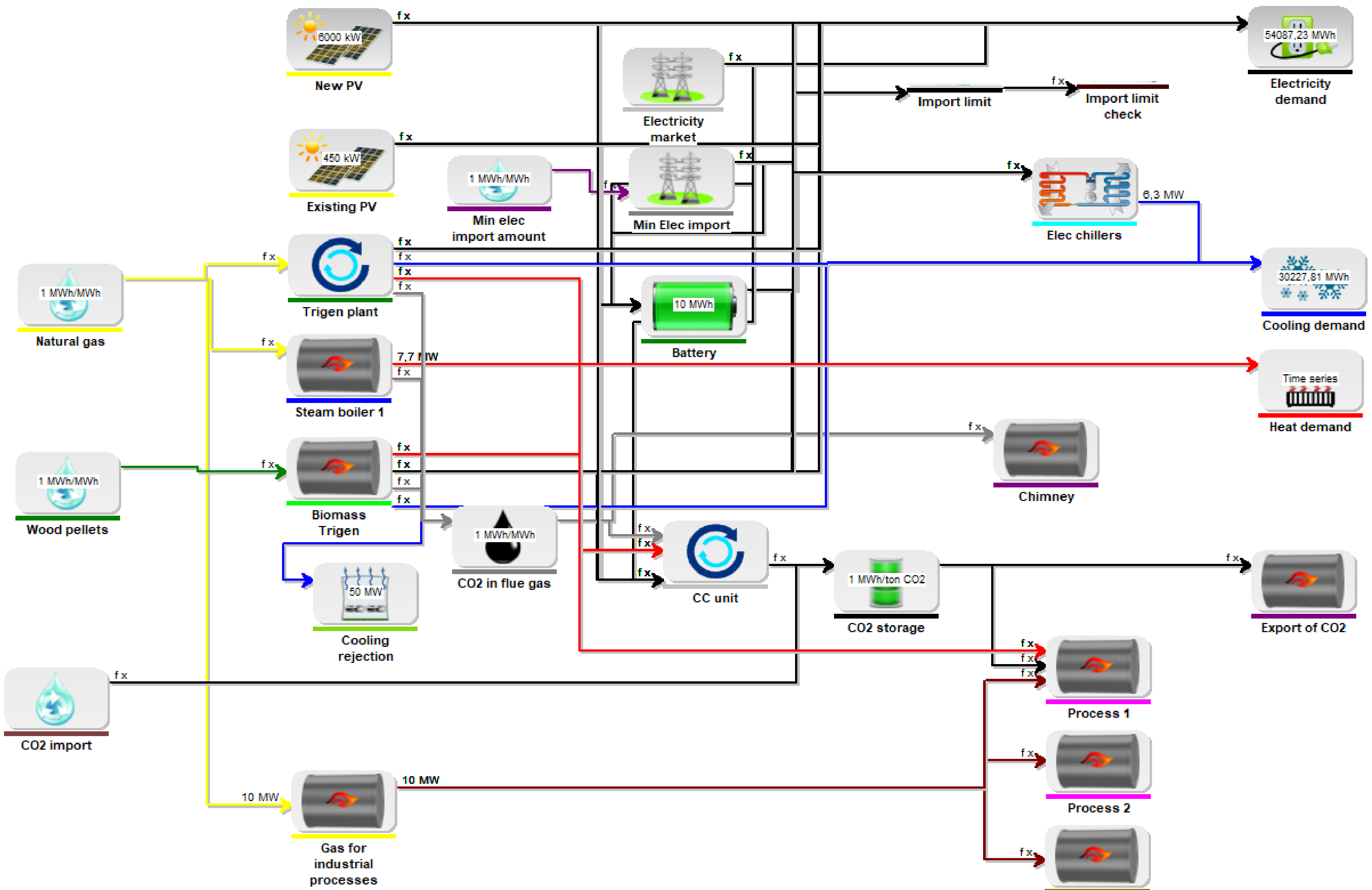
REGION, Danish district heating system example



Power to X example



Industrial complex example



energyPRO modules

energyPRO is a commercial tool

- Download for free at https://www.emd.dk/energypro/
- Explore more than 50 project examples
- Ask for a time limited test license, sales@emd.dk for building your own models
- Find prices and make orders at https://www.emd.dk/energypro/order-energypro/

Thank you for your attention

Leif Holm Tambjerg
Energy System Product Manager
lht@emd.dk

Pandaplan: quasi-dynamic assessment of hybrid energy network design and operation (Dennis Cronbach, Fraunhofer IEE)

IEA TS3 Webinar

Pandaplan: quasi-dynamic assessment of hybrid energy network design and operation

Dennis Cronbach

April 27th 2021

Kassel

Fraunhofer IEE

- Was formerly known as Fraunhofer IWES, having a focus on power grids and wind energy systems
- In 2018, the institute was split up into two independent ones – the IEE in Kassel and the IWES in Bremerhaven

Energy economics	Energy system technology
Energy meteorology information systems	Grid planning and operation
Analysis and consulting for energy economics	Power electronics and electric drive systems
Wind resource assessment with LiDAR	Hardware in the loop systems
Training and knowledge transfer	Measuring and testing

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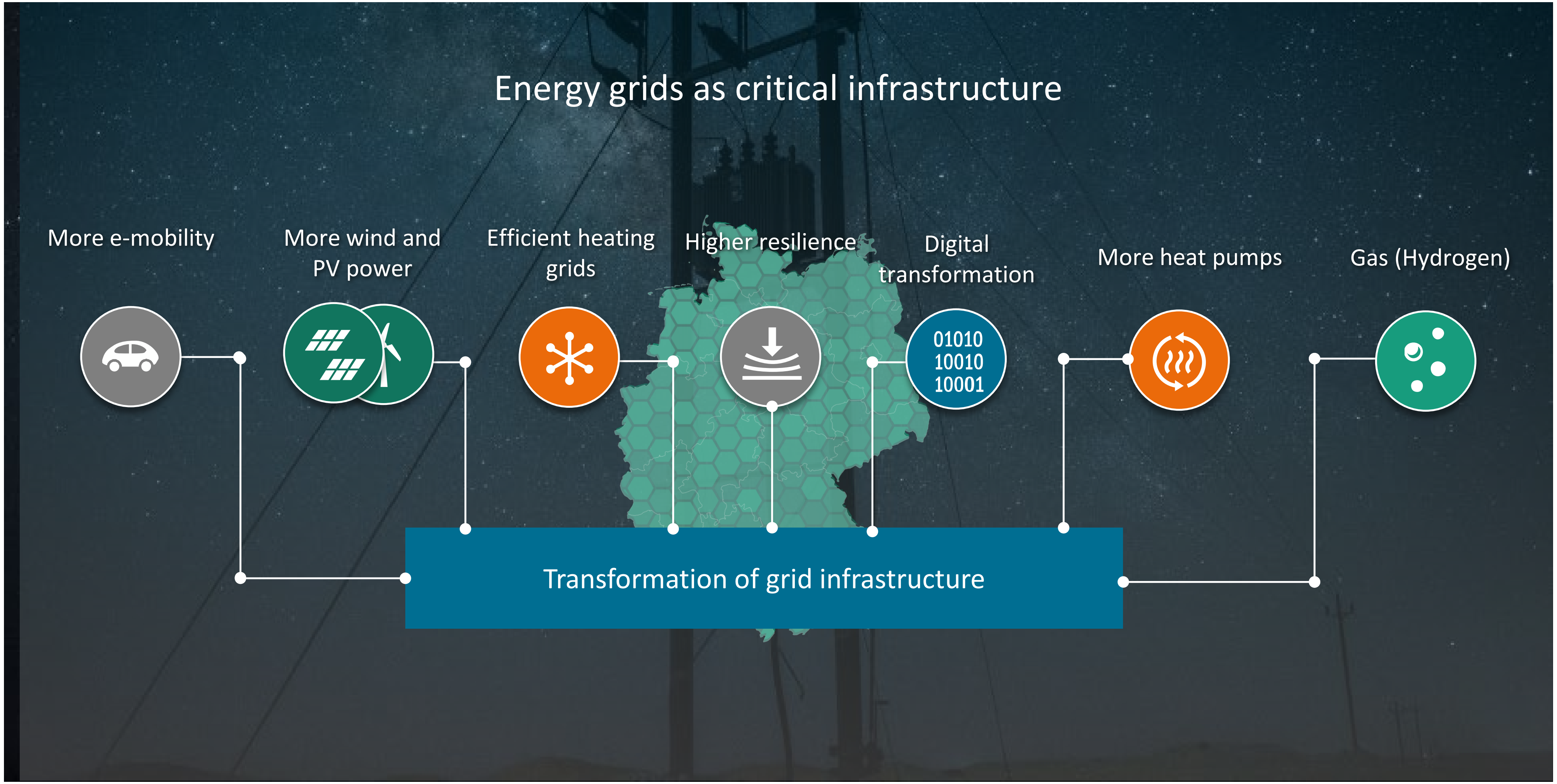
Fraunhofer IEE



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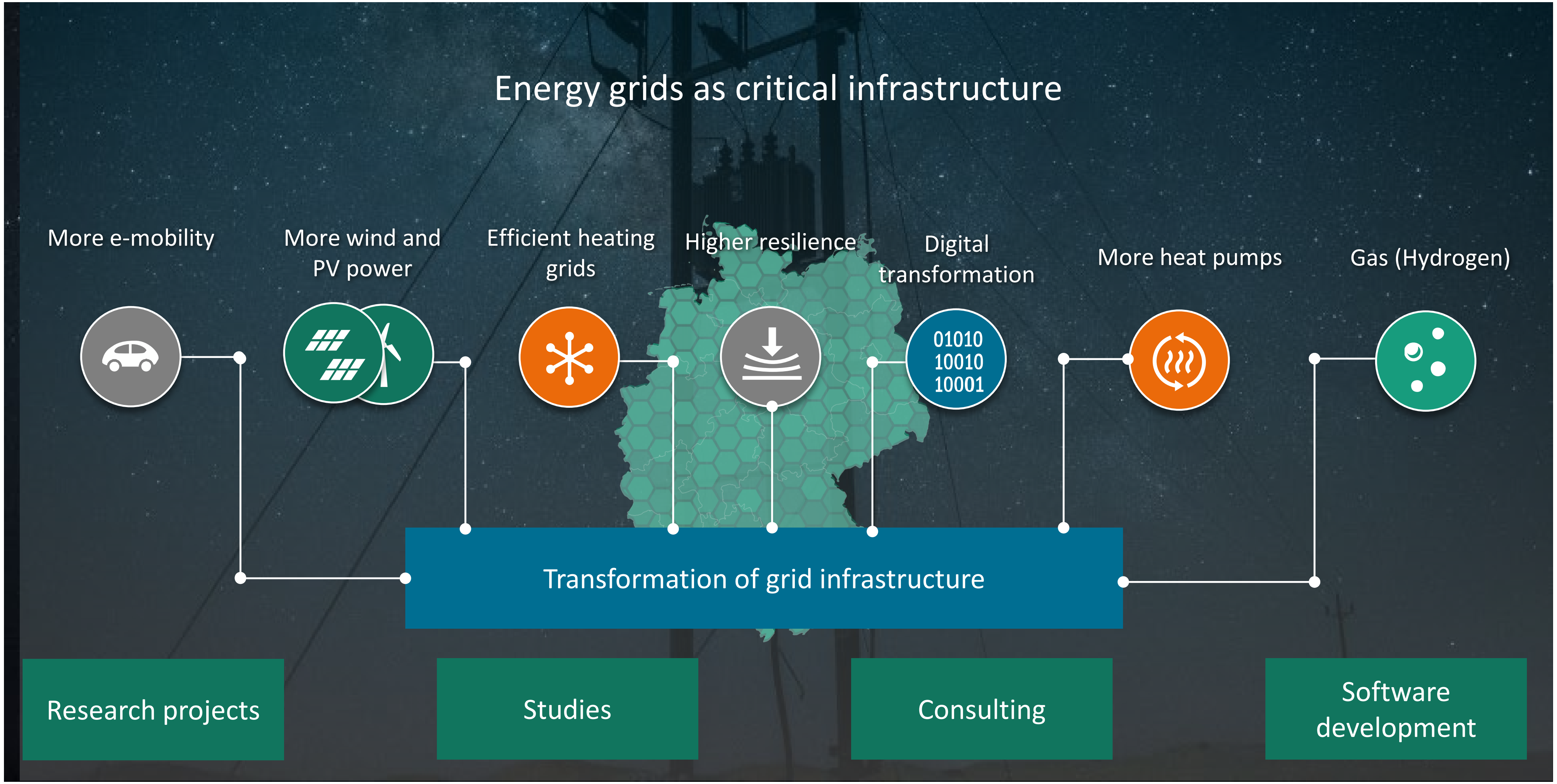
Fraunhofer IEE

Fraunhofer IEE



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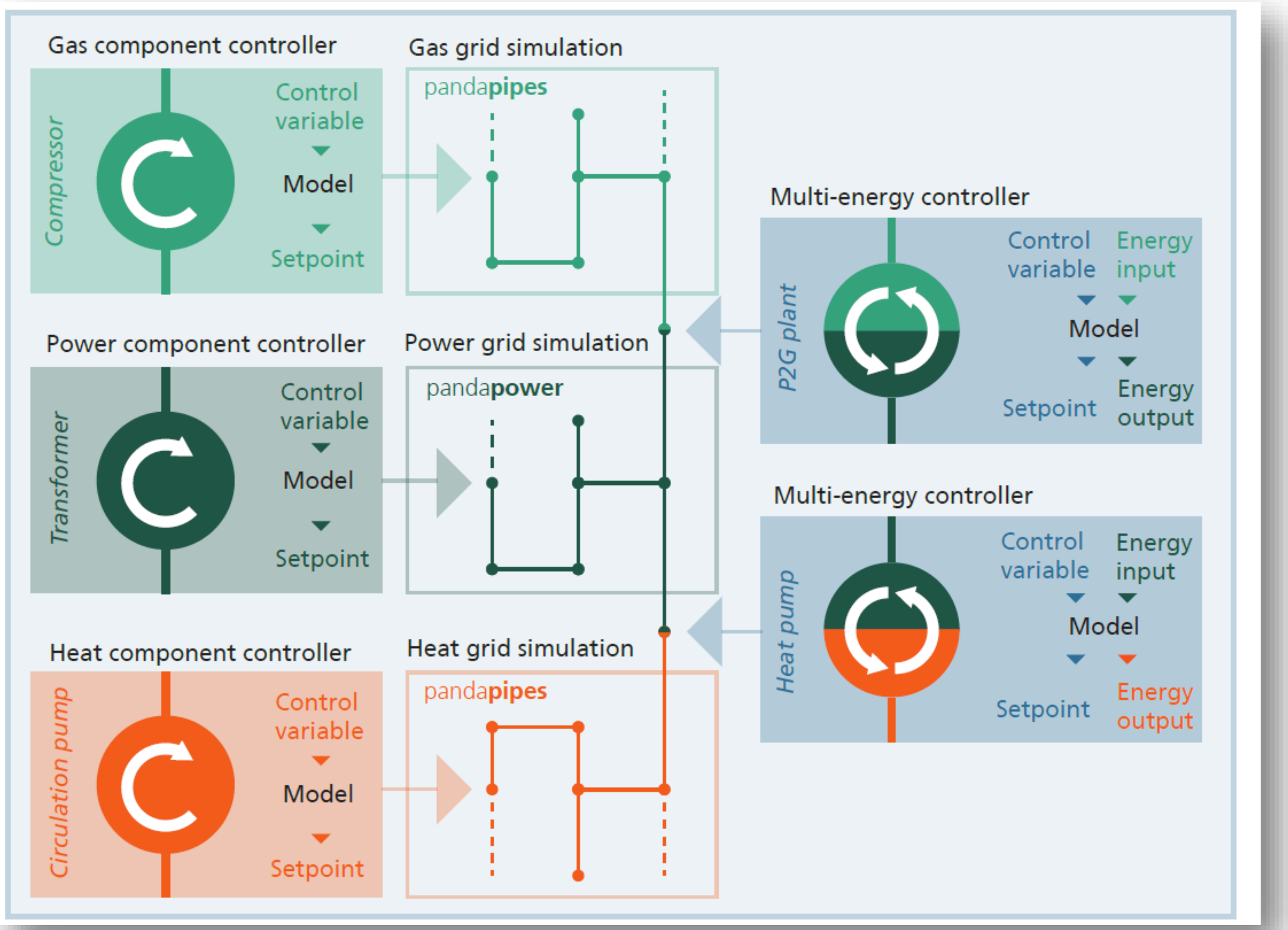
Pandaplan - Motivation of development & Features

- energy transition includes all sectors
- gas and district heating infrastructure exists and will be extended in many regions
- coordinated planning of all infrastructures saves costs
- tools for pipe flow calculation are rare, especially in open-source world

Pandaplan - Motivation of development & Features

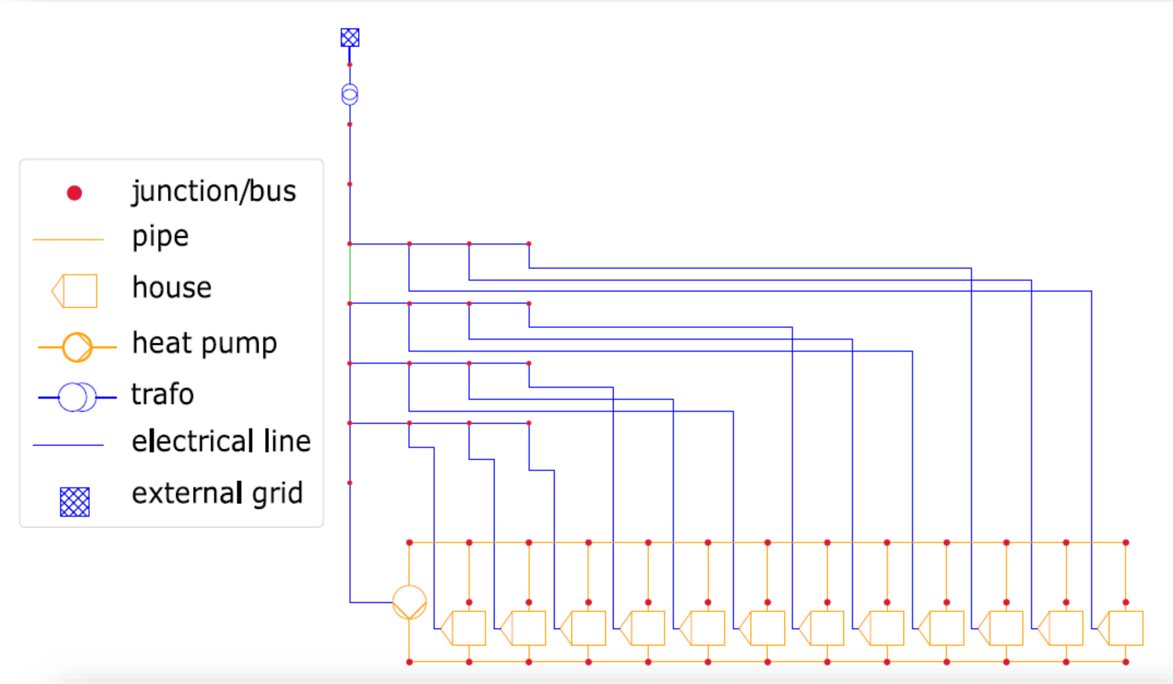
- Open source
- Implemented as a python module
  - Automation of calculations
  - Including additional modules, e.g. for data evaluation
  - Code can be modified completely
  - easy coupling of the applications
  - easy to use for pandapower users
- Calculation of the combined grid for quasi-stationary applications
  - Calculation of pressure, flow velocity and temperature for gas and district heating grids
  - Calculation of voltage and phase for power grids
  - Further variables can be derived

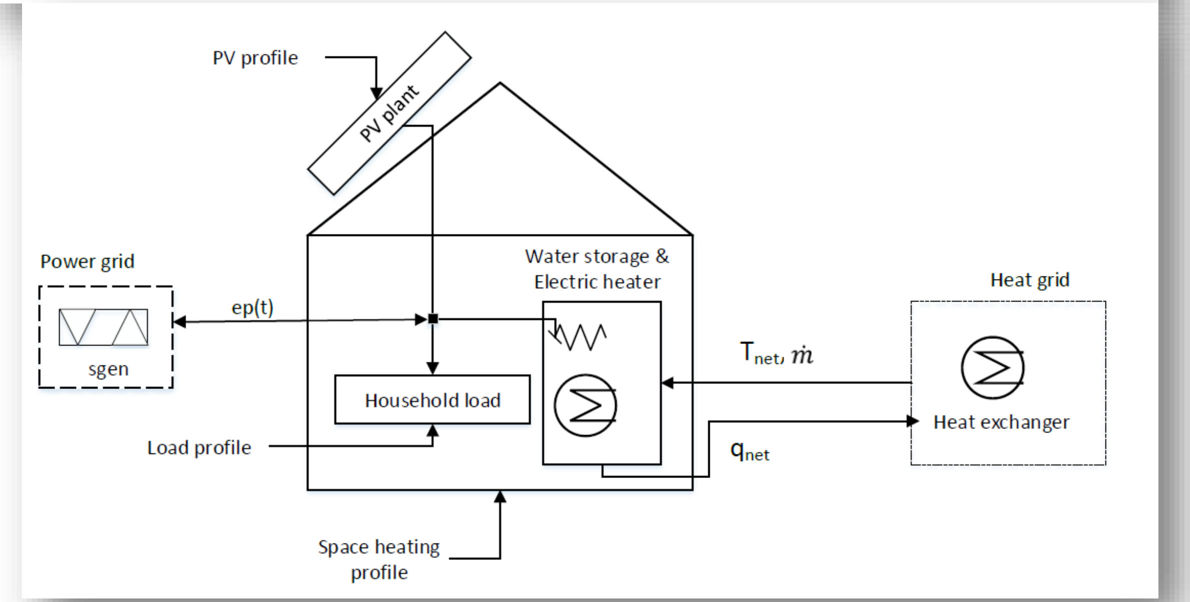
Pandaplan – How sectors are coupled



Pandaplan – Use case

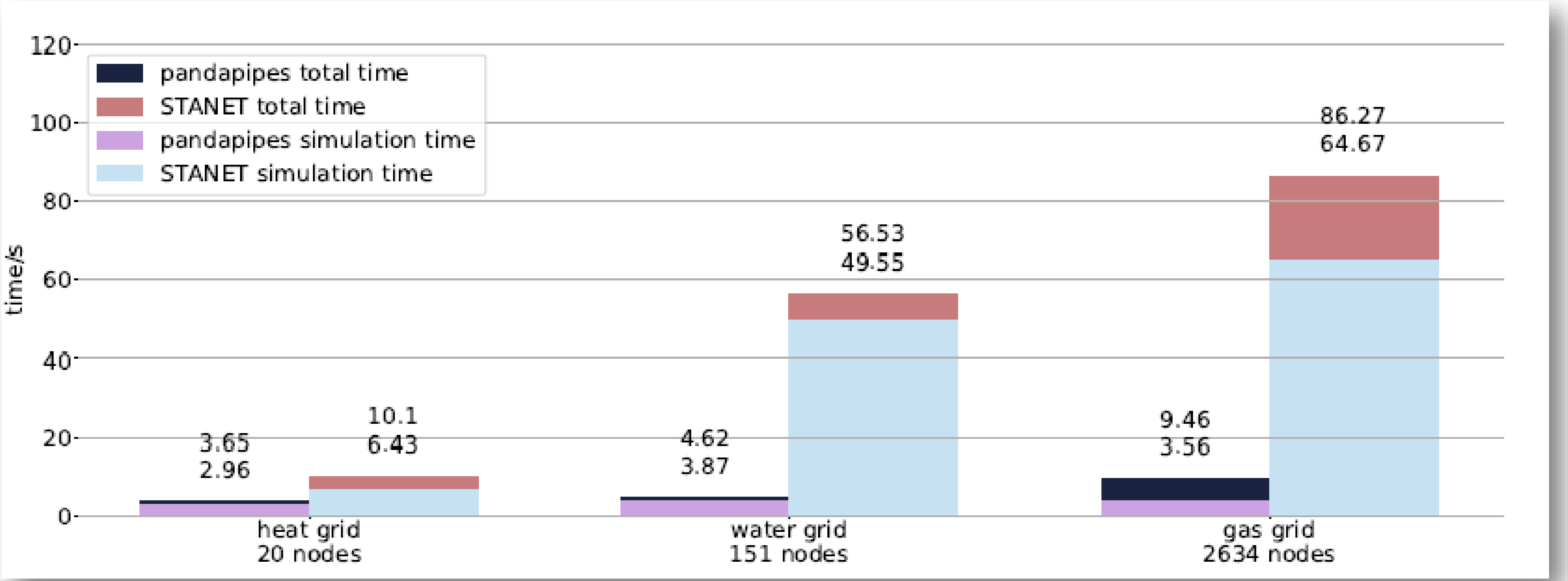
- Simulation of a coupled district heating and power grid
- District heating grid is supplied by a central heat pump
- Household water storages are additionally equipped with an electrical heater
- Households may generate power with PV roof plants
- Depending on the congestion state of the power lines and the availability of excess PV power, the heat pump may be operated at different temperatures





Fraunhofer
IEE

Pandapipes – Performance



Outlook

- Calculation of gas mixtures
- Transient calculation mode for heating applications
- Additional controller components for the open source version

www.pandapower.org

www.pandapipes.org

Fumola & DisHeatLib: co-simulation-based analysis of the dynamics of hybrid energy network operation (Benedikt Leitner, AIT)

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INTEGRATED NETWORKS

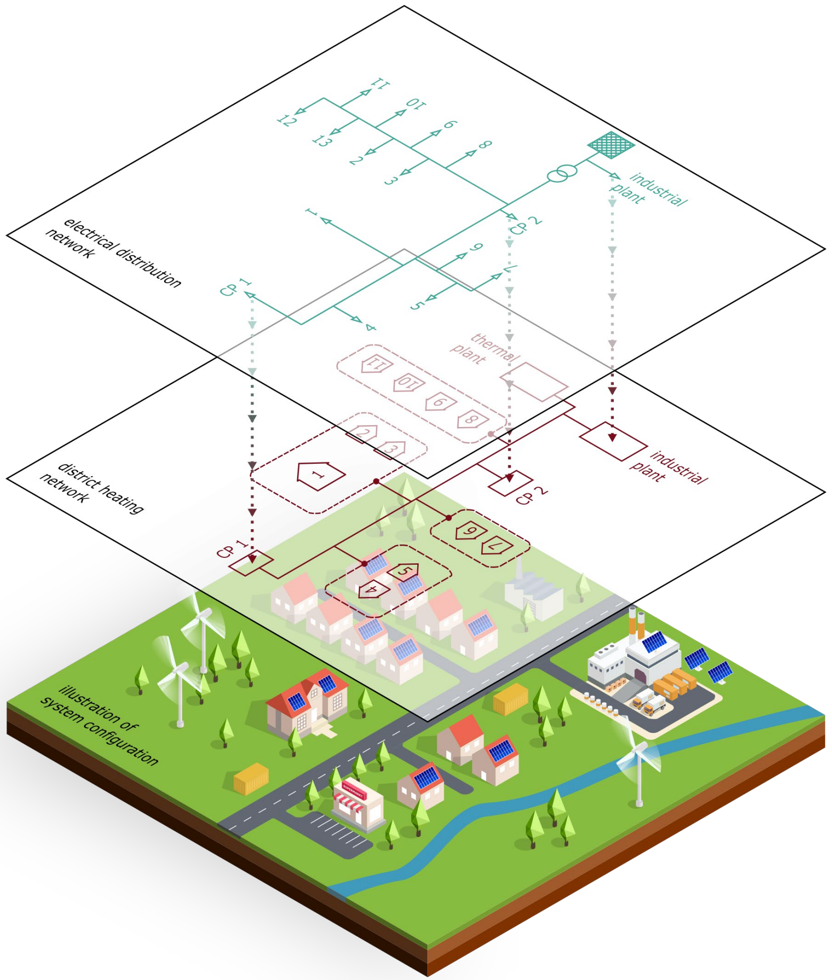
Co-simulation-based analysis of the dynamics of hybrid energy network operation

Benedikt Leitner

AIT Austrian Institute of Technology

Vienna, Austria

benedikt.leitner@ait.ac.at

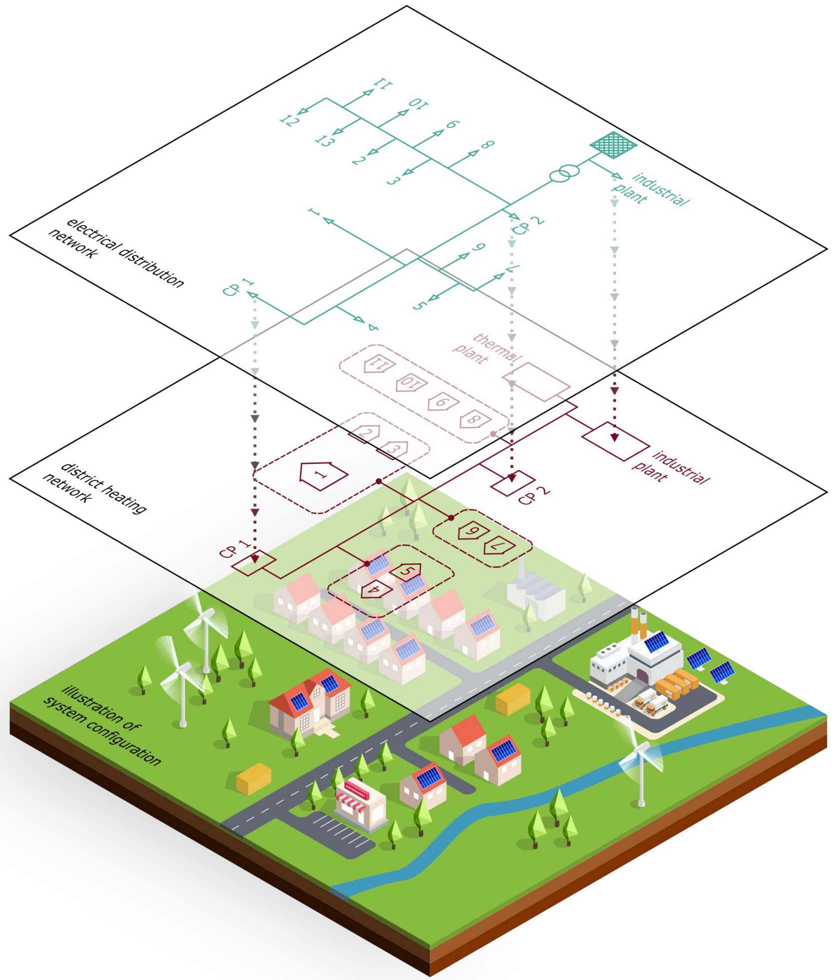


SMART ENERGY SYSTEMS

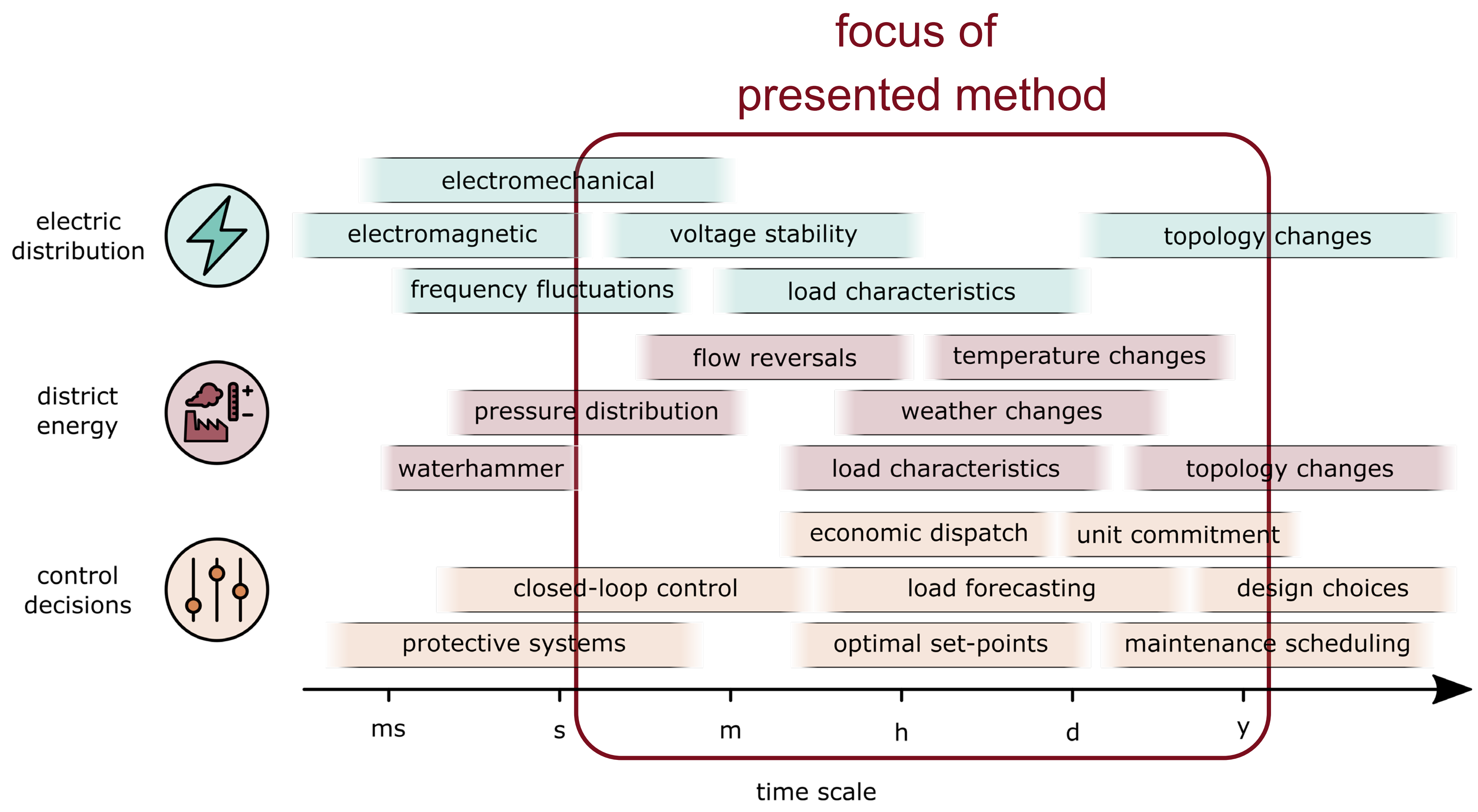
Heat and power networks transform from centralized fossil fuel based generation to:

- Bi-directional networks
- Distributed generation and storages
- Prosumers
- Intelligent control
- Low energy buildings
- Distributed thermal-electric coupling
- …

→ Increasing complexity of multi-domain systems



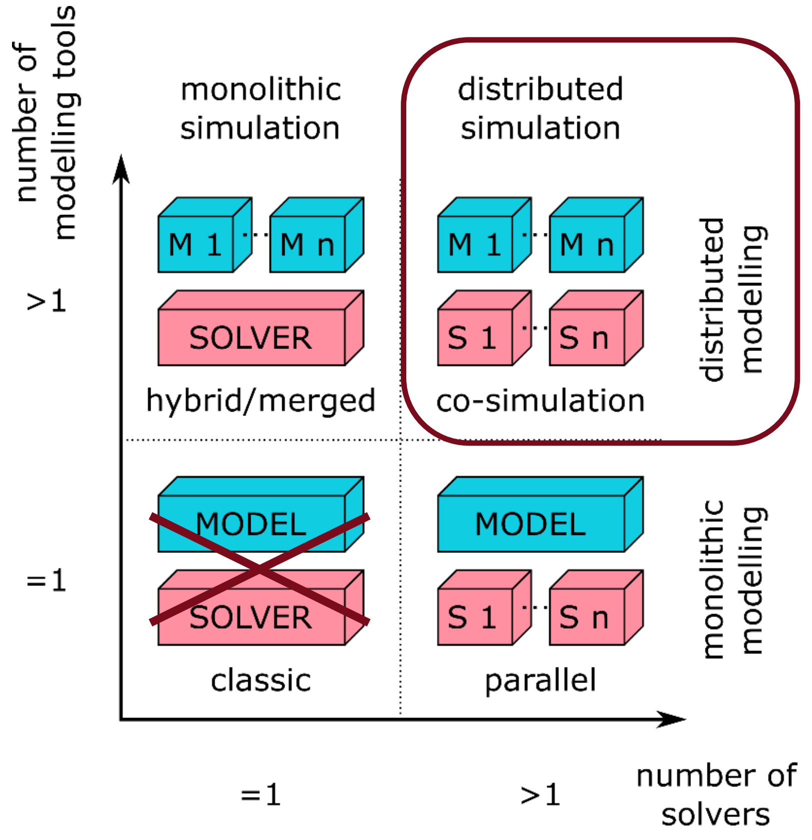
RELEVANT PHENOMENA AND TIME SCALES



CO-SIMULATION MOTIVATION

- **No single tool** that covers all necessary domains:
  - Thermo-hydraulic models
  - Electric distribution networks
  - Extendable to advanced control algorithms, detailed building models …

- **Co-simulation** is a possible solution
  - Cherry-picking of tools
  - Diverse setups possible

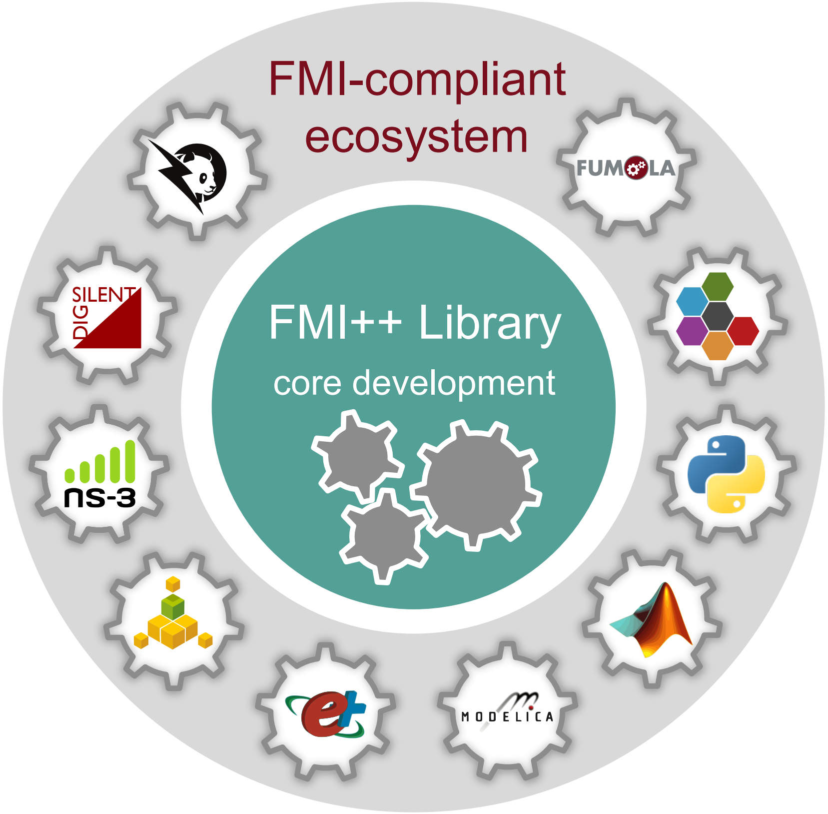


Towards a classification scheme for co-simulation approaches in energy systems,
F. Schloegl et al., in proceedings of SEDST, 2015.

CO-SIMULATION TOOLCHAIN

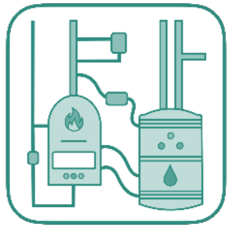
- The **Functional Mock-up Interface (FMI)** specification has been developed to encapsulate and link models and simulators.
  - currently supported by > 100 tools

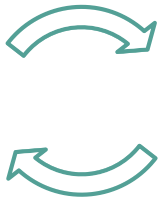
- The **FMI++ Library** is based on FMI
  - open-source development
  - cross-platform and cross-language
  - allows cherry picking of tools and modeling paradigms



Functional Mock-up Interface (FMI) standard https://fmi-standard.org/
FMI++ Python interface https://pypi.org/project/

FOCUS ON OPERATIONAL ASSESSMENT

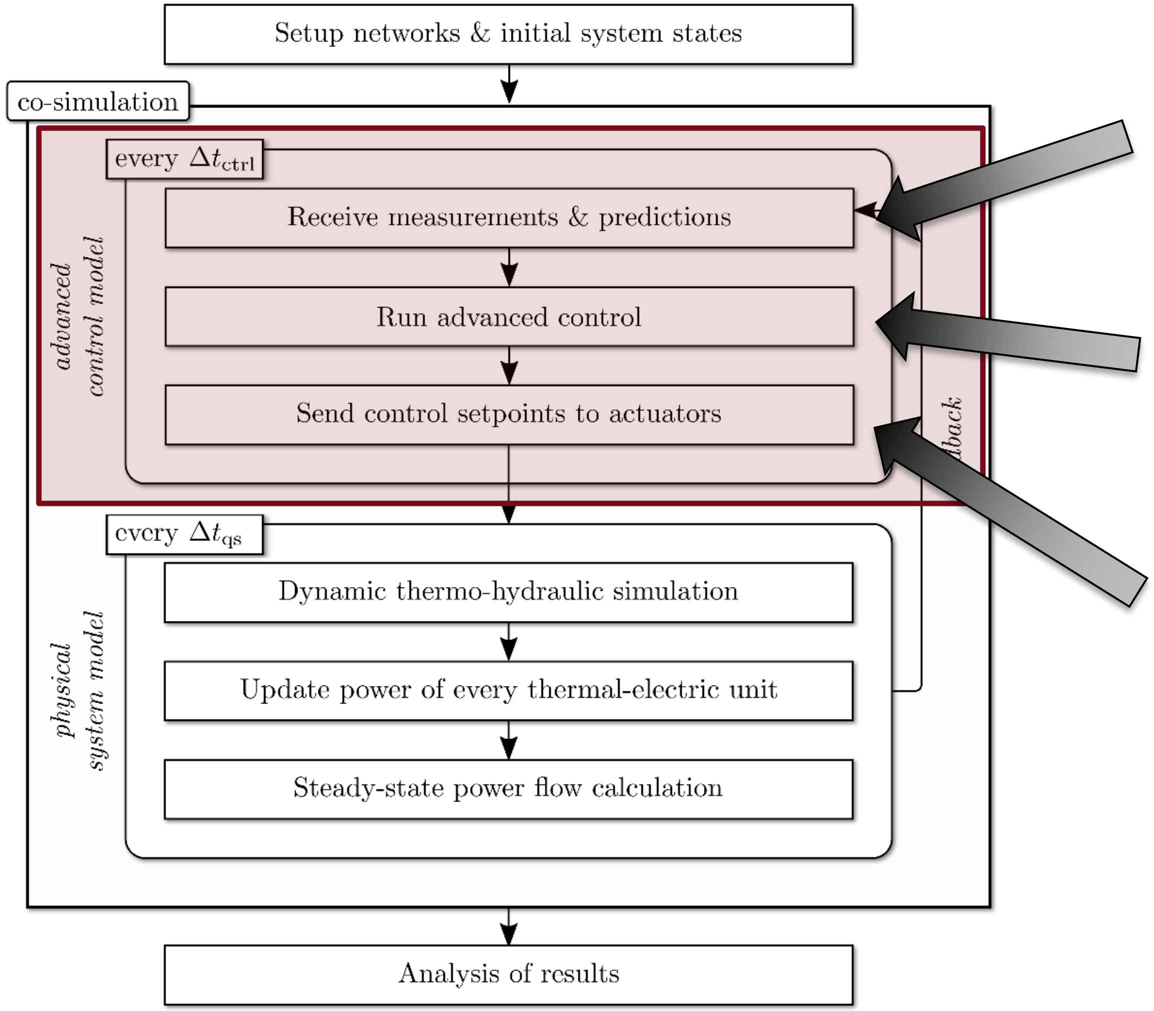




- **Physical system** modeling
  - Electric distribution modeling approaches (quasi-static, dynamic, …)
  - District heating modeling approaches (hydraulics, temperature propagation, dynamics, …)

- **Control system** modeling
  - Discrete, continuous, …
  - Rule-based, optimal, …
  - Supervisory, local, …
  - Central, distributed, hybrid, …

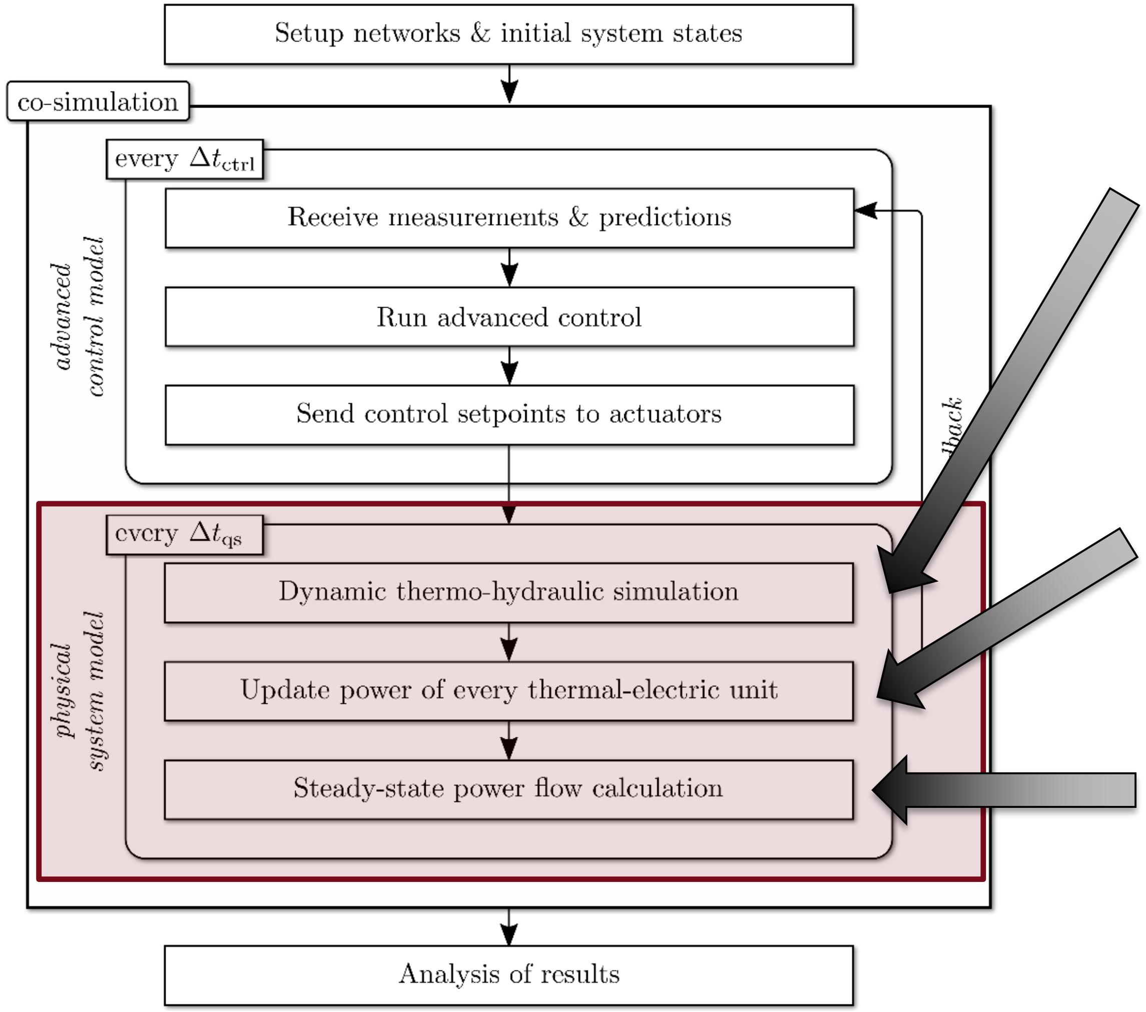
CONTROL ASSESSMENT



- **Feedback** from physical
  - Closed-loop control
  - Corrects for modelling differences
- **Advanced control algorithms**
  - E.g., model predictive control
- **Setpoints** sent to physical system

Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy, 2020

CONTROL ASSESSMENT

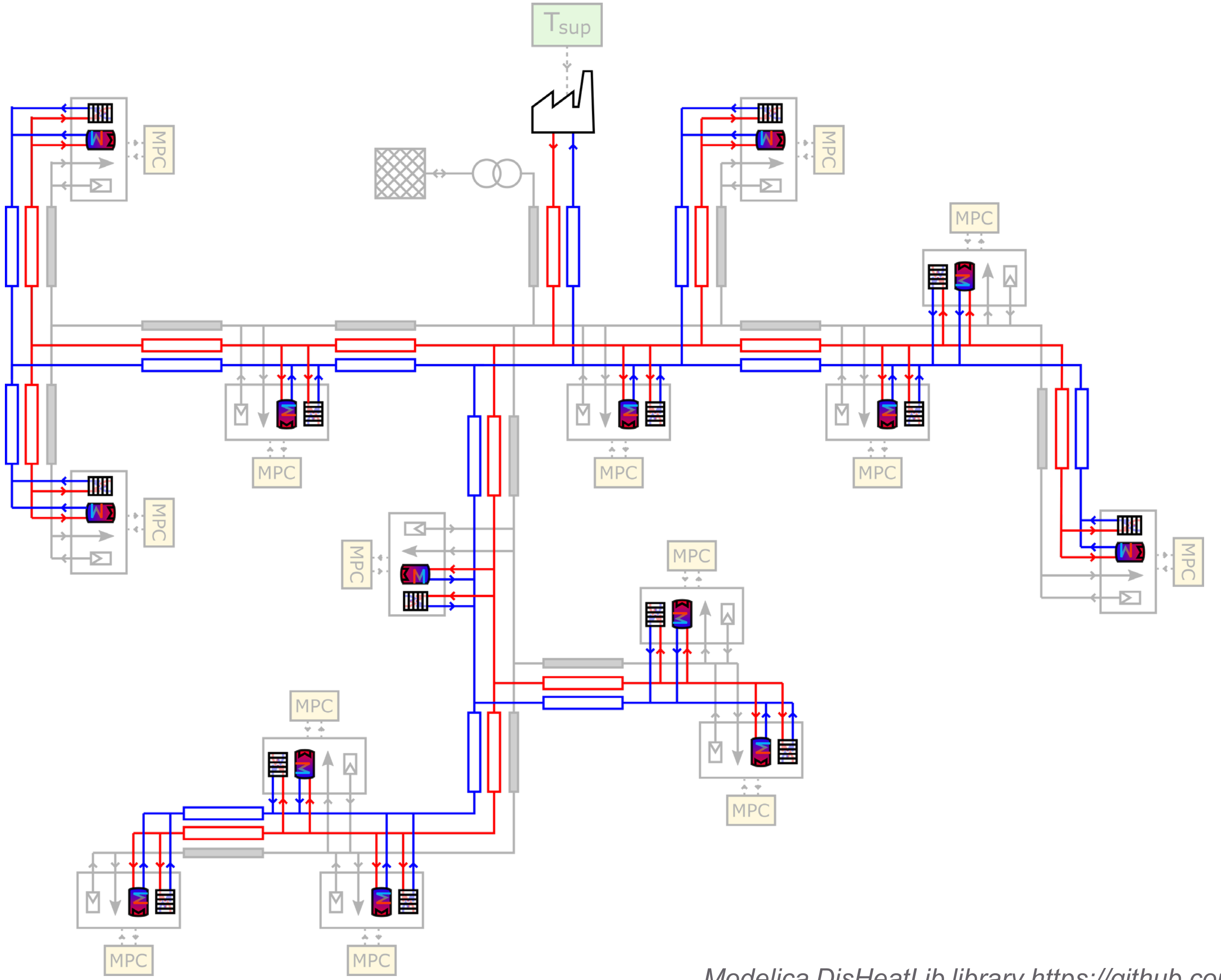


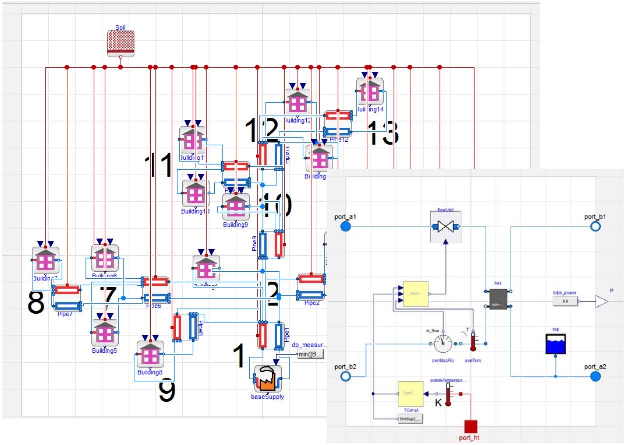
- **District heating** network
  - Transient thermal & quasi-static hydraulic models
- **Sequential coupling** of smodels
  - Exchange of power consumption/generation
- **Electrical distribution** network
  - Quasi-static simulation solving power flow equations each time step

Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy, 2020

EXAMPLE APPLICATIONS: PHYSICAL SYSTEM

- **District heating** network simulation





Modelica DisHeatLib library https://github.com/AIT-IES/DisHeatLib

EXAMPLE APPLICATIONS: PHYSICAL SYSTEM

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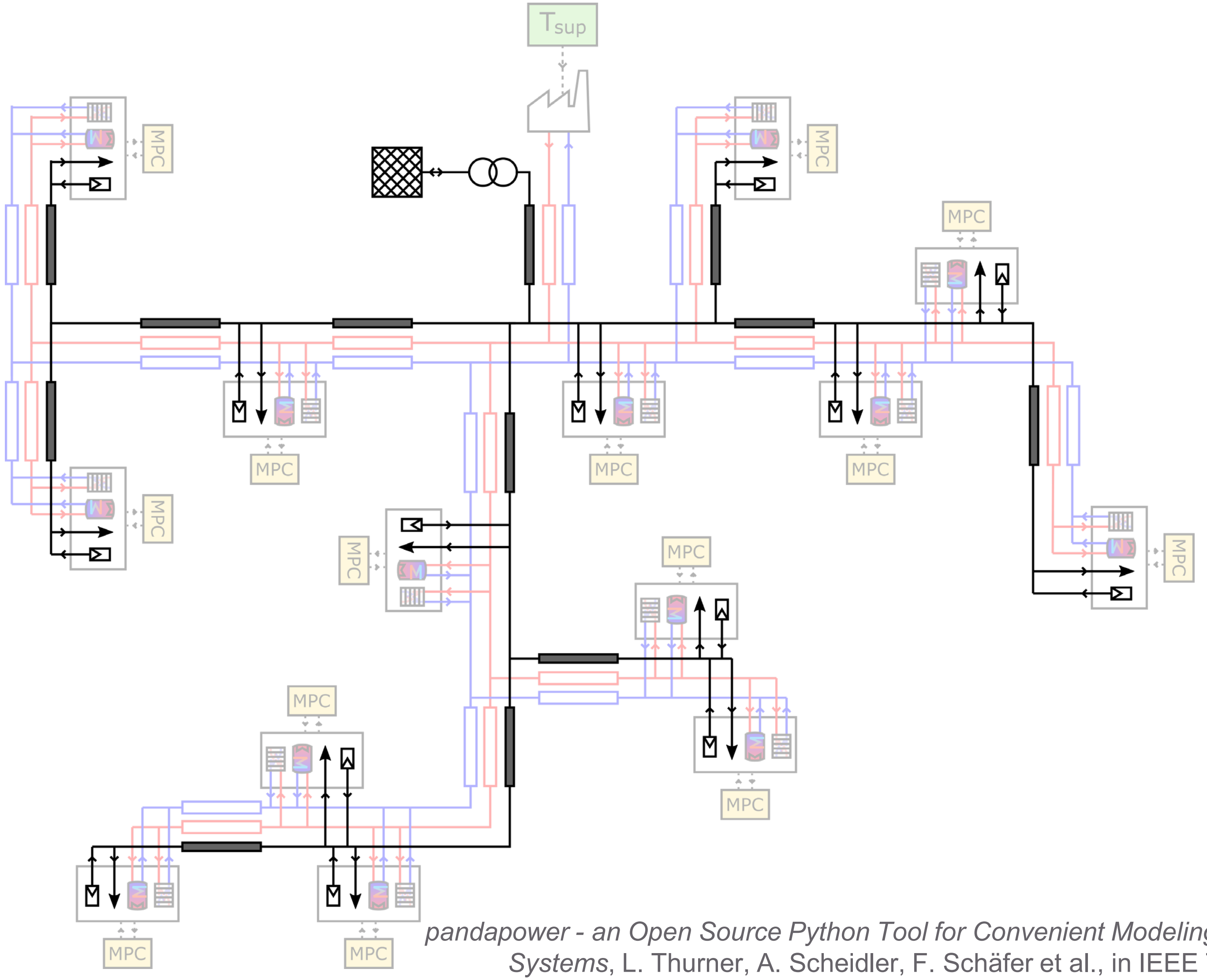
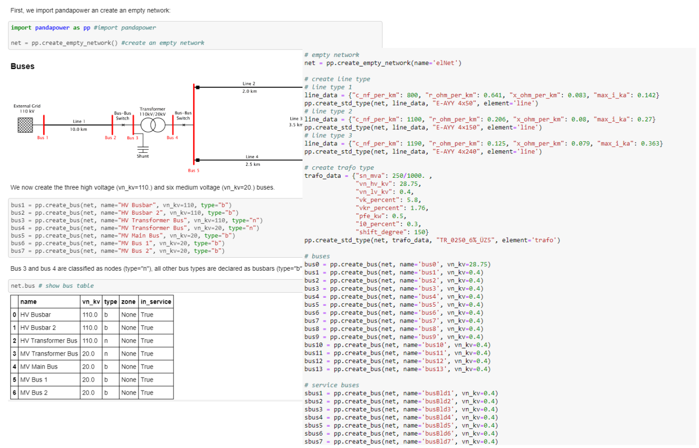


- **Electric network** simulation

pandapower



pandapower - an Open Source Python Tool for Convenient Modeling, Analysis and Optimization of Electric Power Systems, L. Thurner, A. Scheidler, F. Schäfer et al., in IEEE Transactions on Power Systems 2018.

EXAMPLE APPLICATION: ELECTRIC BOOSTER HEATERS

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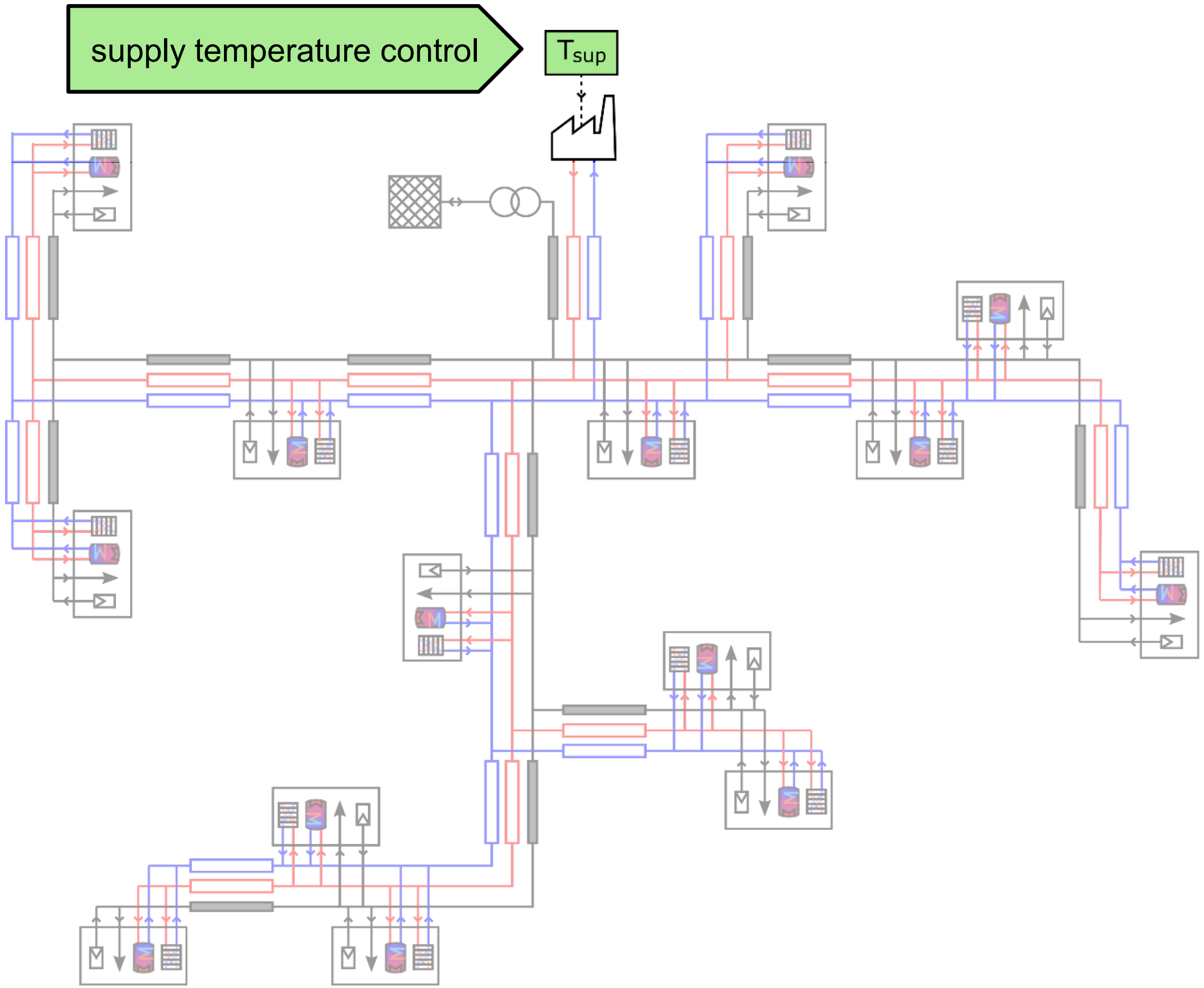
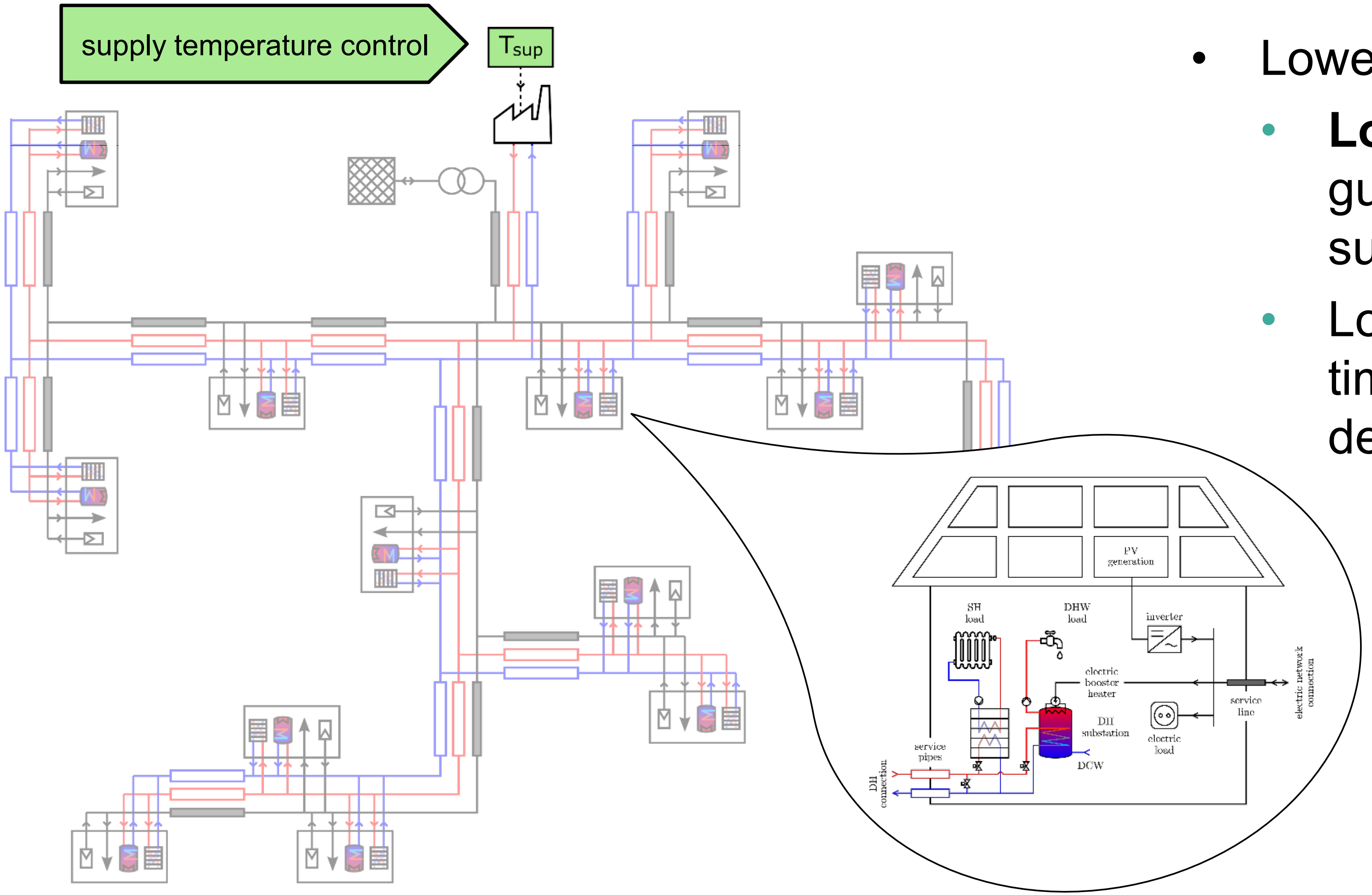


- Lower network supply temperature
  - **Local electric booster** heaters guarantee domestic hot water supply
  - Lower supply temperature in times of no space heating demand

A method for technical assessment of power-to-heat use cases to couple local district heating and electrical distribution grids, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy 2019.

EXAMPLE APPLICATION: ELECTRIC BOOSTER HEATERS



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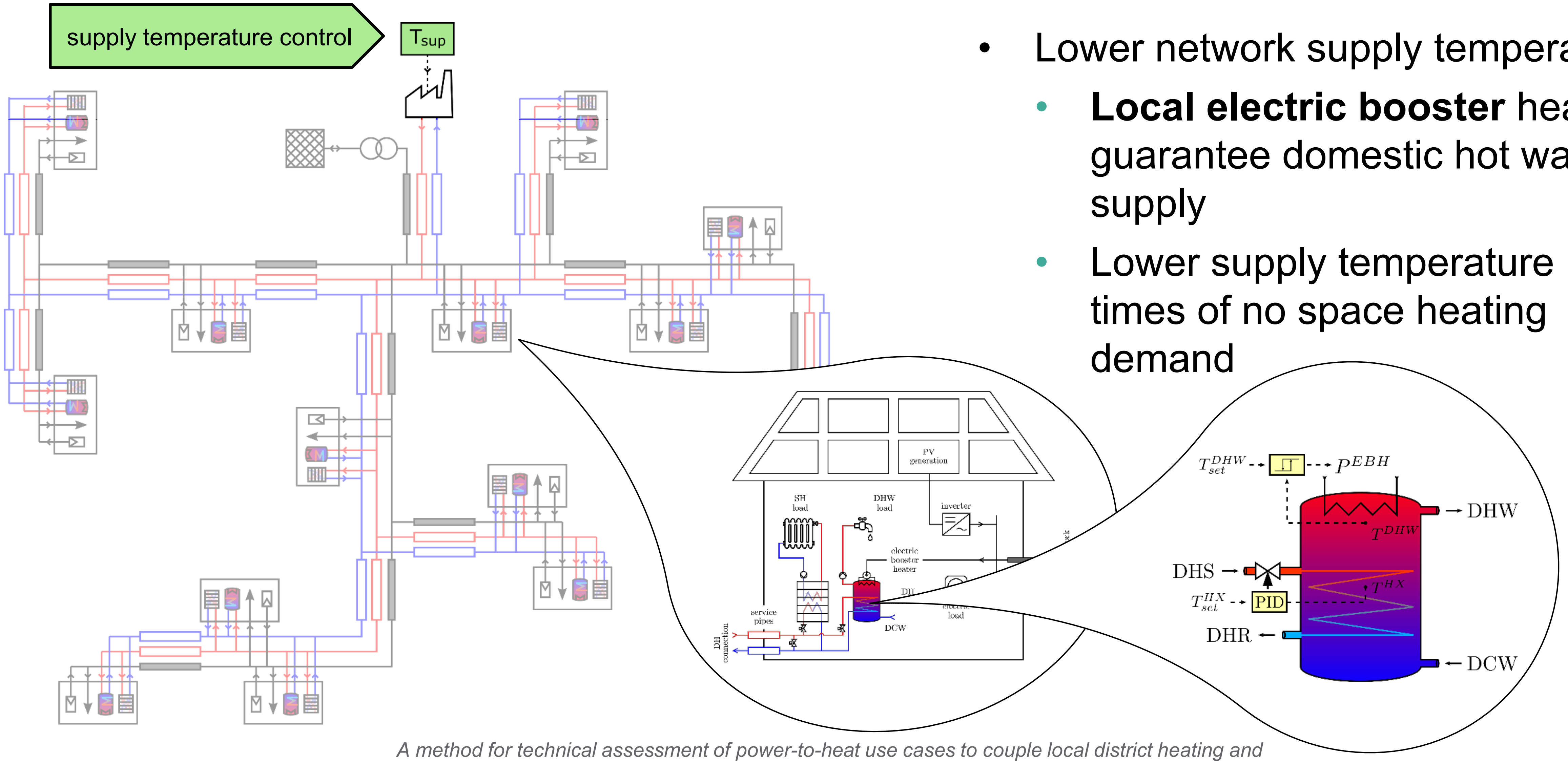

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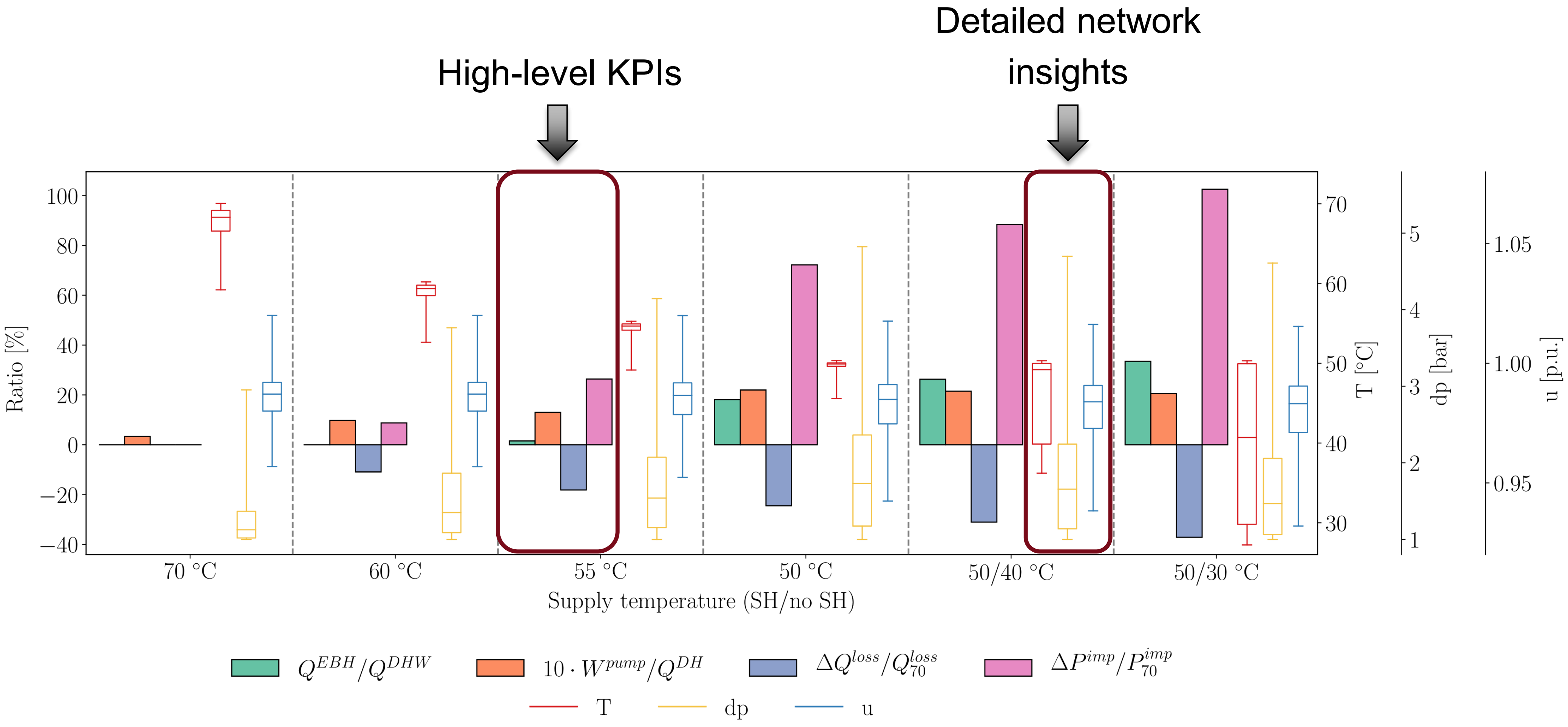
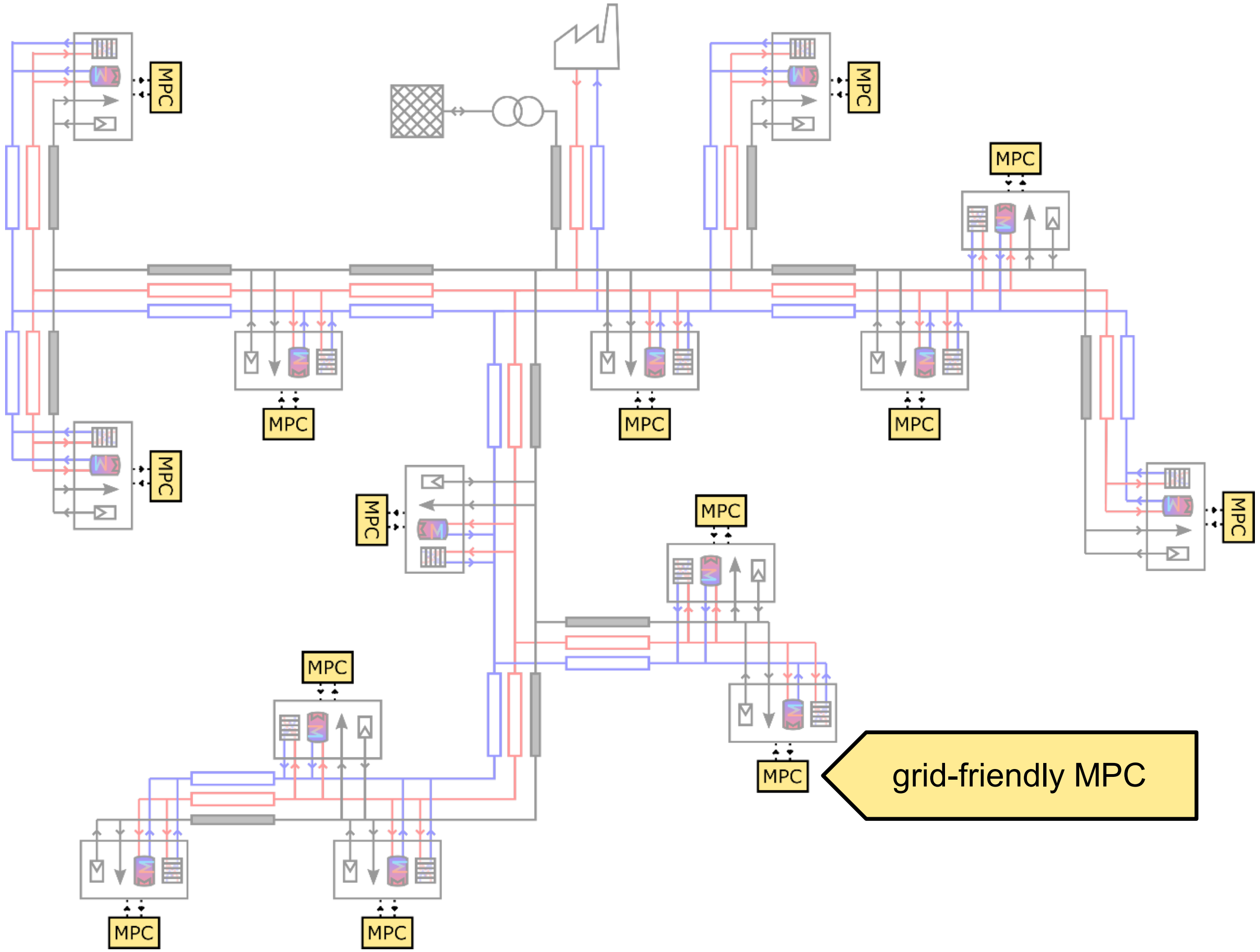
EXAMPLE APPLICATION: RESULTS



A method for technical assessment of power-to-heat use cases to couple local district heating and electrical distribution grids, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy 2019.

EXAMPLE APPLICATION: SMART ELECTRIC BOOSTER HEATER

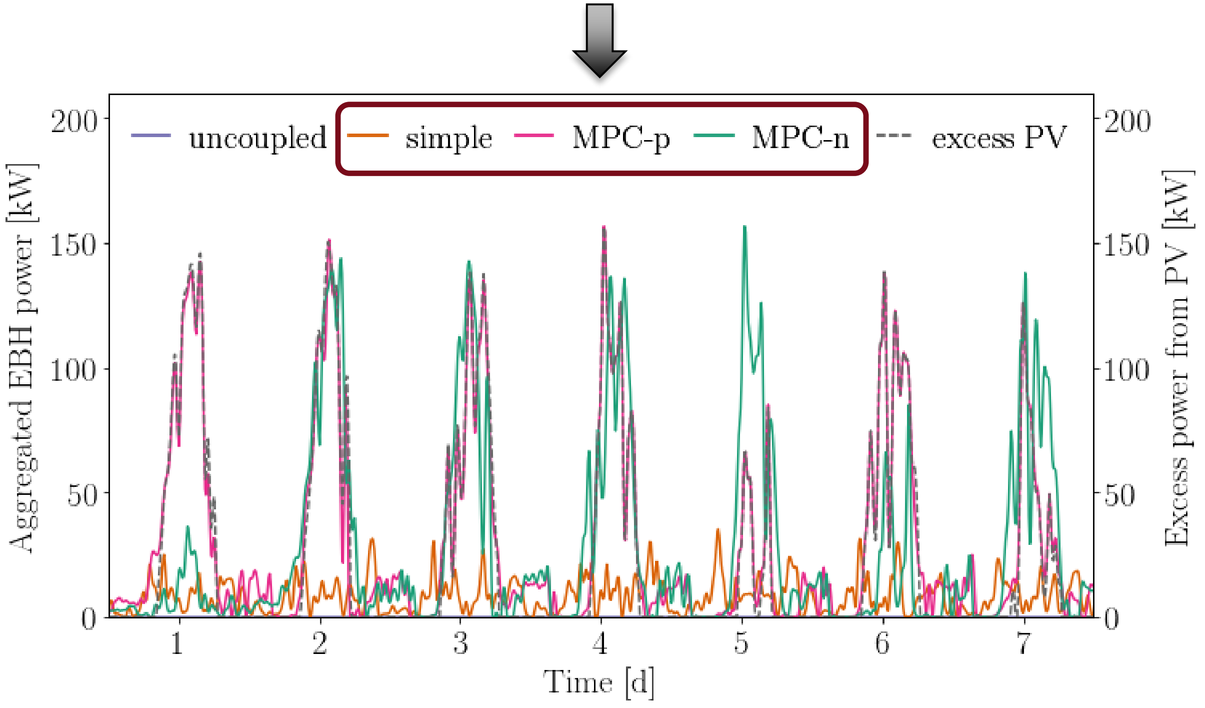


- **Model predictive control**
  - Increase self-consumption of PV generation
  - Avoid power demand peaks
  - Reduce DH demand peaks
  - DHW storage tank as flexibility option

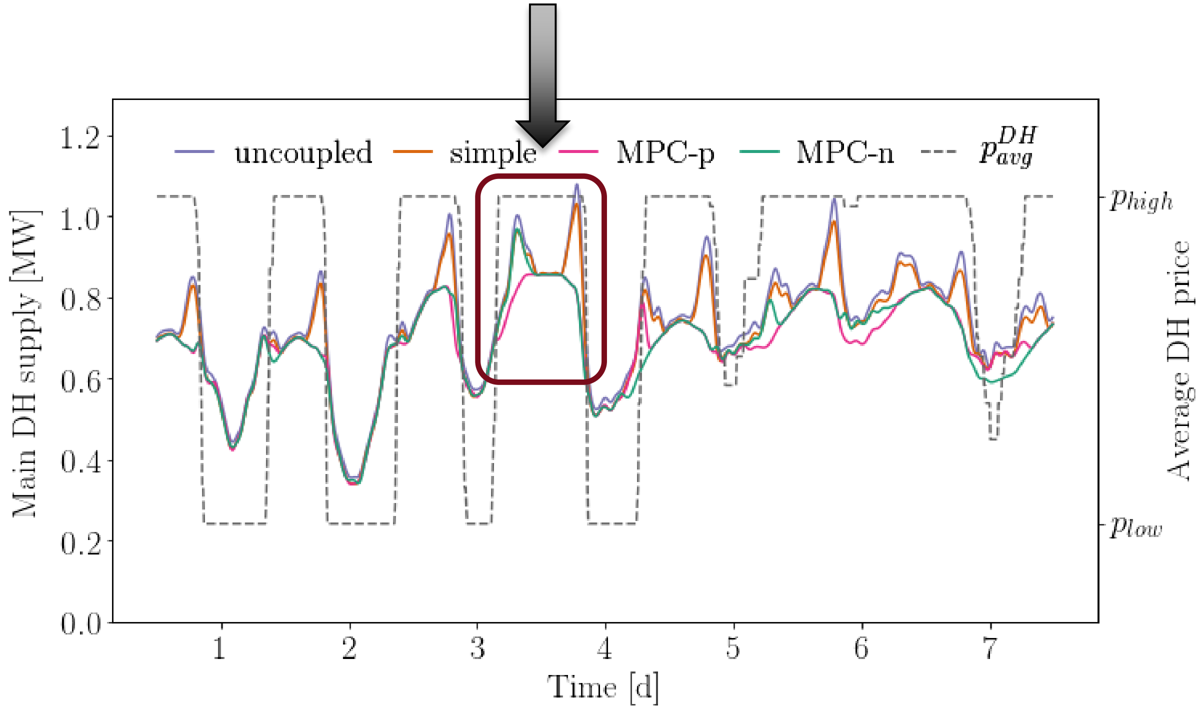
Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy, 2020

EXAMPLE APPLICATION: RESULTS

Comparison of different forecasting methods or control implementions



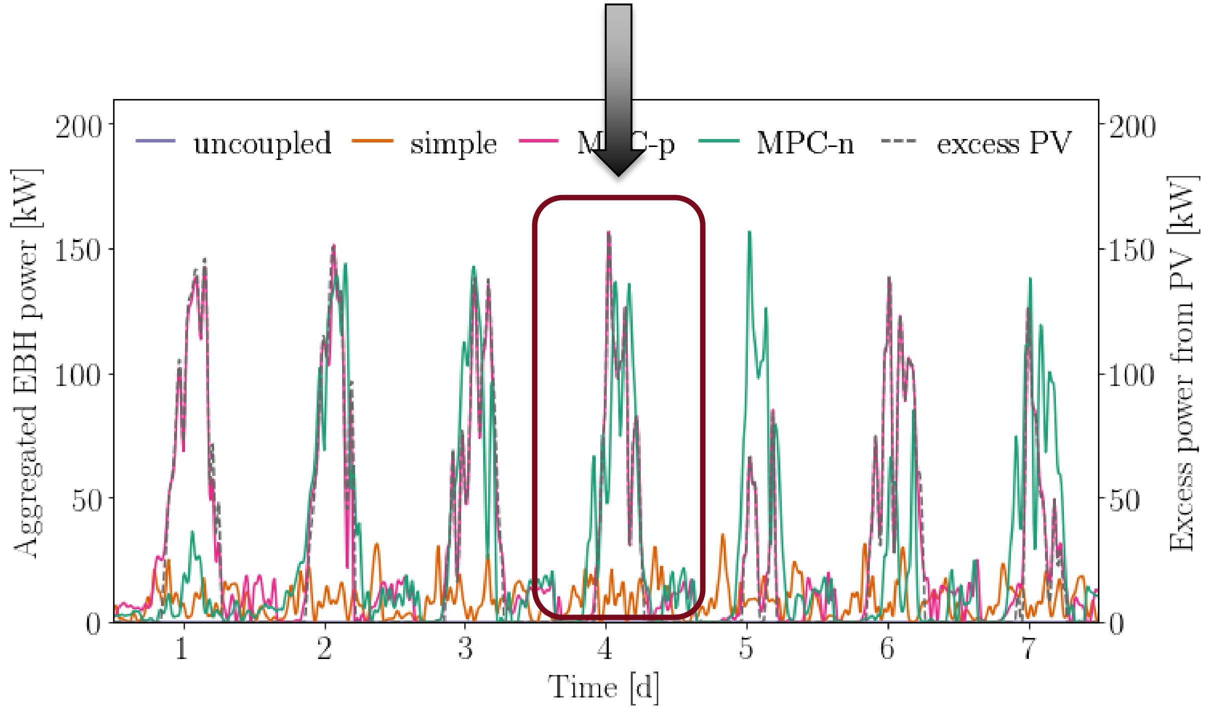
Reduced heat demand peaks in district heating



Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy, 2020

EXAMPLE APPLICATION: RESULTS

Increase self-consumption of local PV generation



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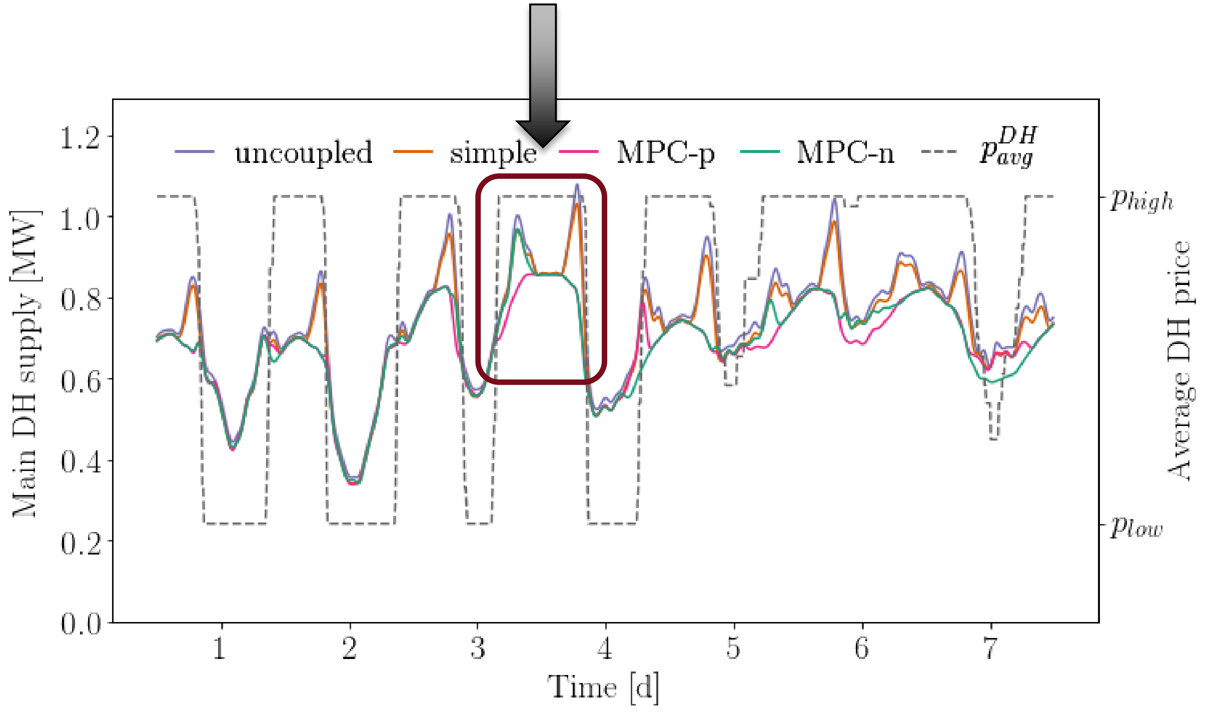

Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy, 2020

CO-SIMULATION APPLICATIONS

- Multi-domain simulation
- Control assessment
- Design validation
- Digital twinning
- „What if?“ analyses
- Understanding and playing around with complex systems :-)

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TOMORROW TODAY

THANK YOU!

RESOURCES:
OPEN-SOURCE & PROPRIETARY

AUSTRIAN INSTITUTE OF TECHNOLOGY

- District heating network model using Modelica/Dymola
  - Dymola: https://www.3ds.com/de/produkte-und-services/catia/produkte/dymola/
  - DisHeatLib: https://github.com/AIT-IES/DisHeatLib
- Electric distribution network model using pandapower
  - pandapower: https://pandapower.readthedocs.io/
  - pandapowerFMU: https://github.com/AIT-IES/pandapowerFMU
- Control implementation using Python/Pyomo
  - Python: https://www.python.org/
  - Pyomo: http://www.pyomo.org/
  - FMI++ Python Interface: https://pythonhosted.org/fmipp/
- FMI-based co-simulation using FUMOLA/Ptolemy II
  - FUMOLA: https://sourceforge.net/projects/fumola/
  - Ptolemy II: https://ptolemy.berkeley.edu/ptolemyII

BASED ON JOURNAL PAPERS

- *A method for technical assessment of power-to-heat use cases to couple local district heating and electrical distribution grids*, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy 2019.

- *Combined Optimal Design and Control of Hybrid Thermal-Electrical Distribution Grids Using Co-Simulation*, E. Widl, B. Leitner, D. Basciotti, S. Henein, T. Ferhatbegovic and R. Hofmann, in Energies 2020.

- *Control assessment in coupled local district heating and electrical distribution grids: Model predictive control of electric booster heaters*, B. Leitner, E. Widl, W. Gawlik and R. Hofmann, in Energy 2020.

Interactive session on use cases, strengths, weaknesses, opportunities and threats via SLIDO

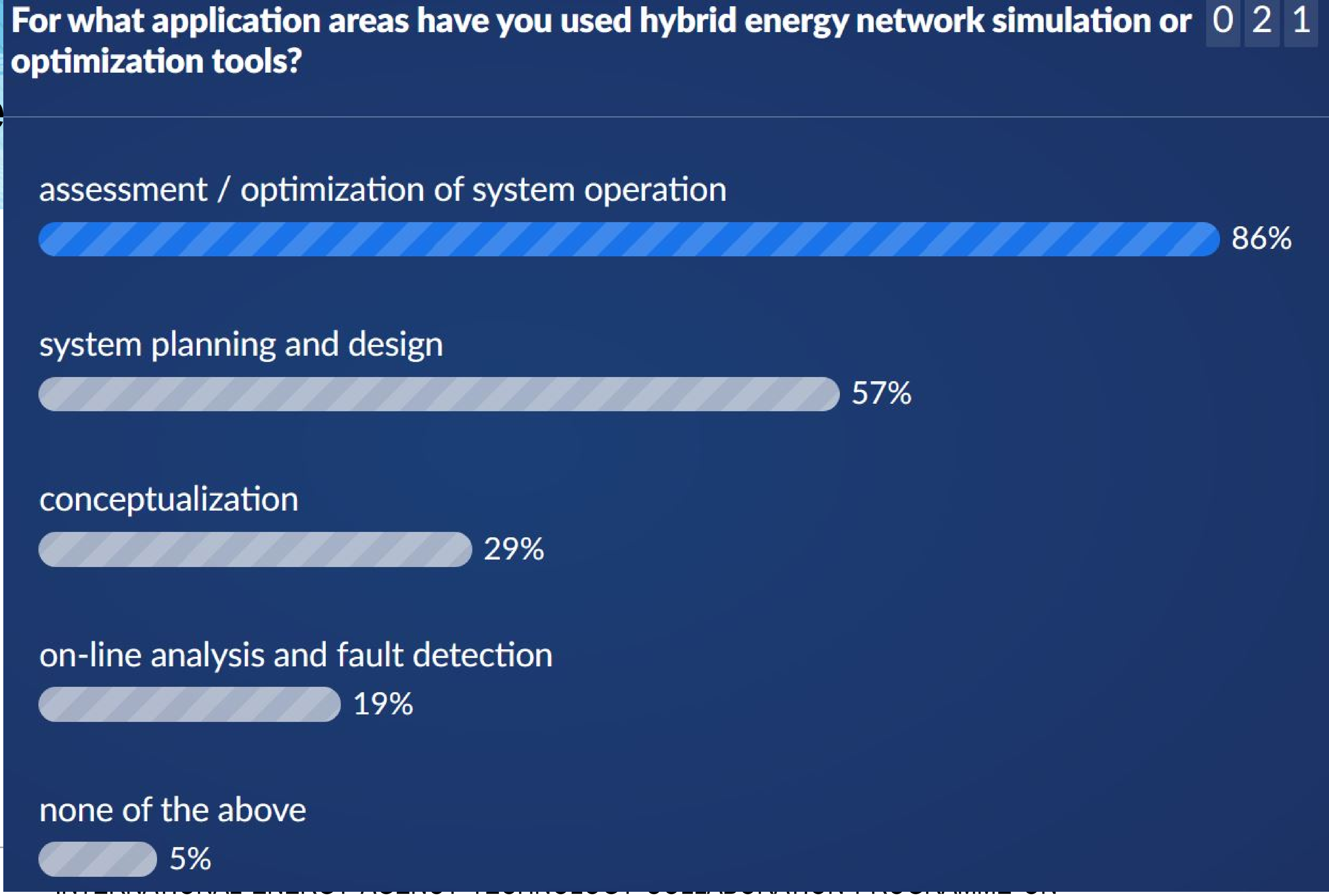
1. **For what application areas have you used hybrid energy network simulation or optimization tools?**
   - Conceptualization; system planning and design; assessment / optimization of system operation; on-line analysis and fault detection; none of the above
2. **What is typically the targeted size of your use cases for hybrid energy network simulations and optimizations?**
   - Buildings; districts / settlements; cities; regions; nations; continents
3. **For what use cases have you used hybrid energy network simulation tools?**
   - Example: "We tested a new control strategy for heat-pump pooling to increase local consumption of excess PV generation." (Please enter complete sentences)
4. **What are the most important weaknesses and threats** of Hybrid Energy Network simulation and optimization tools? What is missing? Why is their use limited? Where do you see barriers? (Please enter keywords)
5. **What are the most important strengths and opportunities** of hybrid energy network simulation and optimization tools? (Please enter keywords)

Join at

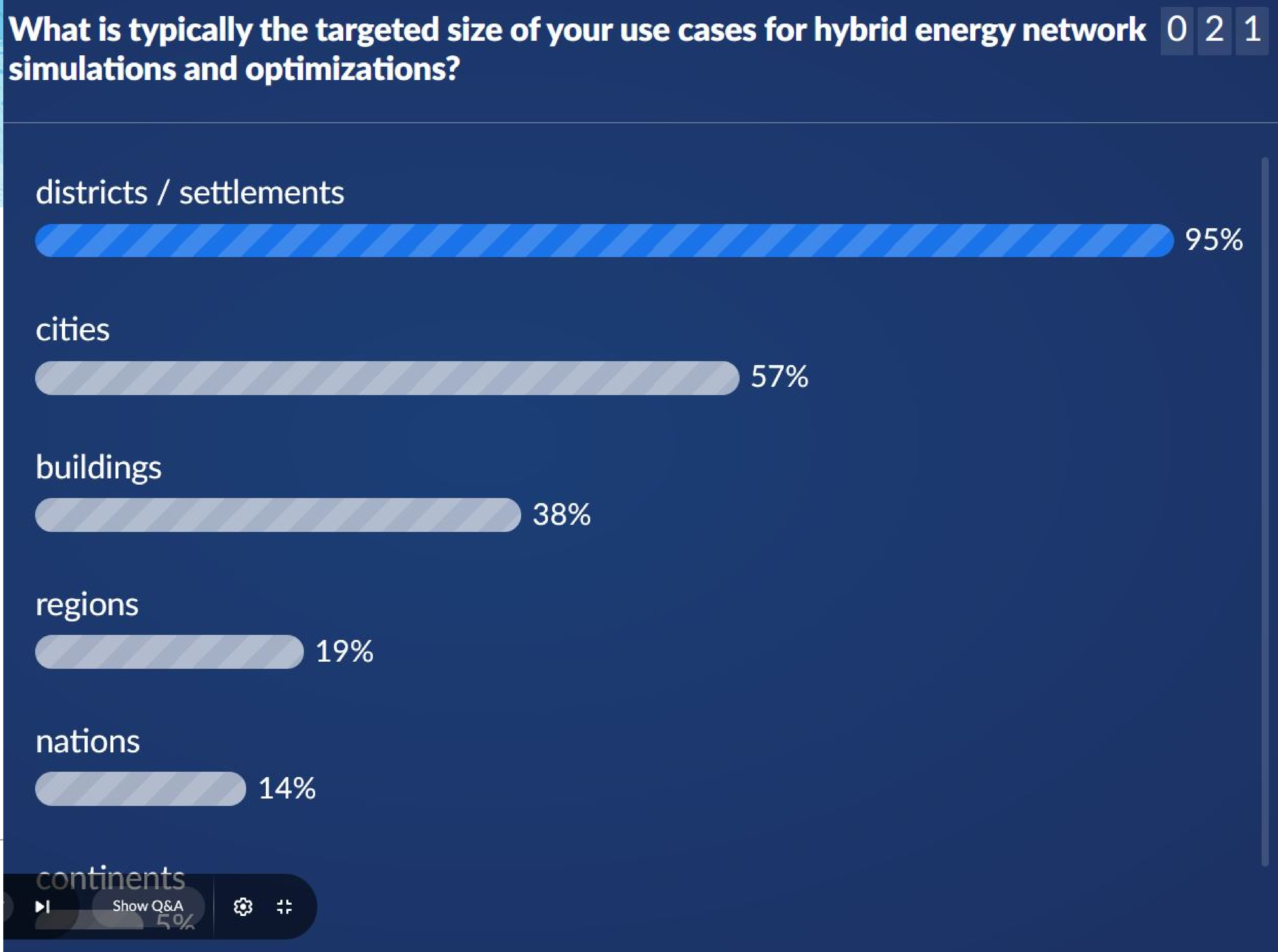
slido.com

#955 524

Interactive session



Interactive session



IEA DHC|CHP

Interactive session: For what use cases have you used hybrid energy network simulation tools?

1. Development of a control system to integrate consumers and producers with increasing flexibility
2. We built an optimization algorithm for a multi-energy production system supplying the DHN of a hospital site (including heat, cool, electricity, steam production) suitable for real-time MPC
3. Optimized sizing of DHC production side in a system with aggregated loads.
4. Sizing of heat pumps and decentralized heat storages in coupled thermal-electrical distribution grid.
5. Evaluated adding electric boiler and thermal energy storage to biomass CHP, supplying heat to DH system
6. We perform dynamic simulation of a Power-to-Heat technology for buildings in order to evaluate the potential of the flexibility of the building to achieve electric peak shifting
7. Simulation of heat losses resulting from different levels of thermal insulation for the pipe network
   2) Holistic analysis of the district energy system from generation to the customers
8. We tried to evaluate the best configuration of PV installation, ambient loops and heat pumps boosters in the energy planning phase of new districts
9. 100% renewable energy system scenarios for countries, regions and cities.
   Operational analyses of national energy system scenarios.
10. o) optimized heating and cooling of buildings
    o) operation of small-scale hybrid DH network
    o) small heating grid operation (coupling of two networks)
11. Design and operation optimization as well as thermo-hydraulic network Simulation.
12. Used PV excess power to convert it to heating energy via heat pumps and electric heaters
    - Optimized the economical operation of a power-to-gas-plant by additionally respecting technical boundary conditions.
13. Evaluating the benefits of local heating networks in reducing the costs of power supply.

Interactive session

What are the most important weaknesses and threats of Hybrid Energy Network simulation and optimization tools?
What is missing?
Why is their use limited?
Where do you see barriers?
(Please enter keywords)

0 1 2

- Expertise in modelling multiple domains
- data input and generation
- multi sectorial expertise of users needed
- multiple time-scales make simulation longer
- Computational costs
- uncertainties
- complex analysis of results
- User friendliness
- APIs
- Complexity
- Connectivity
- expert knowledge in multiple field is required
- confidence of decision makers in results

Interactive session

What are the most important strengths and opportunities of hybrid energy network simulation and optimization tools? (Please enter keywords)

015

- Ability to value Customer Actions
- build trust in completely new operating concepts
- optimal system operation
- scenarios for inputs to democratic process
- Smartness
- what if analysis
- Realistic scenarios (worst-point in network)
- Knowledge base
- **Synergy**
- Optimal sizing
- Understanding
- complexity
- Efficiency
- what if
- Unlocking synergies
- Holistic approach
- synergies between energy domains
- combined planning and of different energy sectors
- Eval of Various scenarios

note on other events

IEA DHC | CHP

DHC Industry

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY TOMORROW TODAY

Invitation to the Webinar on

IEA DHC Annex TS7: Industry-DHC Symbiosis

"A systemic approach for highly integrated industrial and thermal energy systems"

Friday, 30th April 2021, 12.30 to 15.30 (CET)

https://missioninnovationaustriaweek.at/events/industry-dhc-symbiosis-a-systemic-approach-for-highly-integrated-industrial-and-thermal-energy-systems/

https://www.nefi.at/new-energy-for-industry-2021/

NOTTINGHAM TRENT UNIVERSITY NTU

6th - 9th September 2021

http://dhc2021.uk/

7th International Conference on

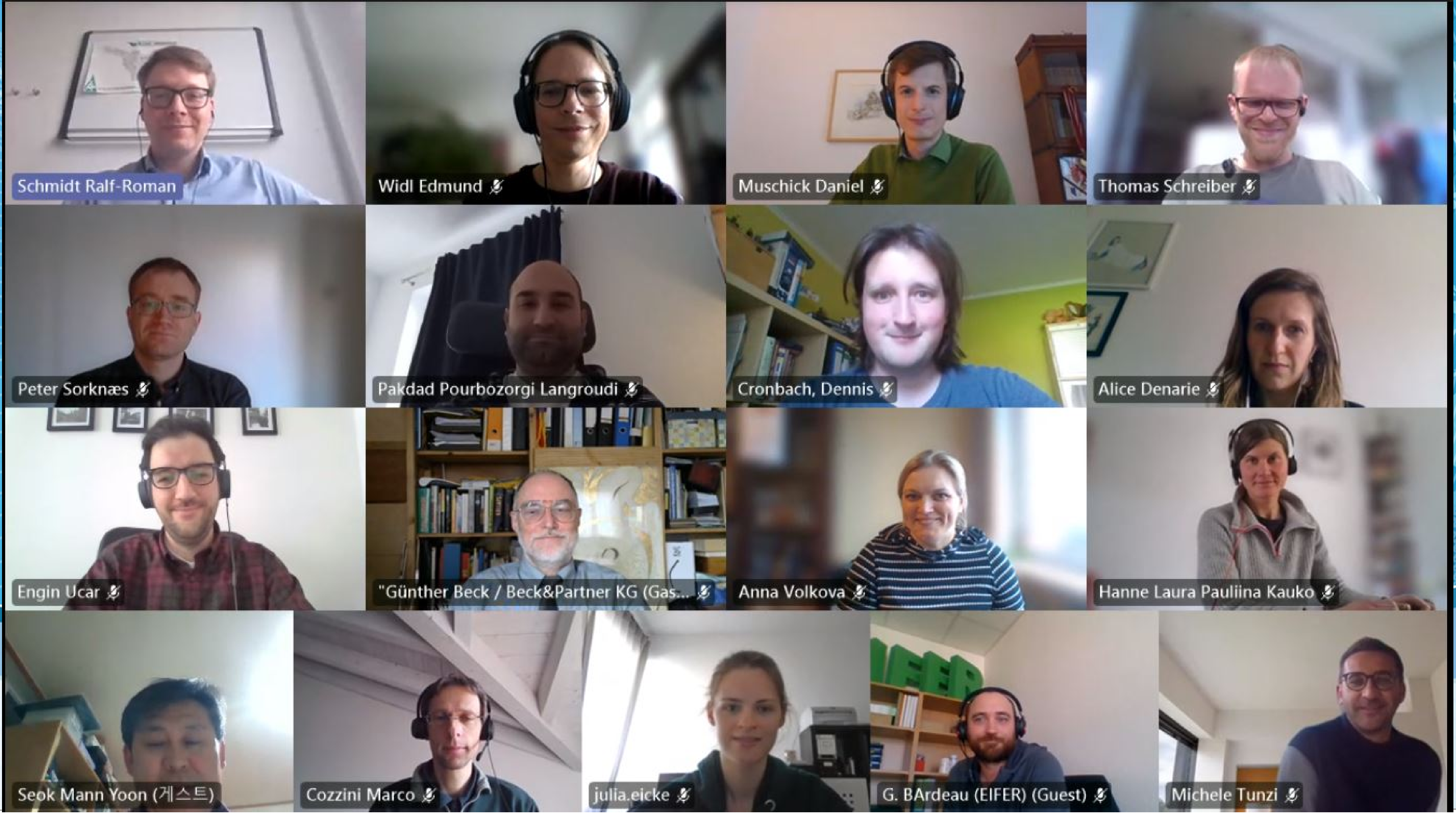
Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

21-22 September 2021, Copenhagen

AALBORG UNIVERSITY DENMARK

https://smartenergysystems.eu/



IEA DHC|CHP

INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING INCLUDING COMBINED HEAT AND POWER

Thanks for your active participation!

- **The slides will be available at http://www.iea-dhc.org/the-research/annexes/2017-2020-annex-ts3-draft.html**
- **Contact: Ralf-Roman Schmidt (AIT); ralf-roman.schmidt@ait.ac.at**