Simulation-assisted development of a mini-split air-to-water façade-integrated heat pump for minimal invasive renovations

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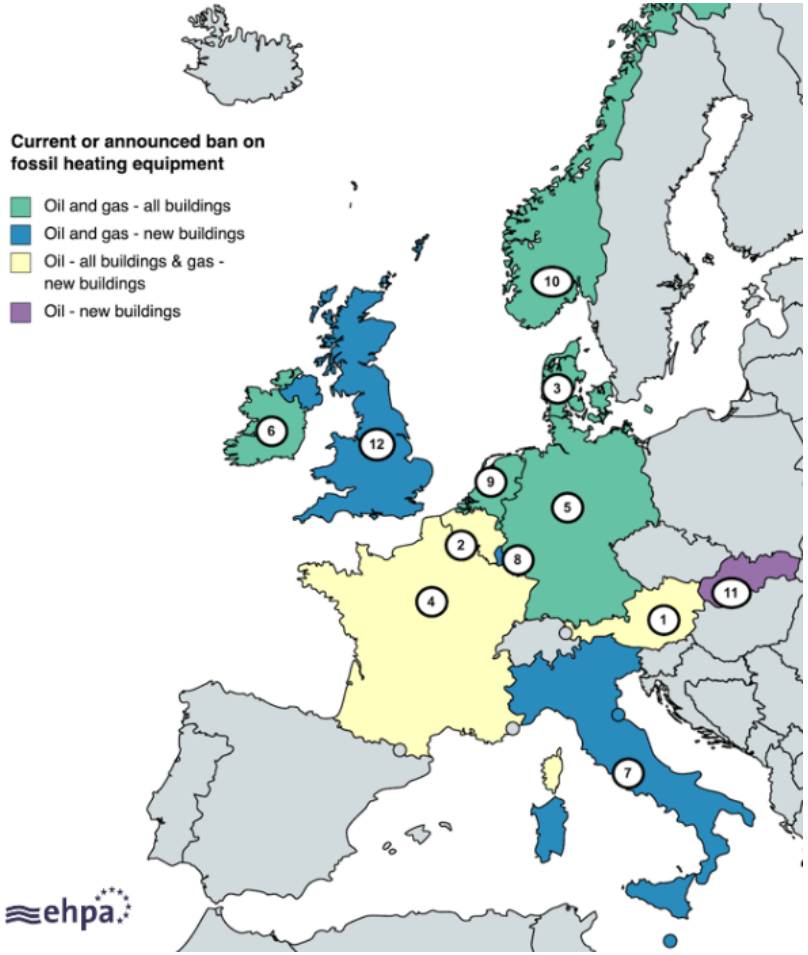
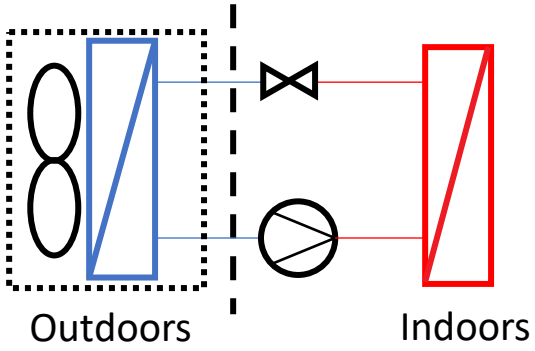
Target market



- 35% of EU building stock over 50 years old (Source: Renovation Wave EU)
- Residential multiple-family buildings are the most conspicuous group
- Average flat size in Austria: 65 m^2
- Need to phase-out oil and gas-fired boilers for space heating and domestic hot water (in Austria complete decarbonisation by 2040)

Source: EHPA

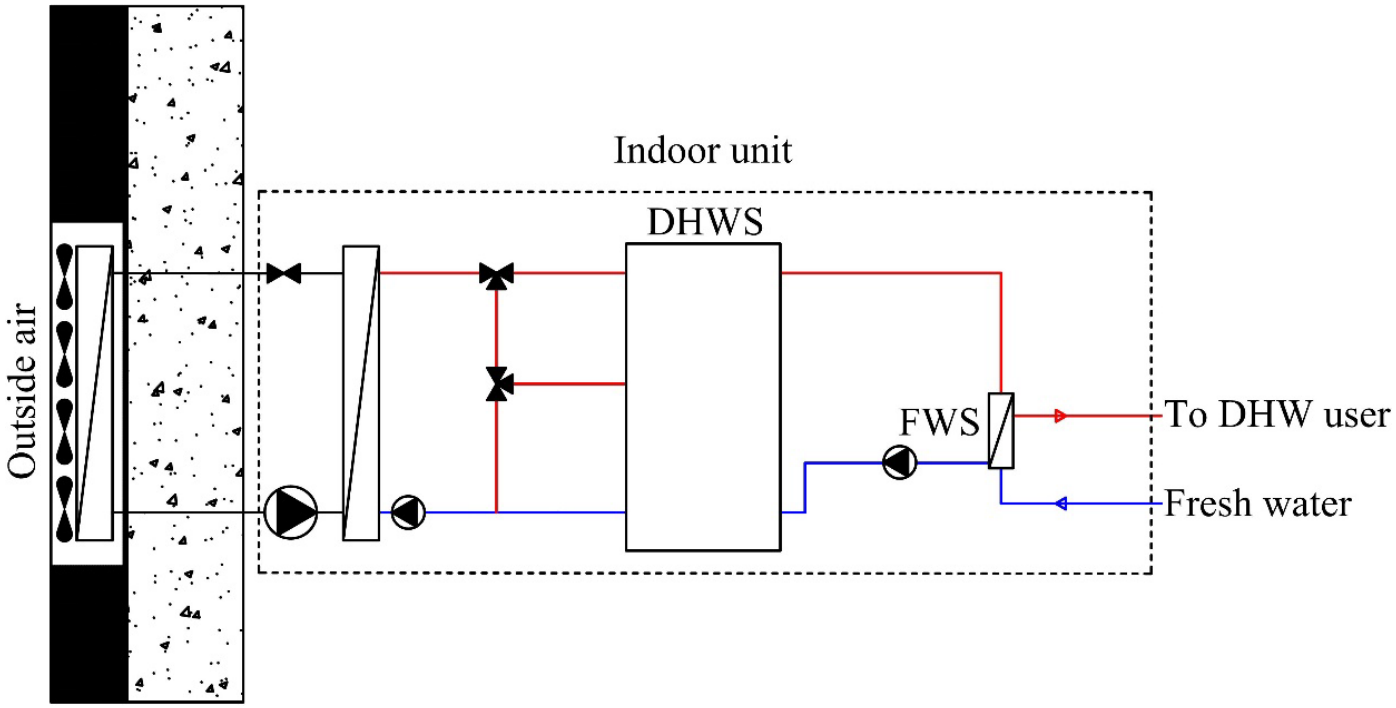
Decentral DHW split heat pumps for multiple-family buildings



Source: https://resi.co.uk/advice/heat-pumps/how-do-heat-pumps-work

- Outdoor unit:
  - Evaporator
  - 1 or multiple fans
  - (Compressor, EXV)
- Indoor unit:
  - Condenser
  - (Compressor, EXV)
- More space saving compared to internal monoblock heat pump for DHW
- Need for a more compact outdoor unit

Concept: a mini-split HP for DHW



- Split-type air-source heat pump for domestic hot water
- Façade-integrated outdoor unit
- 1.5 kW at A7W50
- R290 (< 150 g)
- Compact indoor unit with integrated hot water storage (90 – 120 liters) and freshwater station

Prefabricated façade elements for serial renovations

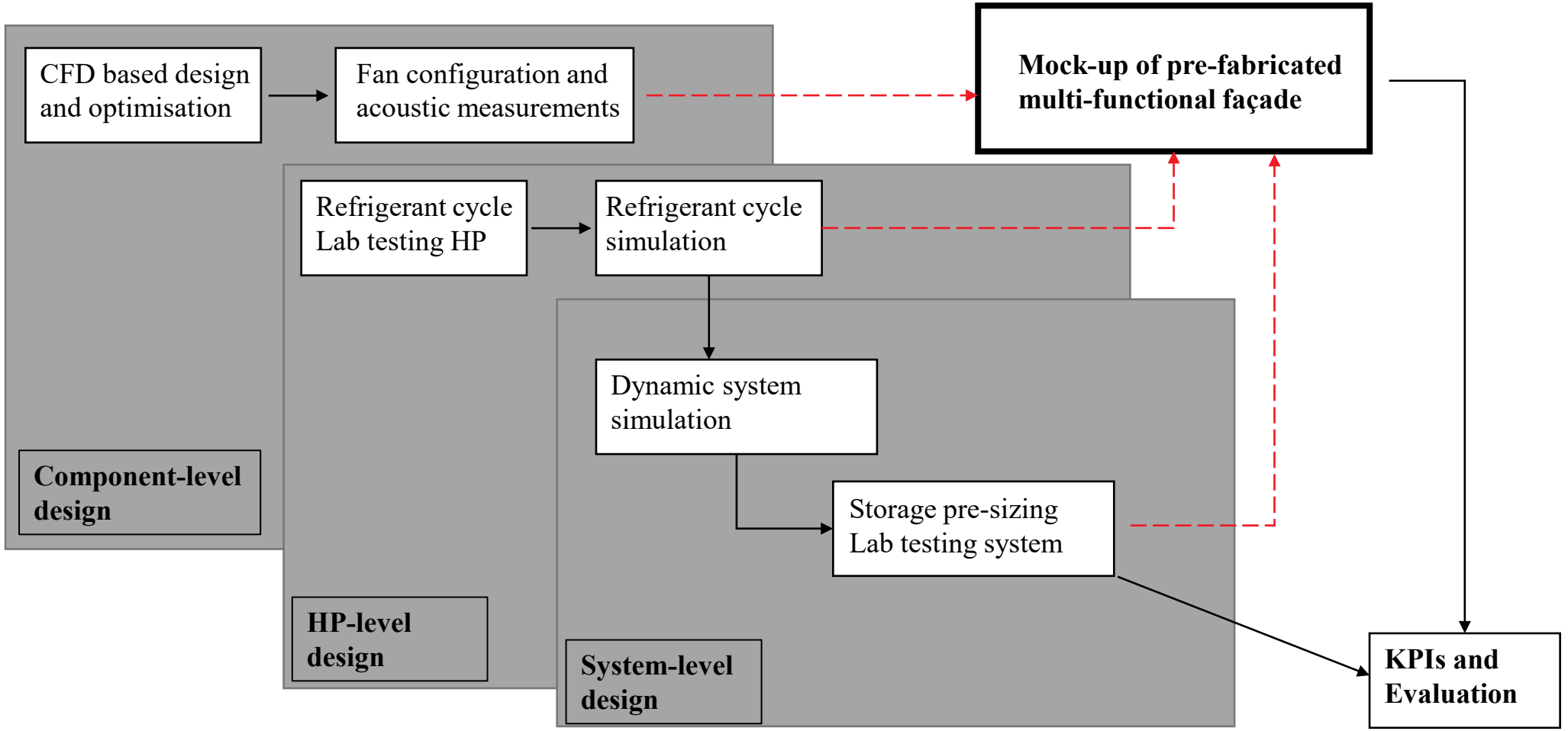
- HP Façade-integration can boost through prefabrication the renovation process and increase cost-effectiveness;
- Accessibility for maintenance and pleasant architectonic appearance;
- Flow condition must be accurately investigated (efficiency, sound emissions).

Source: EU Fp7 Inspire project

Research goal

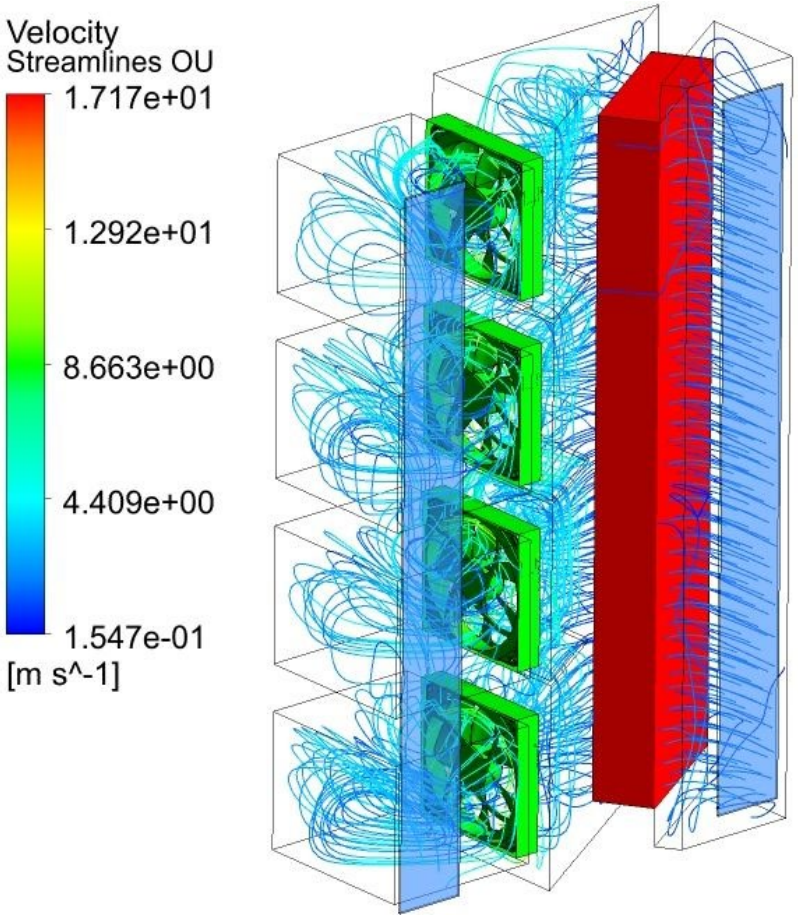
- Develop an alternative to decentral gas or electric boilers for domestic hot water preparation in multiple family buildings:
  - Compact design of indoor unit for space saving;
  - Silent compact façade-integrated outdoor unit;
  - Increase social acceptance and improve architectonic appearance of the façade.

Holistic development approach



CFD-based developed design

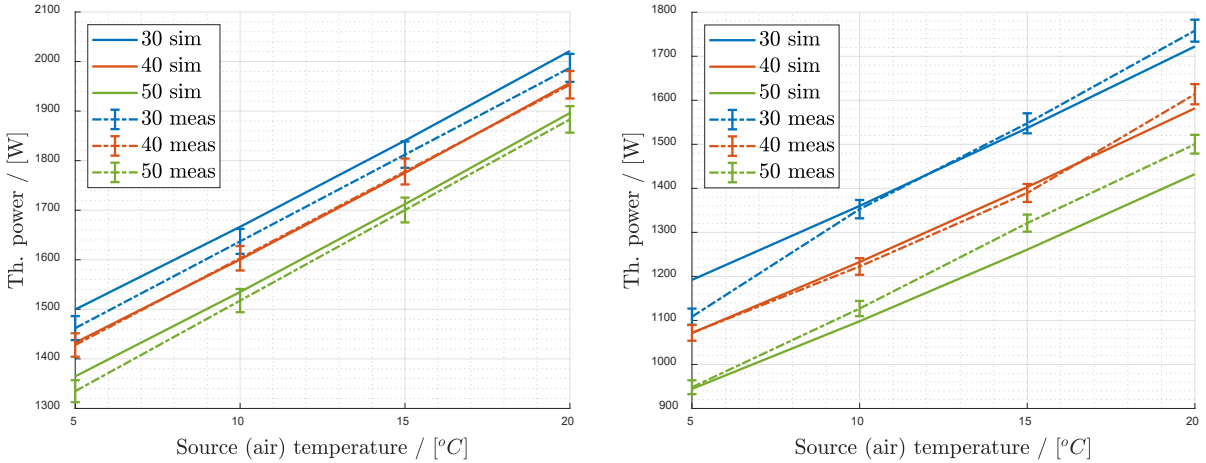
Component level

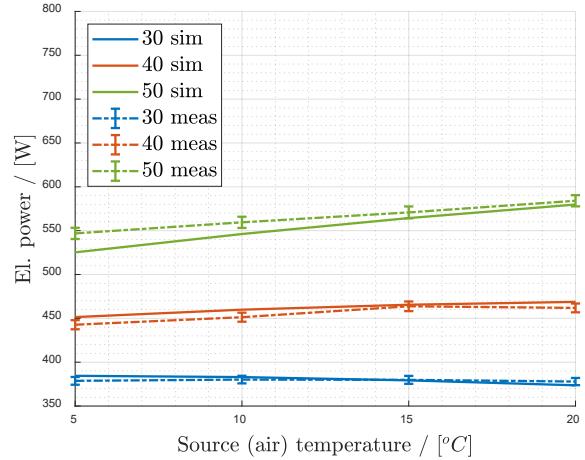


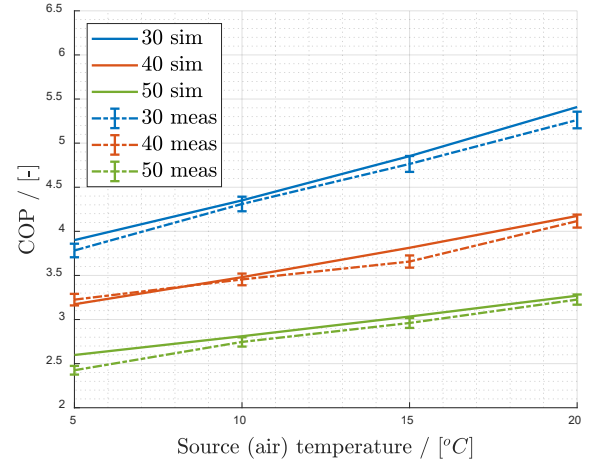
- Outdoor unit of split-type heat pump:
  - Evaporator
  - Four parallel axial fans
- Lower power consumption and lower sound emissions compared to radial fans
- Four separate outflow chambers lined with sound-insulating material
- Dimensions: 860 x 540 x 200 mm

Simulation-assisted design and optimization

Heat pump level



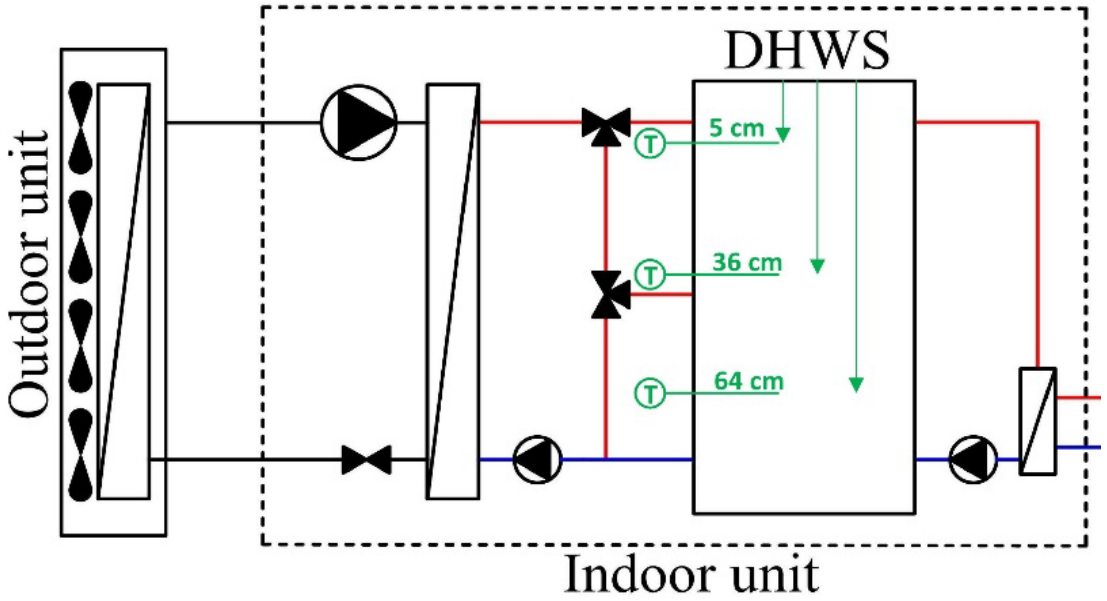




- Generation of performance maps for heating, cooling, electric power depending on source and sink temperatures
- Input for dynamic system simulation (pre-sizing of DHW storage and assessment of dynamic performance)

Dynamic system testing for DHW preparation System level

Measurement setup of the outdoor unit in the cold climate chamber

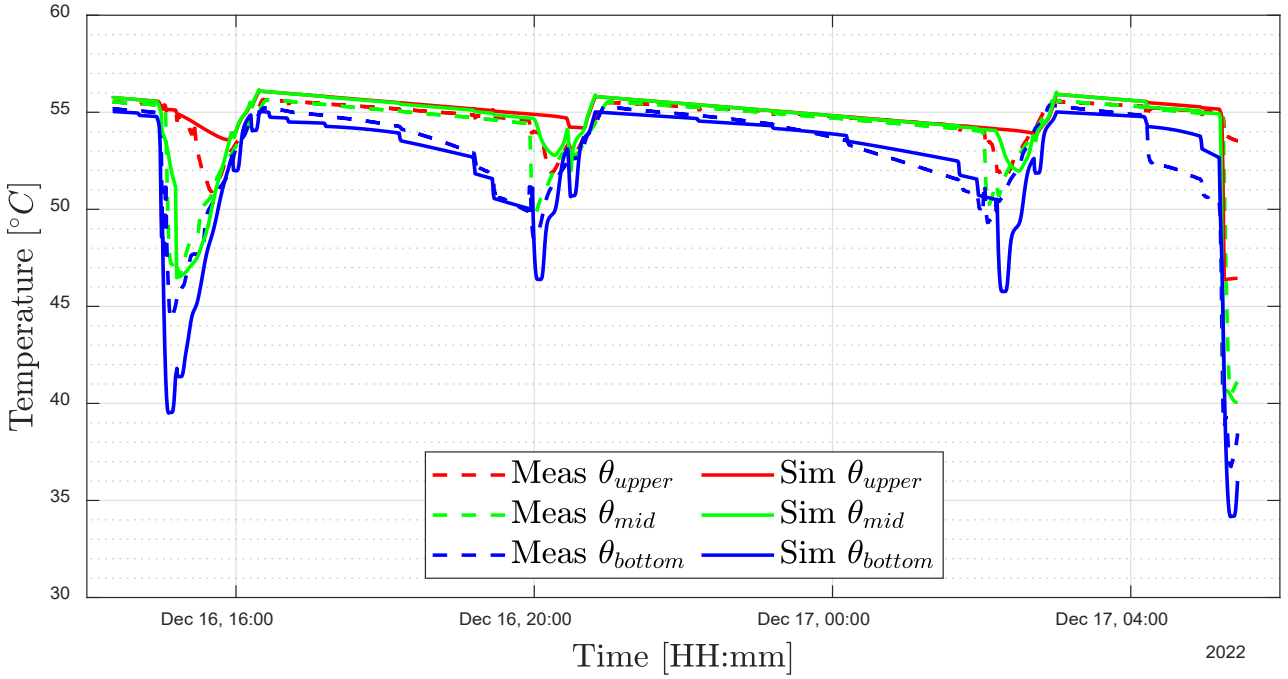


Lab setup:

- Double-room climate chamber
- 120 liters storage size
- Intermittent tapping with Hardware-in-the-Loop

Measurement setup of the indoor unit in the warm climate chamber

Dynamic system simulation performance



Temperature [°C]	Q_{DHW} [kWh]	Q_{el} [kWh]	COP_{sys}[-]
10	6.05	2.02	2.99
15	6.05	1.88	3.22
20	6.05	1.76	3.43

- Cylindrical storage model simulated
- Assessment of storage size and dynamic system performance („M“ profile EN 16147)
- Cross-comparison between dynamic simulations results and measurement data (temperatures)
- 90 liter storage sufficient for a 2-persons household with moderate hot water consumption

Conclusions

- A prototype of a propane 1.5 kW split-type air-to-water heat pump was developed through coupled simulation and experimental work
- Designed for a refrigerant charge lower than 150 g
- Through a steady-state refrigerant cycle simulation tool, physics-based performance maps of the heat pump were generated and used as input in dynamic system simulations
- A 90 liter storage is sufficient for a 2-persons household and moderate hot water consumption
- Good agreement between dynamic system simulation results and measurements

Outlook

- Combined SH and DHW production to be evaluated in detail:
  - Possible with the current design with 120 liter storage size for a 40 m^2 flat and a heating demand of 50 kWh/m^2y
  - Control optimization
- Evaluation of deicing control strategy by means of dynamic simulation and experiments

Photo courtesy of element design and Kulmer Holzbau

Thank you very much for your attention

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raumklima : intelligent und einfach