District Heating Systems Laboratory Infrastructure

Key features, challenges and notable examples from Europe

Workshop on Intelligent Planning and Control of

District Heating and Cooling Systems

8 April 2026

CoSES at a glance


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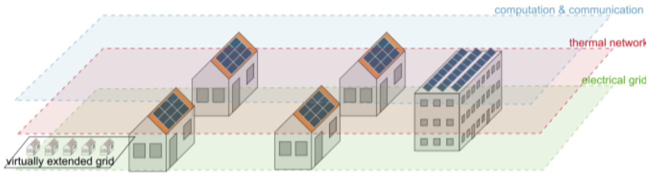
Integrated Multi-Energy Systems

- ❑ Active Distribution Grids
- ❑ Prosumers in District Heating Grids
- ❑ Energy Management Systems
- ❑ Data-driven techniques

Simulation / Emulation



Leads

Focus

Tools

CoSES at a glance

Directly at CoSES

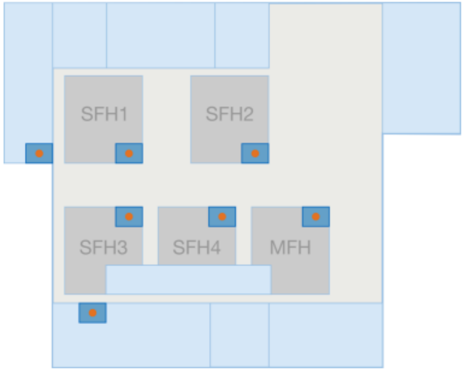
- 7 PhD students
- 1 Post-doc

Associated with CoSES

- 7 PhD students from other TUM groups and external institutions.
- Chair of Renewable and Sustainable Energy Systems.
- Chair of Power Transmission and Distribution.

Frequent Guest Researchers

CoSES: Energy technology of five buildings in one lab



Video Presentation:

[Lickleder er2022]

Detailed info in our publications on the lab:

[Zinsmeister2023]

[Mohapatra2022]

Background – Features of a Laboratory

- State-of-the-art Infrastructure – obviously…
- Easy barrier for entry and collaboration.
- Possible to setup for reproducible and repeatable results.
- A conveyor belt to train new workers and opportunities for internships.
- Possibilities to expand and upgrade.

Background – Features of a Power Systems Laboratory

- State-of-the-art Infrastructure – obviously…
- – Fair consensus on state-of-the-art Infra – RT simulators, PHIL, Live feeders, DERs, Living labs
- Easy barrier for entry and collaboration.
- Possible to setup for reproducible and repeatable results.
- – Established brands and players; experience in documentation, tech support and best practices.
- A conveyor belt to train new workers and opportunities for internships.
- – Part of curriculum lab work; established modelling and simulation environments.
- Possibilities to expand and upgrade.
- – If resouces permit – easy to upgrade to latest simulators, PHIL test beds, new DER etc.

Background – Typical tests for a Power Systems Laboratory

- Control strategy, HIL controllers and commercial controllers.
- Active devices – Inverters, DERs, Protection equipment, Switchgear.
- Passive elements – Cables, Lines, Compensation elements.
- Fidelity of RT models – Grids, Lines, active devices.

- Short term tests – Validation.
- Long term tests – Certification.

Typical tests for a DHC Laboratory?

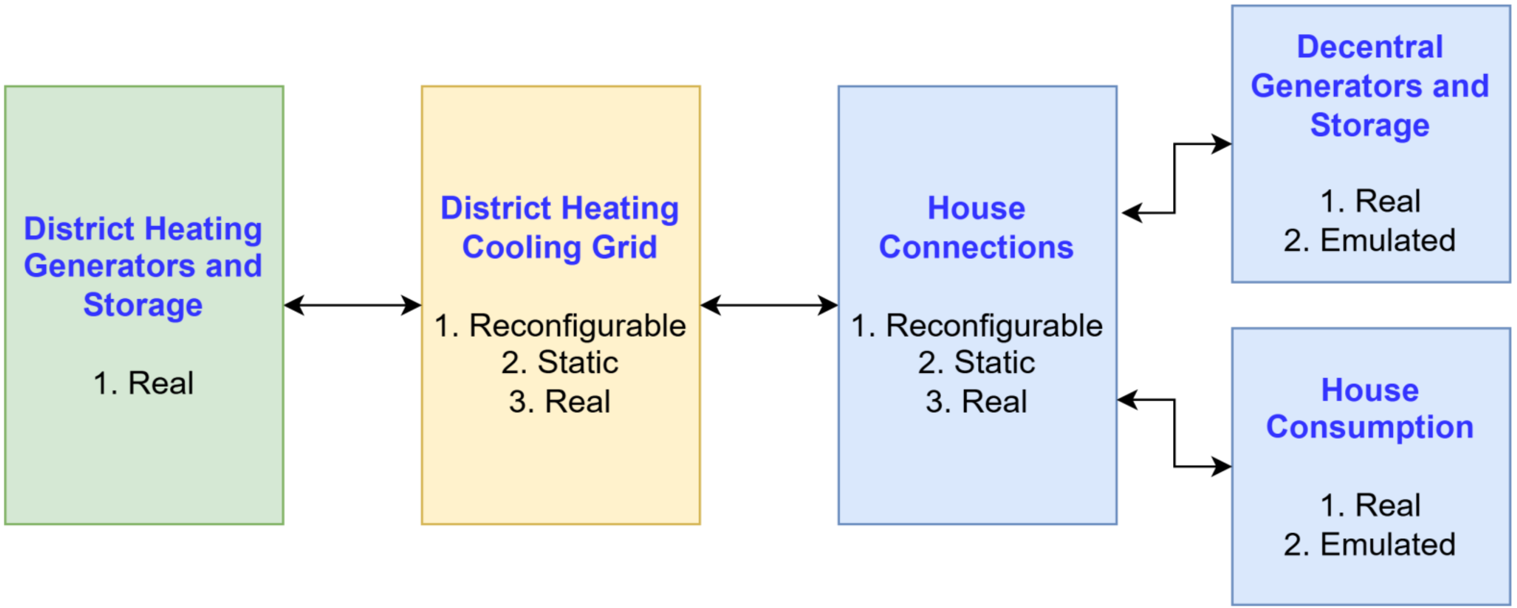
- 4th- 5th generation prosumer connections
- District heating/cooling grid observation, control and operation (long term)
- Active devices – Heat pumps, CHPs, boilers and storages
- Passive devices – Pipes
- Fidelity of digital twin models (corresponding to RT models in electrical systems) – grid and prosumer
- Sector coupling

- Short term tests – Validation.
- Long term tests – Certification.

Features of a DHC Laboratory?

- Reconfigurable prosumer connections and transfer stations at DHC grid interface.
- Emulate prosumer behaviour to test real devices – active and passive.
  - Less chance of being plug and play and complicated to assemble.
- A real DHC network – maybe even permanently in operation.
  - Rare. Might be connected to real consumers and thus cannot be tampered with.
- Option to co-simulate with a real power system for sector coupling.
  - Need separate measurement and control system.
- Standardised simulation environments and consensus on field automation / control design
  - Lack of dominant lab automation environments. Although there is no requirement for RT modeling.

Features of a DHC Laboratory?



Notable Examples in Europe

- District heating and cooling setups in selected european universities / research centers

Karlsruher Institut für Technologie

Fraunhofer
IEE

DTU

Notable Examples in Europe

- Living Lab Energy Campus in KIT North Campus
- 3 standalone buildings with reconfigurable heating connection and generators.
- Consumption – as per occupancy; Control – self developed in SCADA style.

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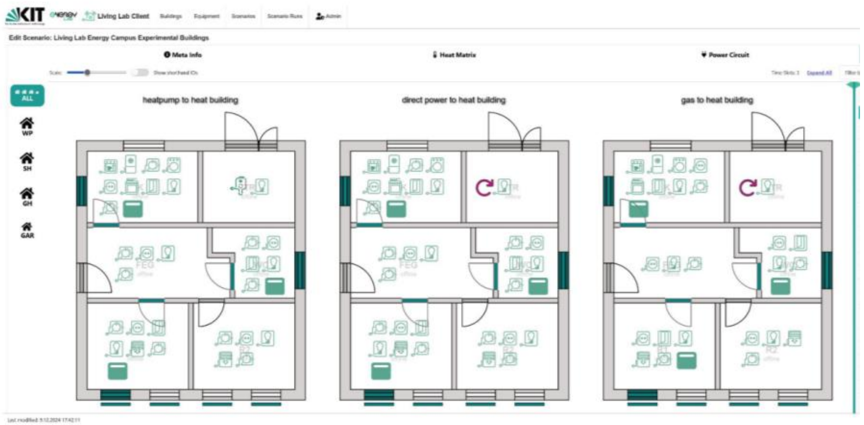
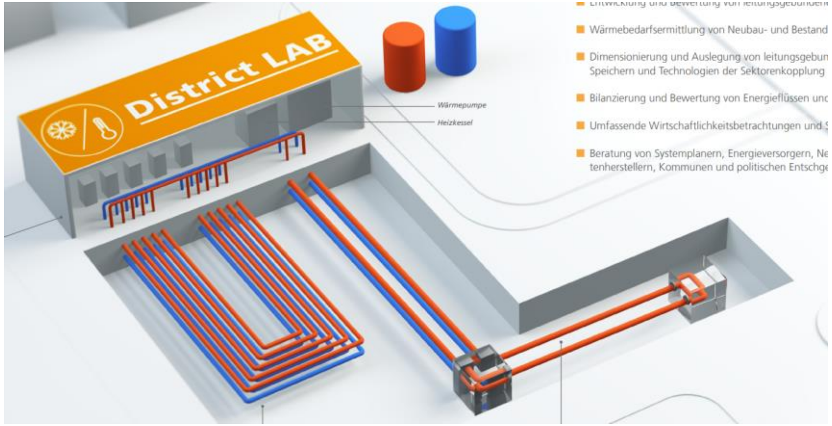
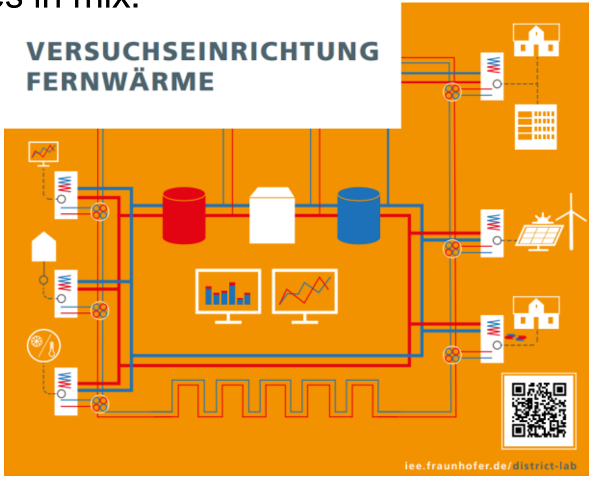


Notable Examples in Europe

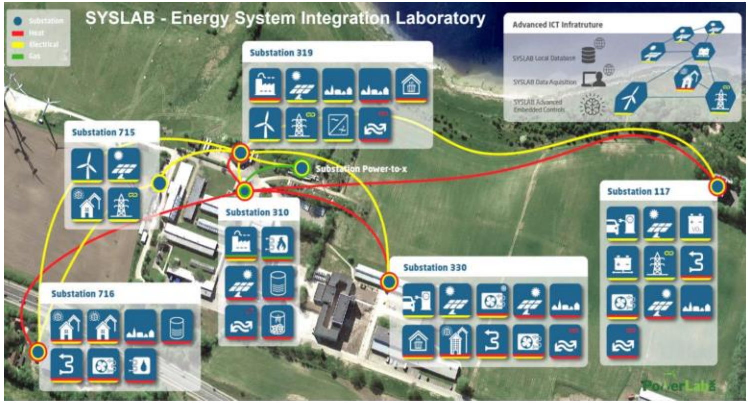
- New flagship laboratory in Fraunhofer IEE Kassel
- Reconfigurable district heating/cooling network, pipe test bench, automation and operation concepts
- Focus on testing and certification for energy efficiency and renewables in mix.

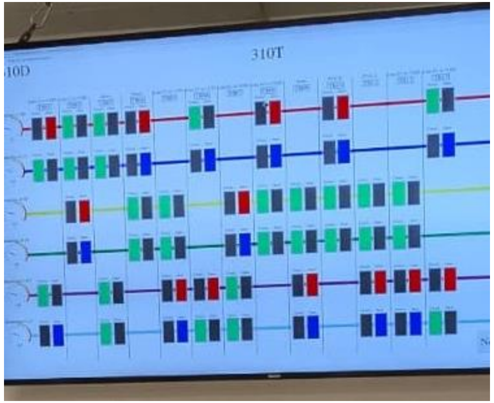




Notable Examples in Europe

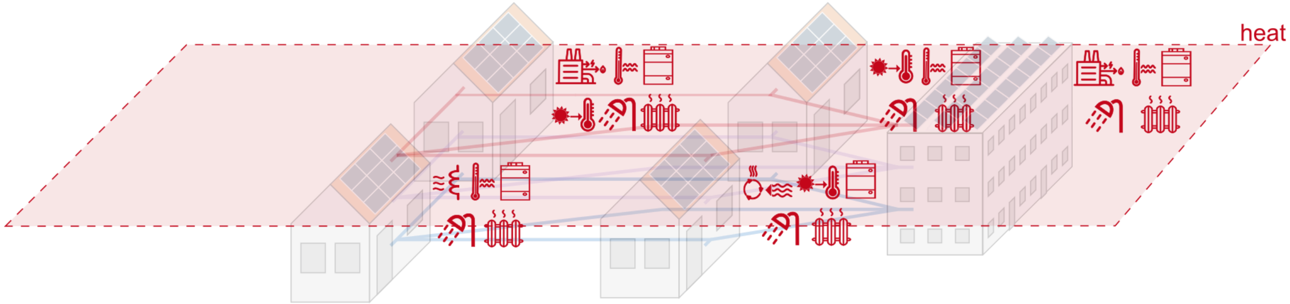
- 4.5km heating network extension to SYSLAB in Risø Campus.
- Multiple heat DERs, connection to SYSLAB microgrid, bus bar concept, 5 interconnected sites
- Focus on long term testing and operation. Control – self developed SCADA system



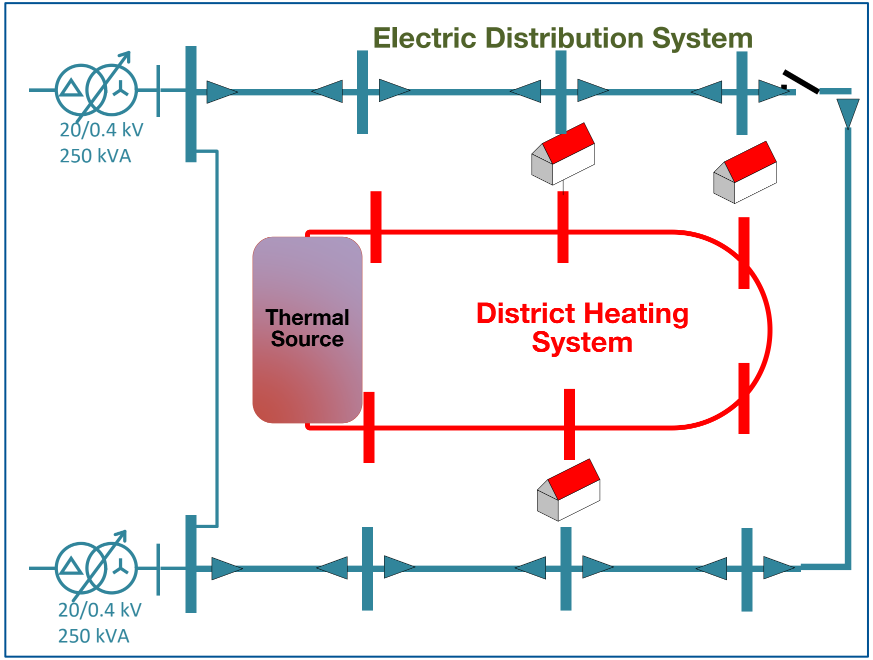


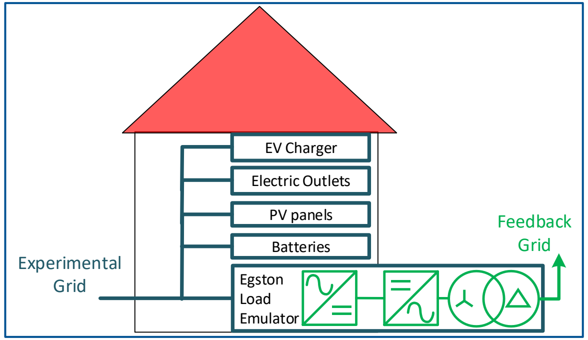
Notable Examples in Europe

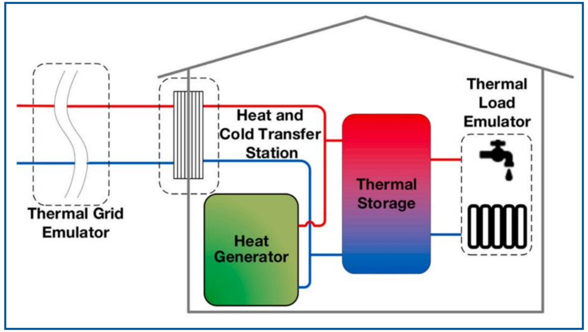
- Active distribution grid laboratory with prosumer heating lab in CoSES
- Prosumer and pipe emulation, reconfigurable network, multiple DERs and 1.5kms LV grid to access
- Consumption – emulation setpoints from building models; Control – NI Veristand and co-simulation



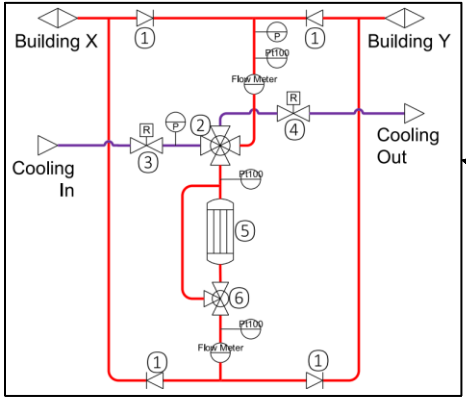
CoSES Lab - Overview



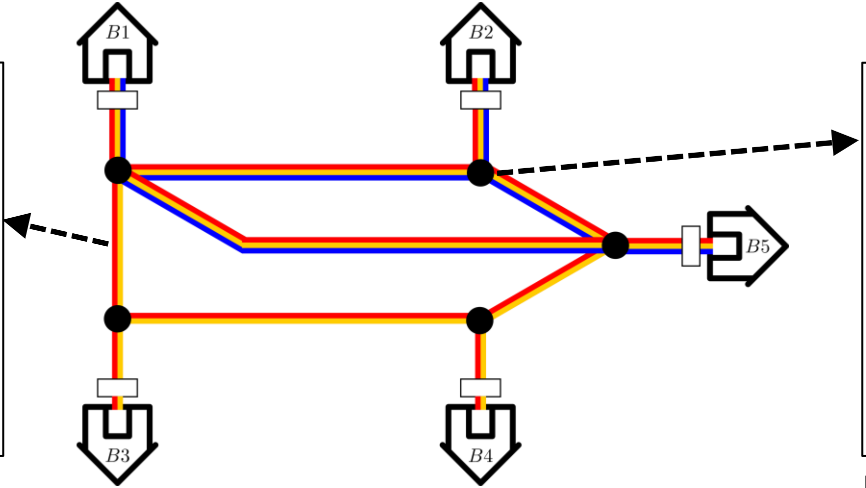




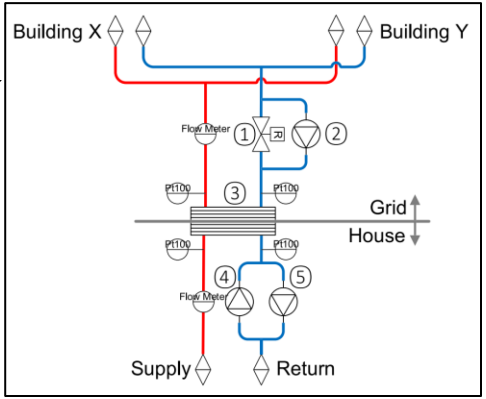
CoSES Lab - Thermal Grid



thermal network emulator / pipe emulator



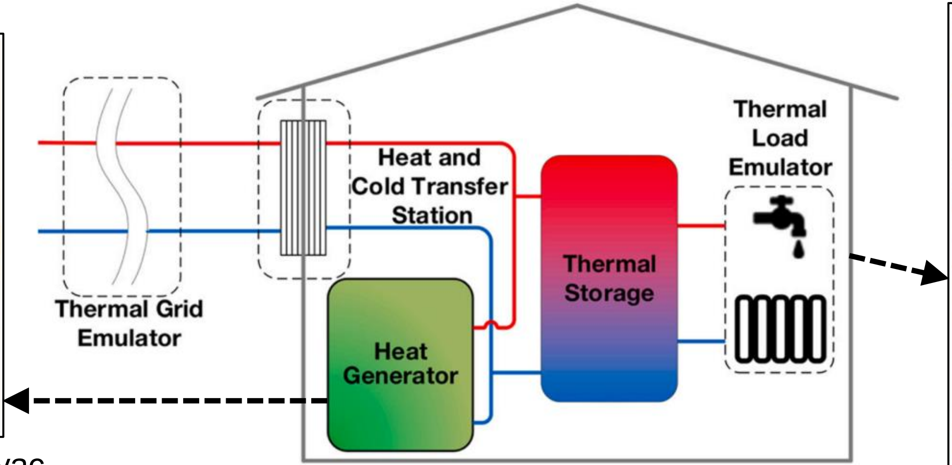
bidirectional thermal network with prosumers



bidirectional heat transfer station

CoSES Lab - Thermal Building Emulator

e.g. air source heat pump incl. hvac
system for ambient emulation



In comparison

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CoSES	Living Lab EC	District LAB	SYSLAB
Focus on prosumer operation and sector coupling	Focus long-term technology showcase	Focus on certification and testing for industy	Focus on long-term sector coupled microgrid operation.
Emulated – prosumer, grid Real - DERs	Heat matrix connection Real - DERs	Emulated - prosumer Real – grid (small), DERs	Bus bar connection Real – Grid, Prosumers, DERs

Conclusion

- Many variations of district heating/cooling laboratories already available in Europe.
- Key difference to power system laboratories :-
  - Relative lack of consensus state-of-the-art in control systems and simulation environments.
  - Higher difficulty to troubleshoot due to lack of big automation brands for research and bespoke hardware.
  - Large variation in regulations and decarbonization policies across countries.
  - Much higher degree of hands-on technician skills needed from employees.

- High risk, high reward endeavour.

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