A Modular Model of Reversible Heat Pumps and Chillers for System Applications

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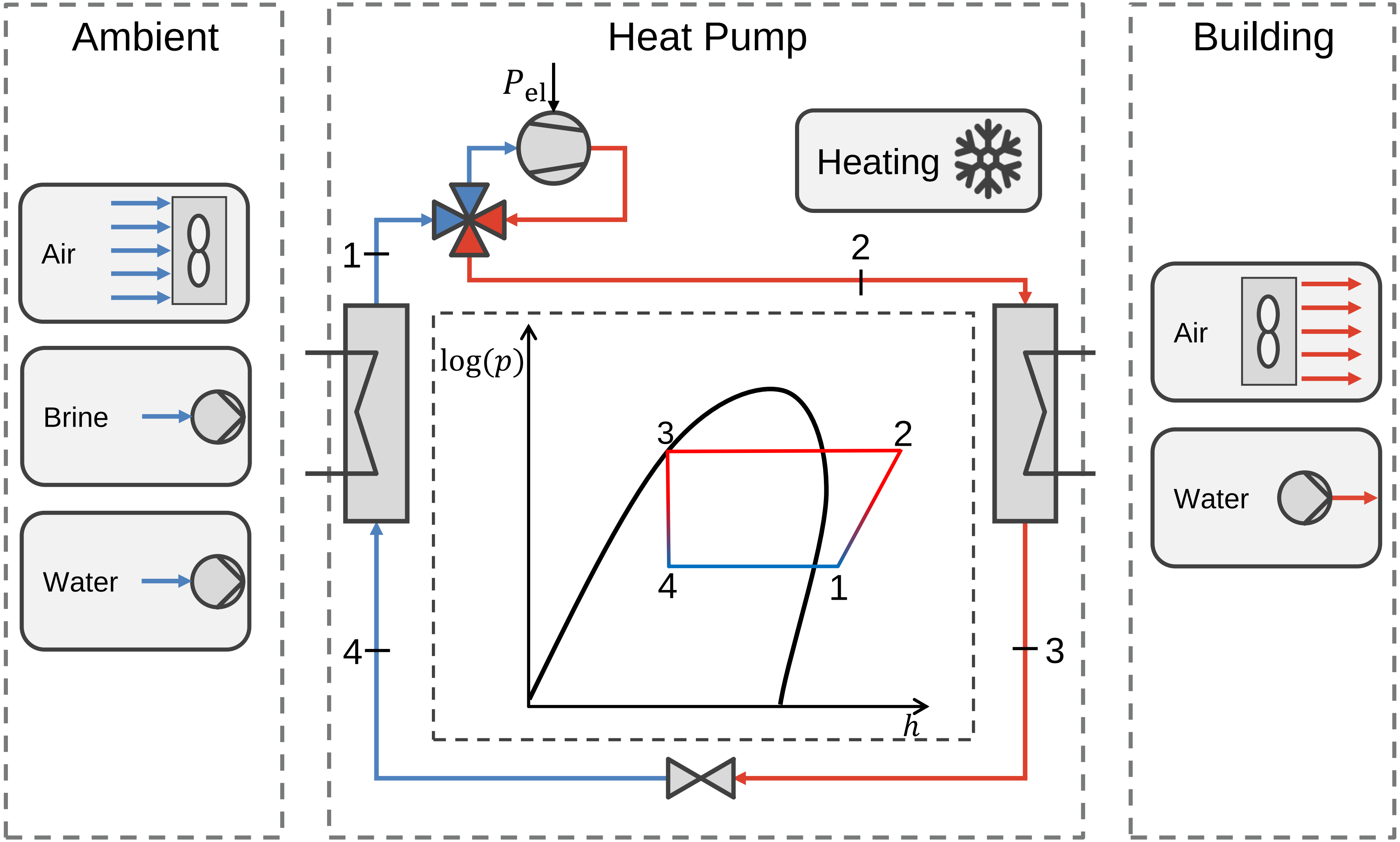
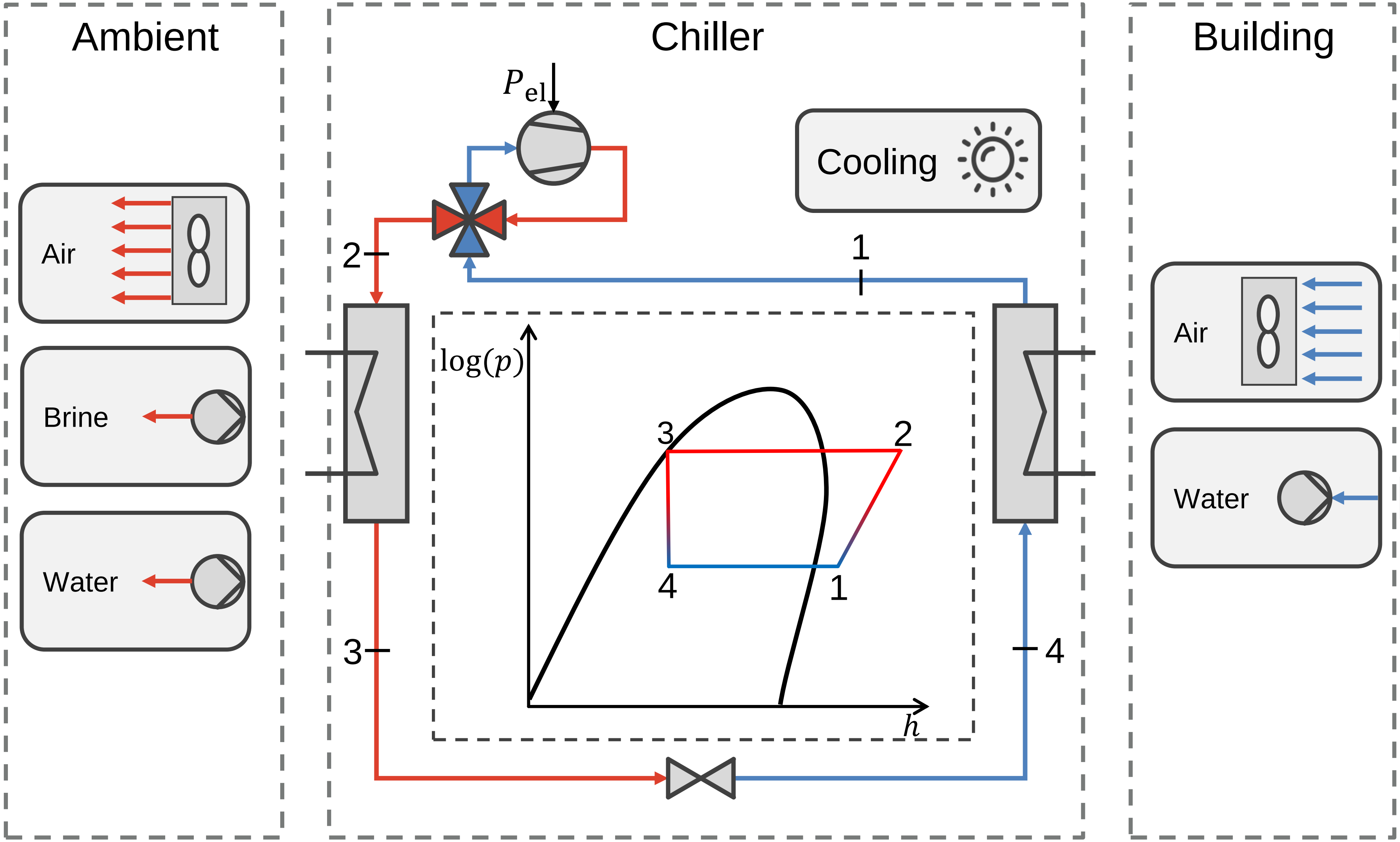
Working principle of a *heat pump* applied in buildings



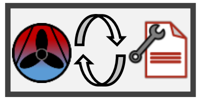
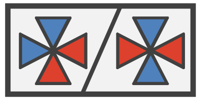
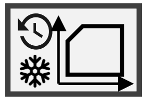
Working principle of a *chiller* applied in buildings



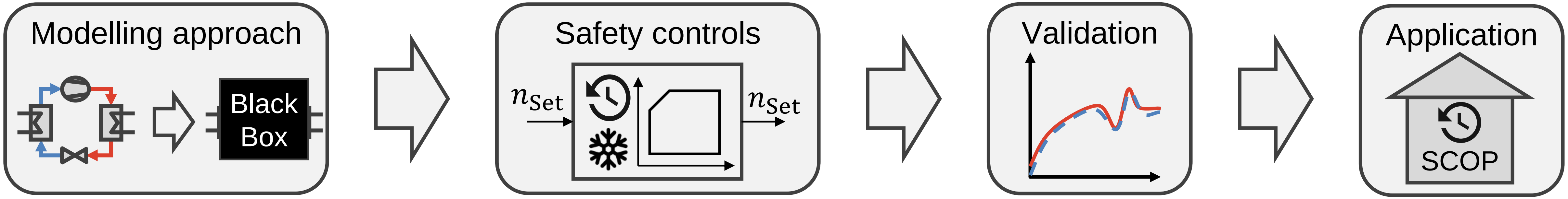
Same source and **sink** fluids

Same **vapour compression cycle**

Motivation for a heat pump and chiller model

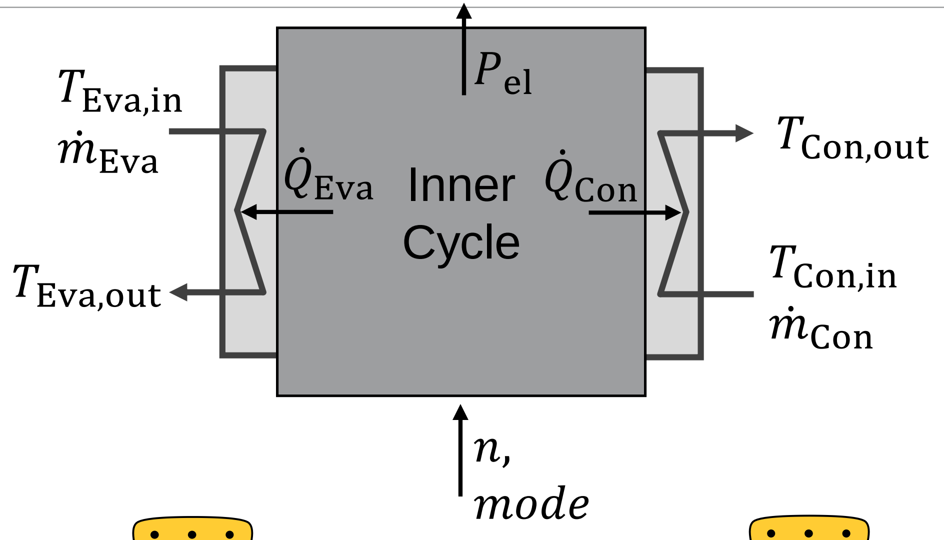
- Heat pumps and chillers are key to achieve climate goals
- Efficiency mainly depends on the device interaction with the energy system
- We have to better understand this interaction and optimize it
- On system level, various open source approaches exist
- However, existing approaches …
  - … are not **modular** 
  - … are not **reversible** 
  - … (mostly) do not regard **safety controls** [1] 

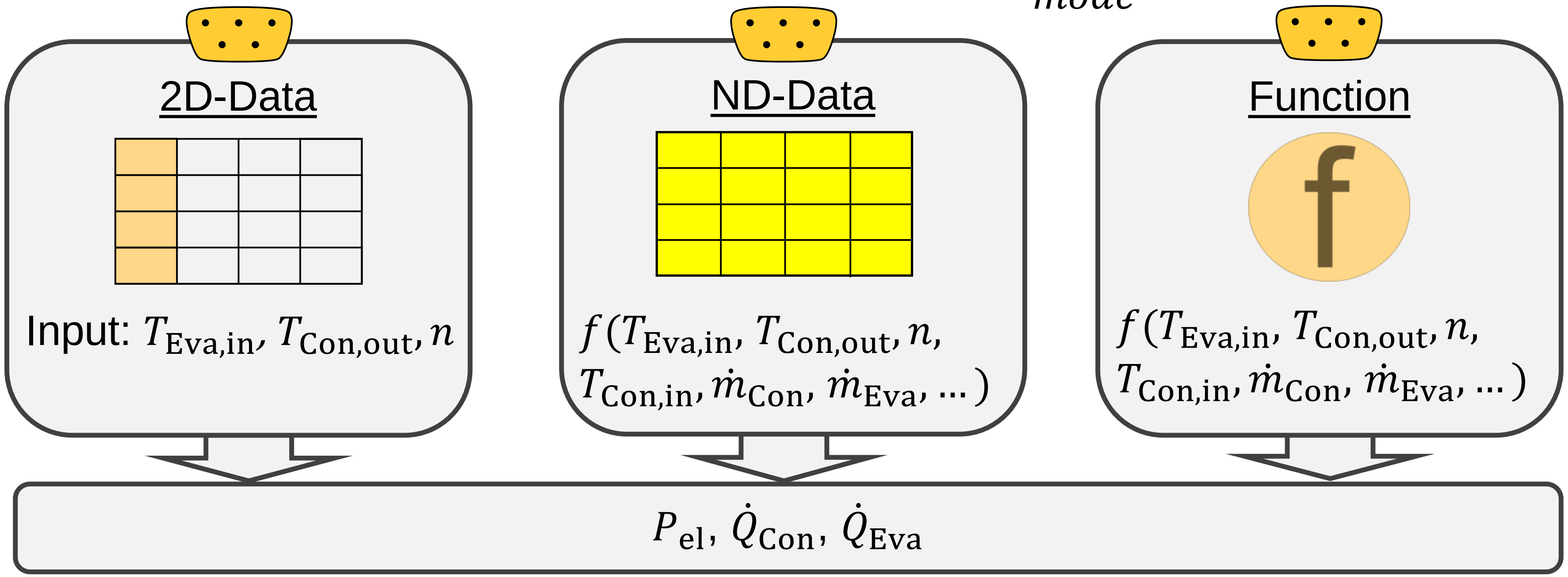
One model can be **modular** and **reversible!**



Black-box approach for vapour compression cycle

- Outputs are always the same three values
- Modular Black-Box
  - Based on expandable bus connector
- Data based on
  - 2D data of European Standard 14511 [2]
  - Stationary compression cycle simulations [3]
  - Functional approaches [4]



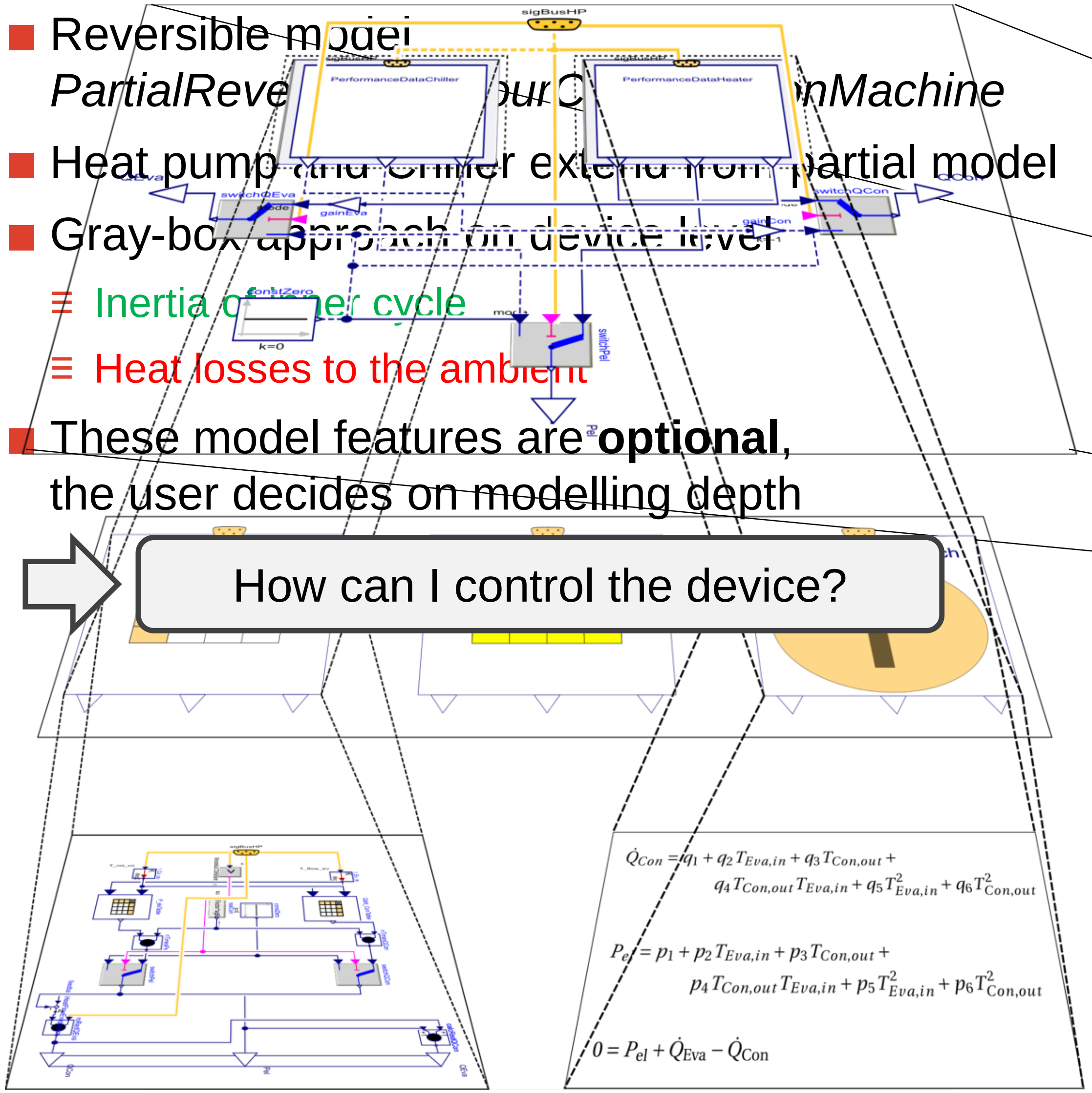


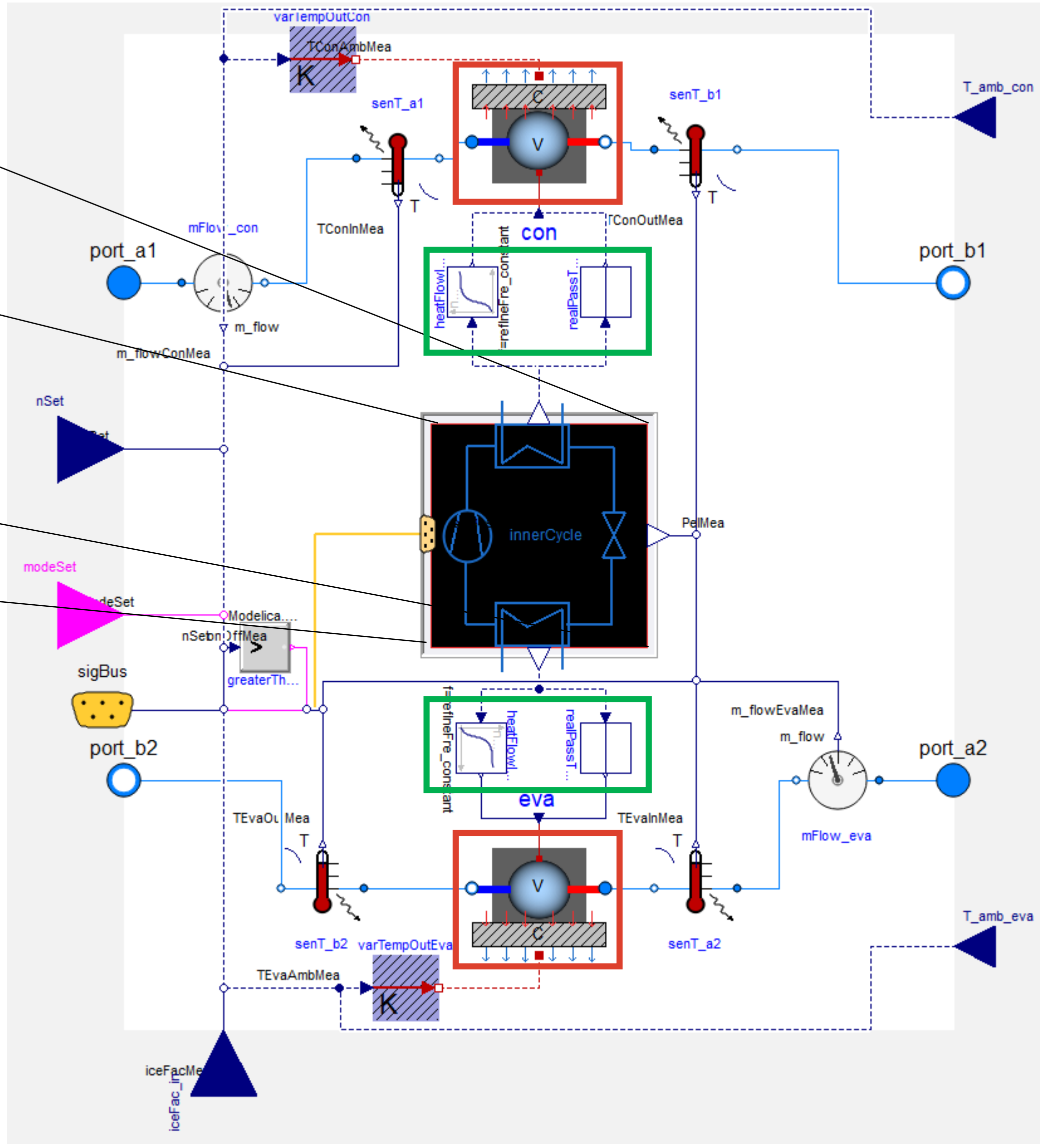
Black Box

Integration of custom black-box models into gray-box system model

- Reversible model *PartialReversibleVapourCompressionMachine*
- Heat pump and chiller extend from partial model
- Gray-box approach on device level
  - Inertia of inner cycle
  - Heat losses to the ambient
- These model features are **optional**, the user decides on modelling depth

How can I control the device?





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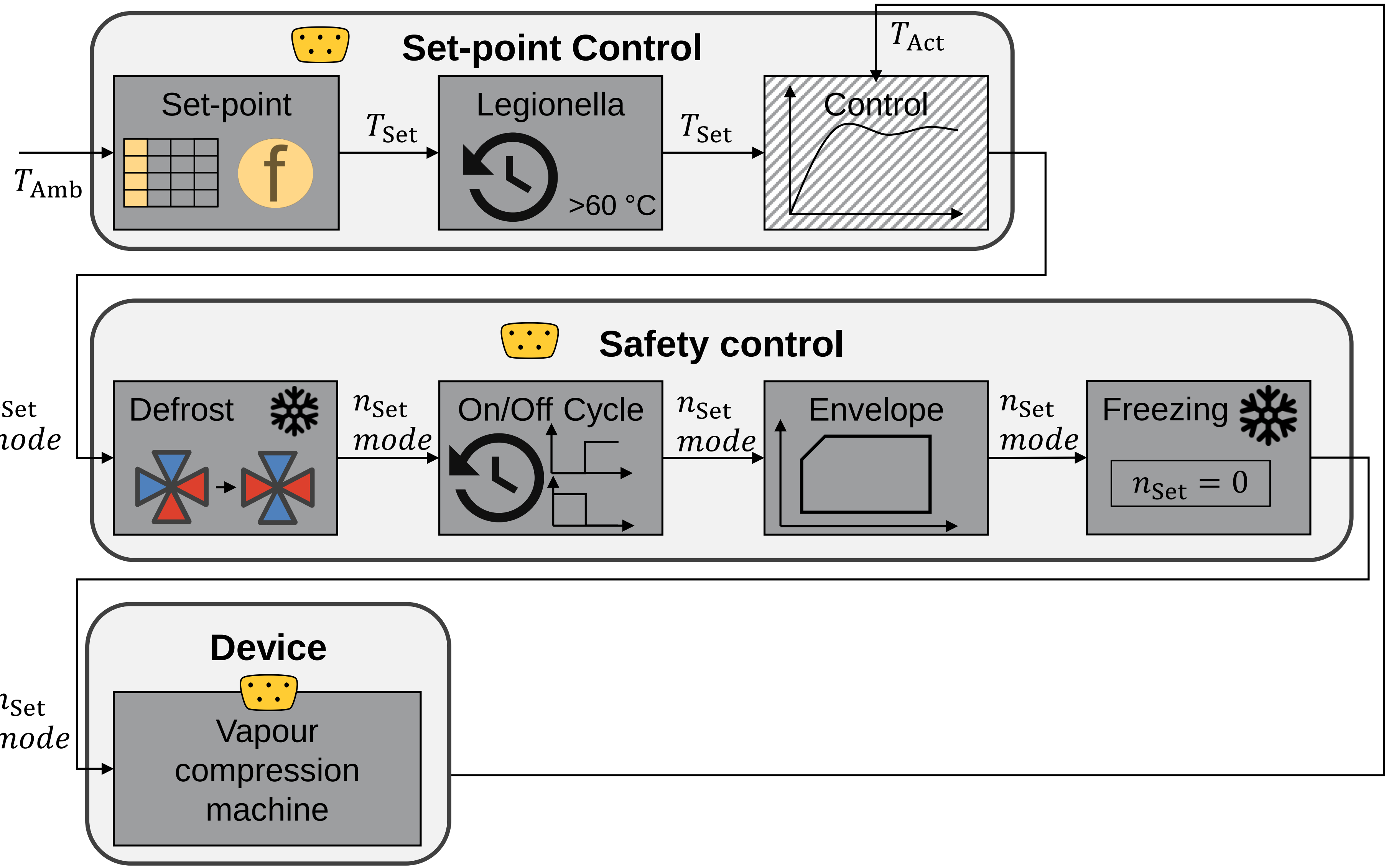
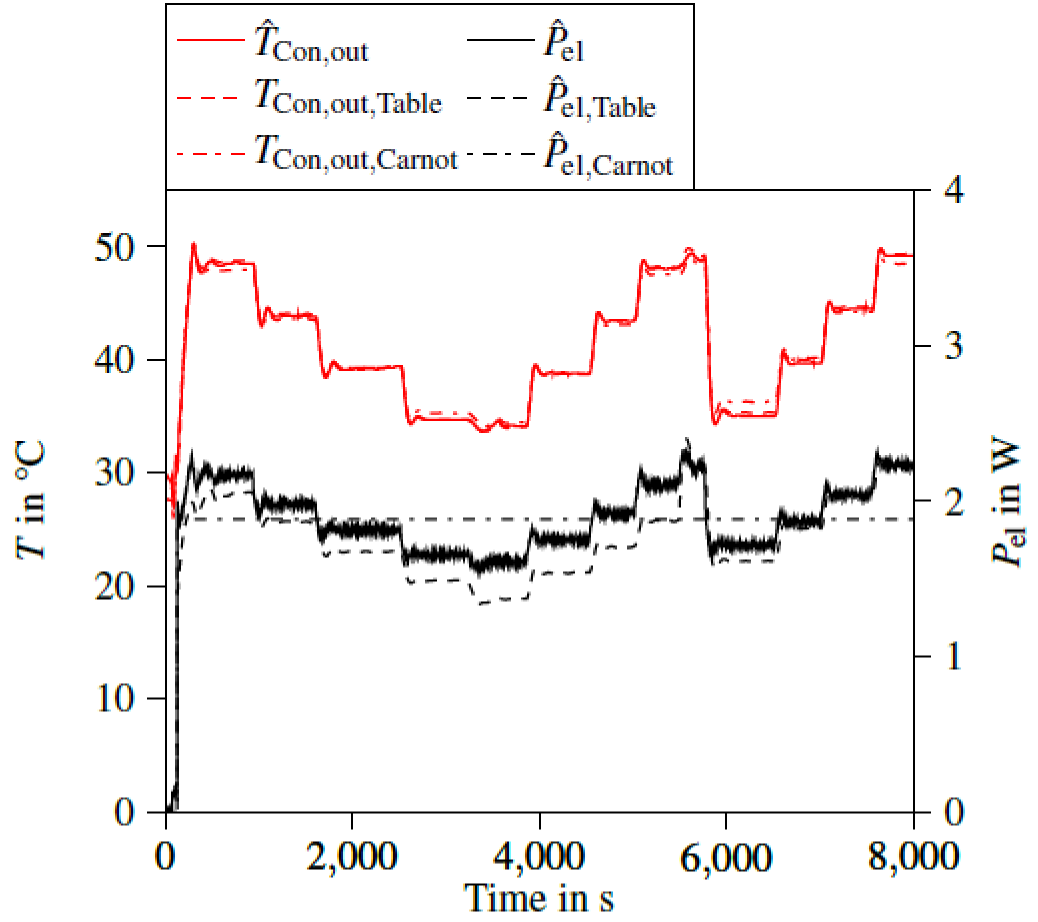
Ontology of set-point and safety control



Calibration and validation of different model options

- Water-to-water heat pump
- Calibration of two modelling options
  - Table (4 points only) based on European Standard 14511 [2]
  - Carnot-Approach from IBPSA [4]
- Validation during last 30 min
- Equally weighted NRMSE[1] for P_{el} and $T_{\mathrm{Con,out}}$

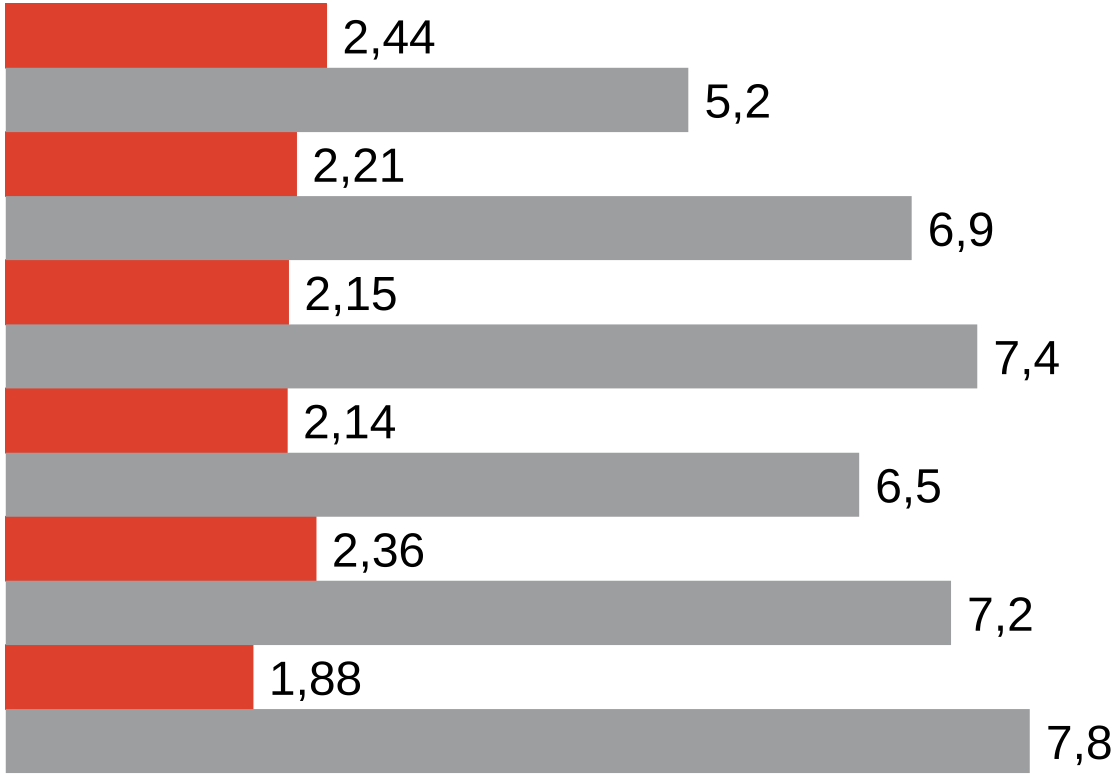
Calibrated and validated fit:



[1] Normalized Root Mean Square Error

Influence of models options in coupled building energy simulations

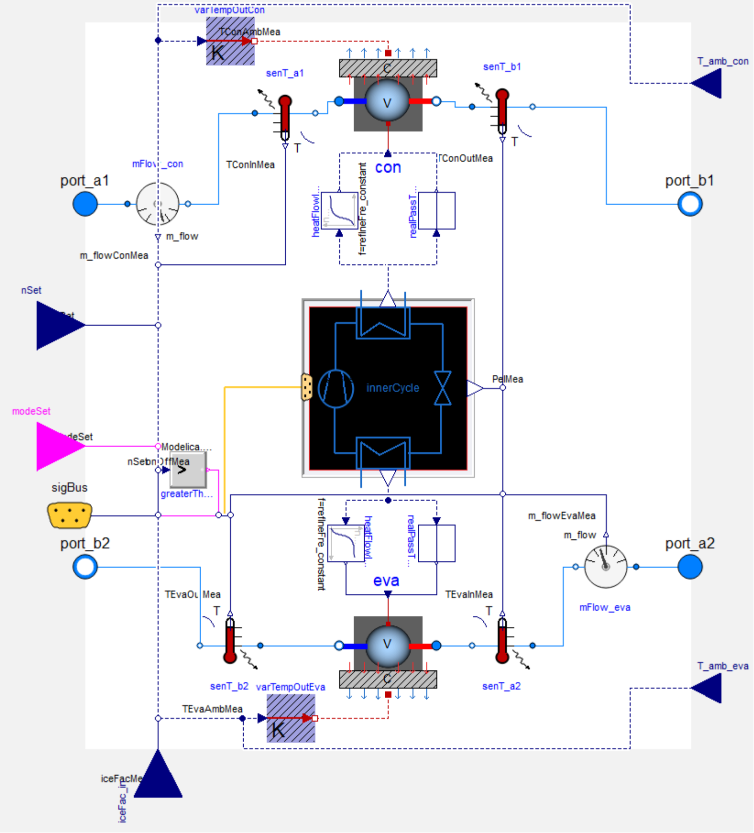
- Coupled building energy simulation with high order model from *AixLib* [3]
  - Air-to-water heat pump | One heating period | $T_{\mathrm{Set}} = 55\ °\mathrm{C}$, $2\ \mathrm{K}$ Hysteresis
- Variation of different modelling options
- Analysis of SCOP and computation time



Conclusion and discussion of future research

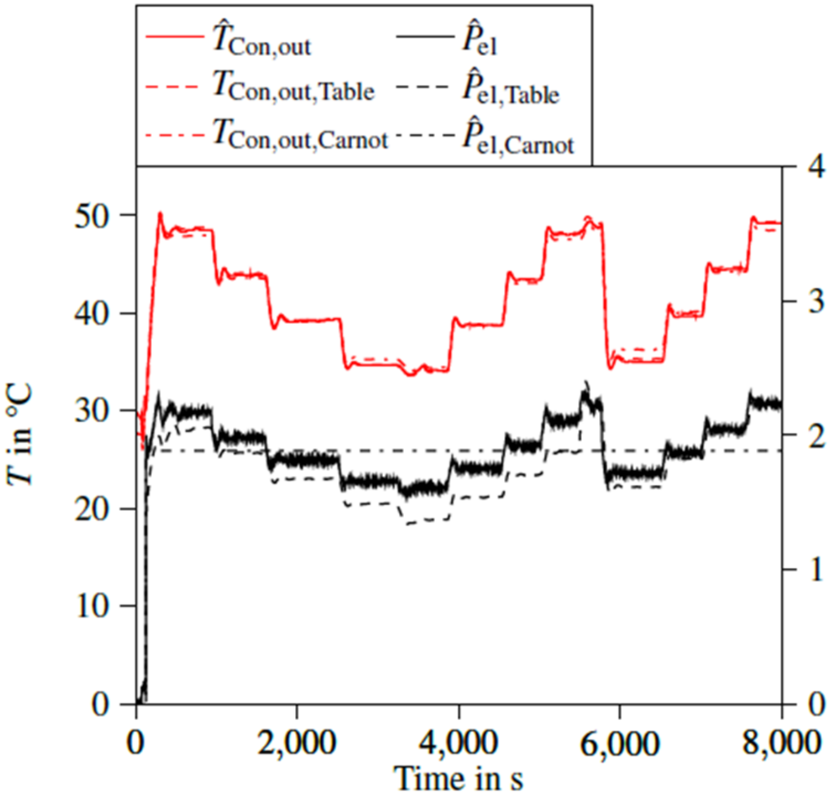
Conclusion

- Modular model for heat pumps and chillers
- Validated different modelling approaches
- Implemented in the *AixLib*



Future Research

- Implementation of further black-box options
- Validation for Chiller applications
- Integration into other libraries?



Sources

- [1] Jorissen, Filip et al. (2018). “Implementation and Verification of the IDEAS Building Energy Simulation Library”. In: Journal of Building Performance Simulation 11 (6), pp. 669–688. DOI: 10.1080/19401493.2018.1428361.
- [2] EN 14511-1:2018-03 (2018-03-14). Air Conditioners, Liquid Chilling Packages and Heat Pumps for Space Heating and Cooling and Process Chillers, with Electrically Driven Compressors - Part 1: Terms and Definitions. Tech. rep. Bruxelles, Belgium: CEN/TC 113.
- [3] AixLib - An Open-Source Modelica Library within the IEA-EBC Annex 60 Framework. Müller D., Lauster M., Constantin A., Fuchs M., Remmen P.. BauSIM 2016, p.3–9, September 2016. link
- [4] International Building Performance Simulation Association (2018). IBPSA Project 1: BIM/GIS and Modelica Framework for building and community energy system design and operation. URL: https://ibpsa.github.io/project1/.