Facade-integrated decentralized cooling system - evaluation in an outdoor test facility

Daniel Brandl
Institute of Thermal Engineering
Graz, University of Technology

E-Mail: daniel.brandl@tugraz.at
Homepage: http://www.iwt.tugraz.at

Content

Introduction

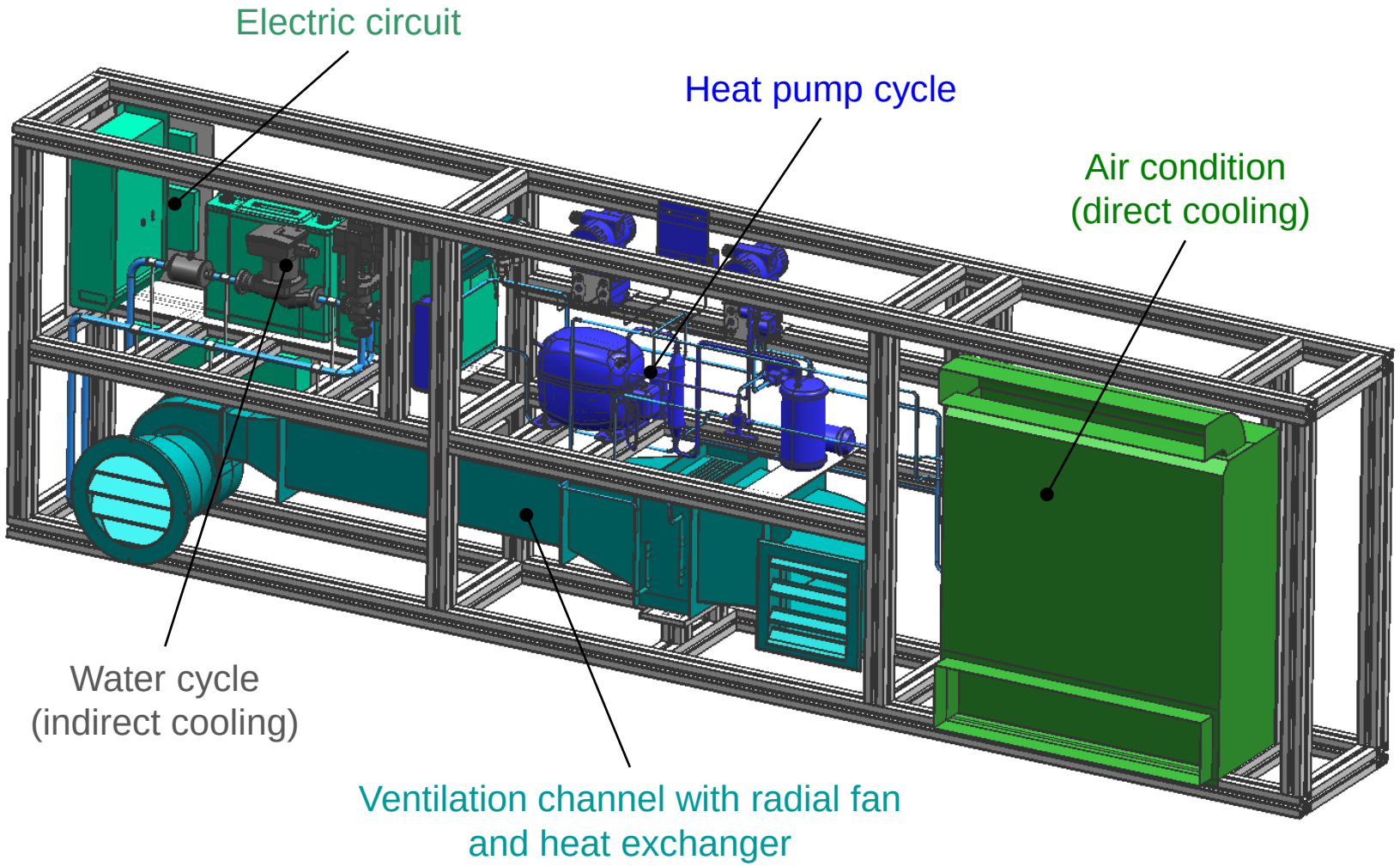
- The objective of the research project COOLSKIN is the development, assessment and functionality approval of a decentralised, façade-integrated energy system for cooling of interior spaces.
- Building integrated photovoltaic (BIPV) modules convert the solar irradiation into electricity in order to operate a heat pump system for controlling the indoor temperature of the adjacent interior room.
- The system concept addresses decentralization of the energy supply and energy autarky.

Introduction of the research project COOLSKIN

Project team

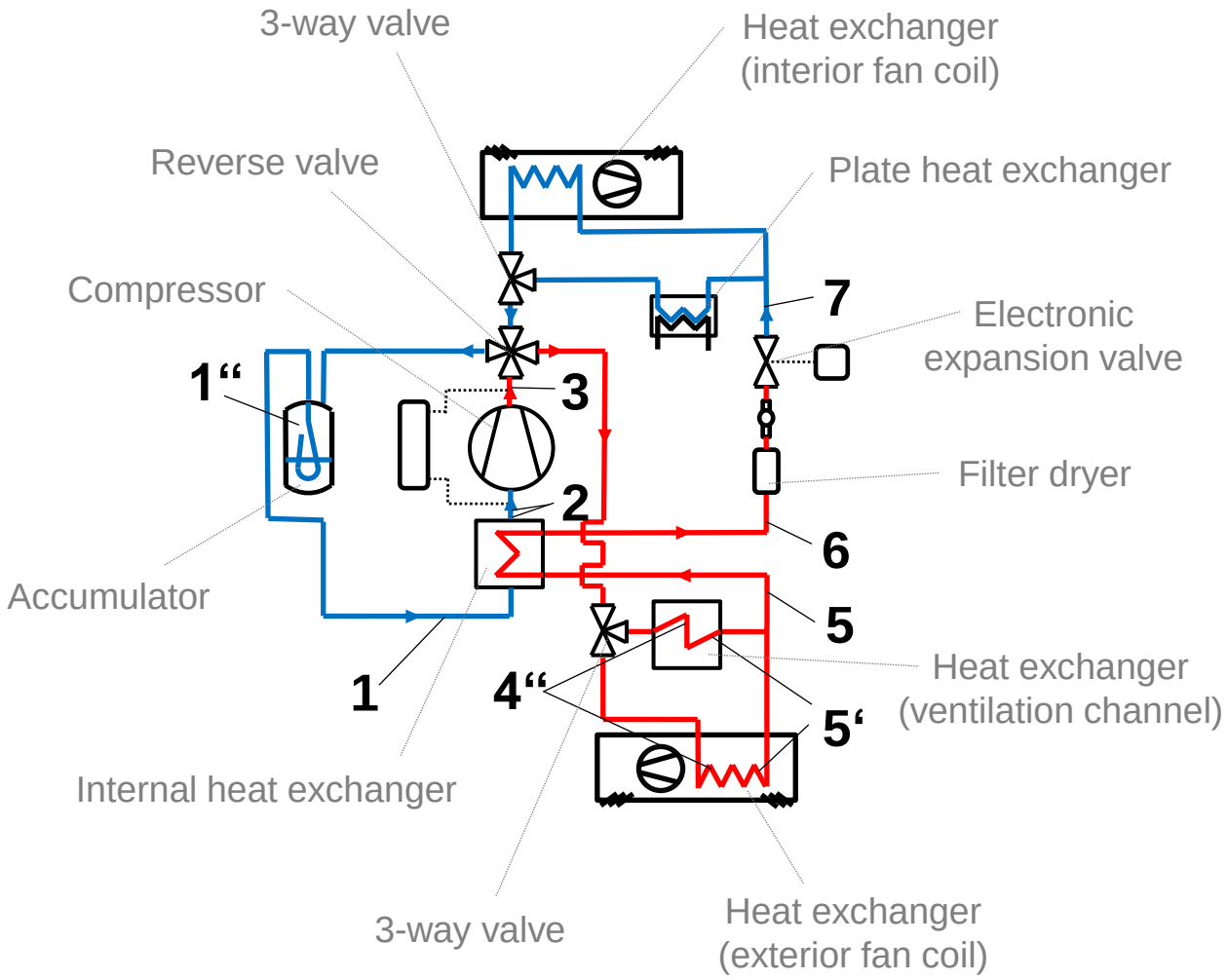
- Institute of Thermal Engineering, Graz University of Technology
- AIT Austrian Institute of Technology GmbH (AIT-Energy)
- SFL technologies GmbH
- qpunkt GmbH
- Architekturbüro Reinberg ZT GesmbH

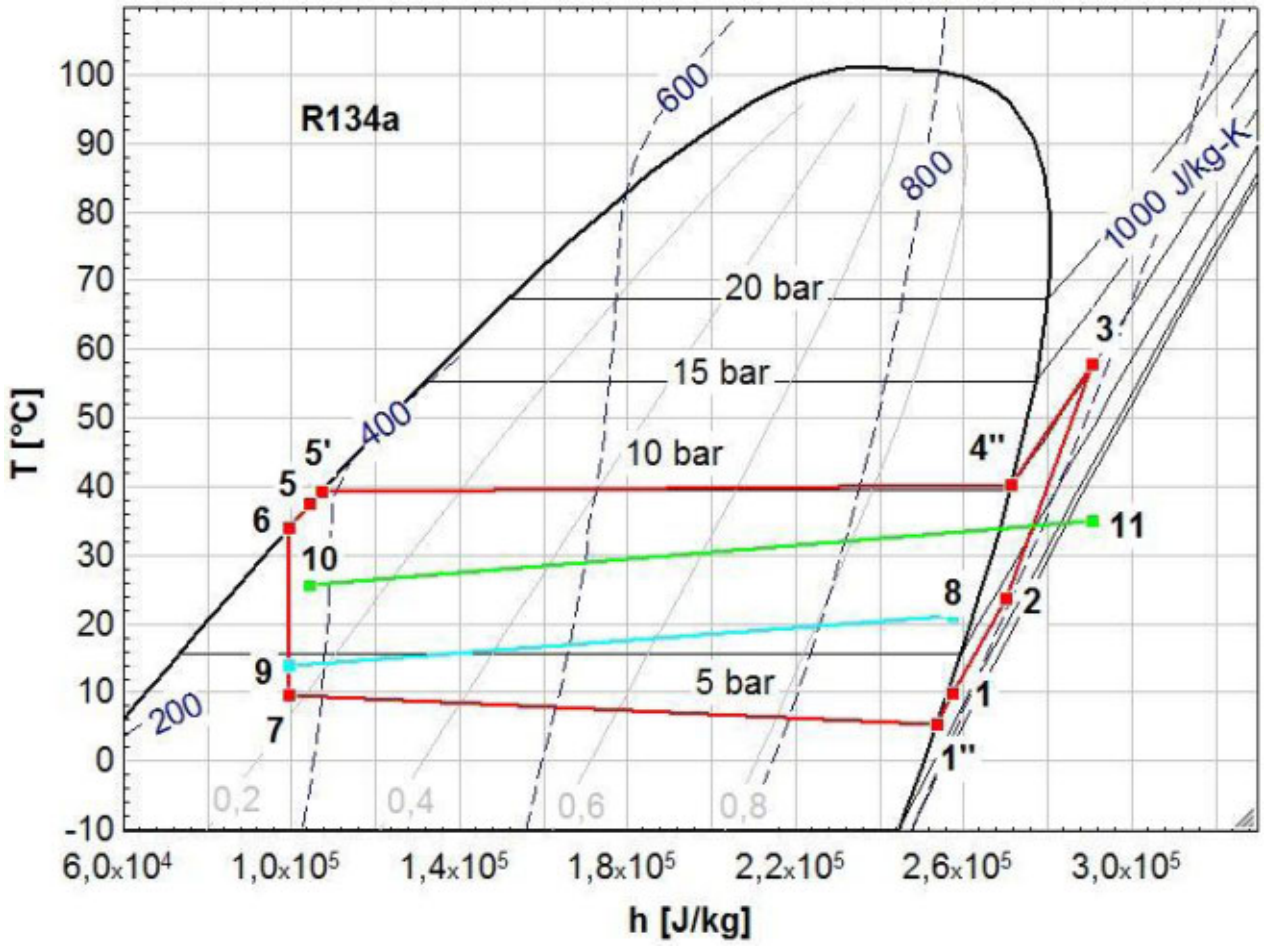
Facade integrated cooling system (COOLSKIN)



- Aluminium framework
  - main dimensions of 2.97 x 0.89 x 0.36m
- Five assembly units
- Electric circuit with battery storage
- Heat pump cycle
  - R134A as refrigerant
  - Cooling capacity 1 - 2 kW
  - Compressor
  - speed 2000 - 4500 min^{-1}
  - electricity consumption 200 - 450 W
- Ventilation channel with integrated heat exchanger
- Direct cooling
  - Interior Fan coil with 0.35 - 1.28 kW cooling power
- Indirect cooling
  - Thermal activation of the concrete ceiling or floor (water cycle)
- Designed for a single office space

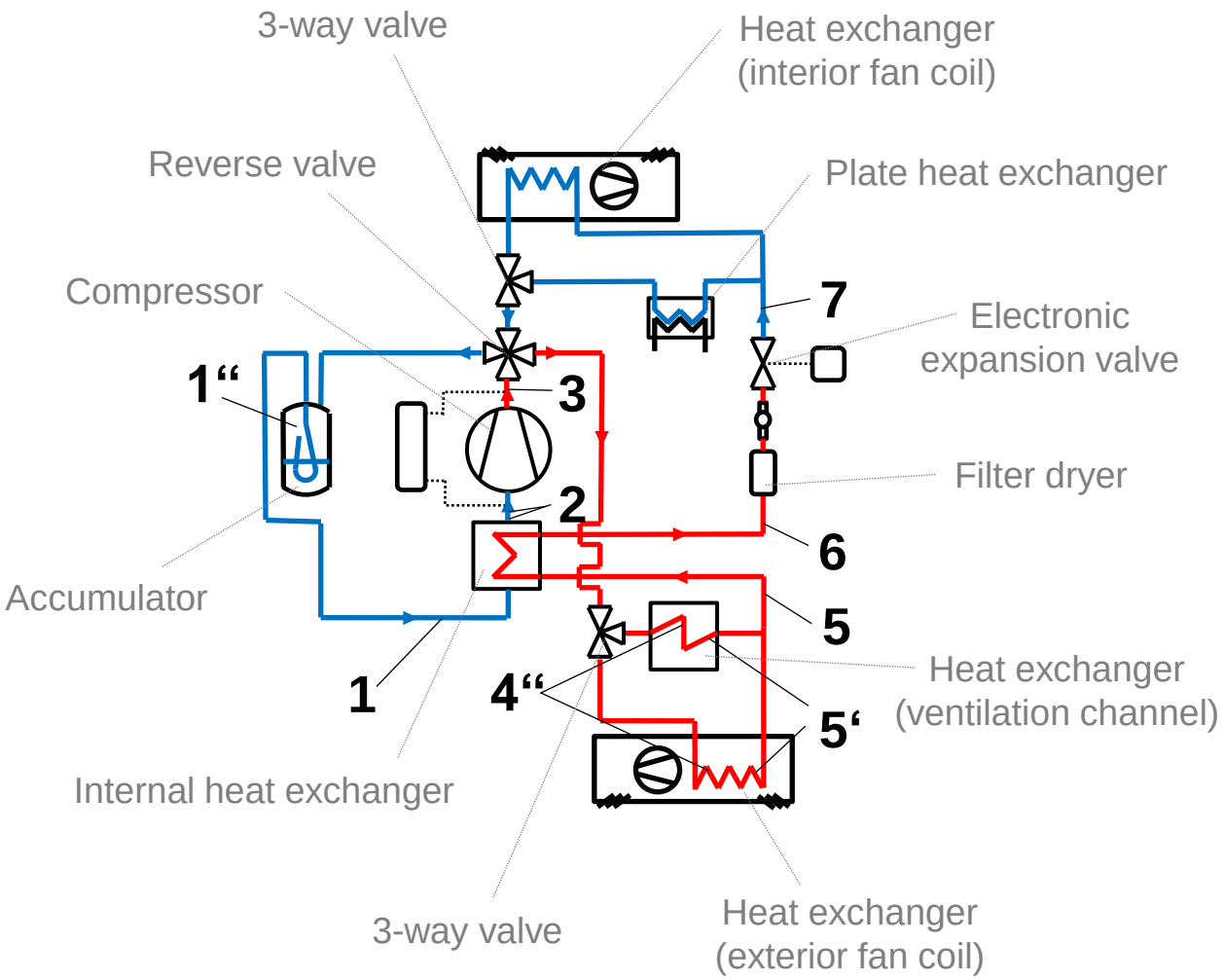
Heat pump cycle



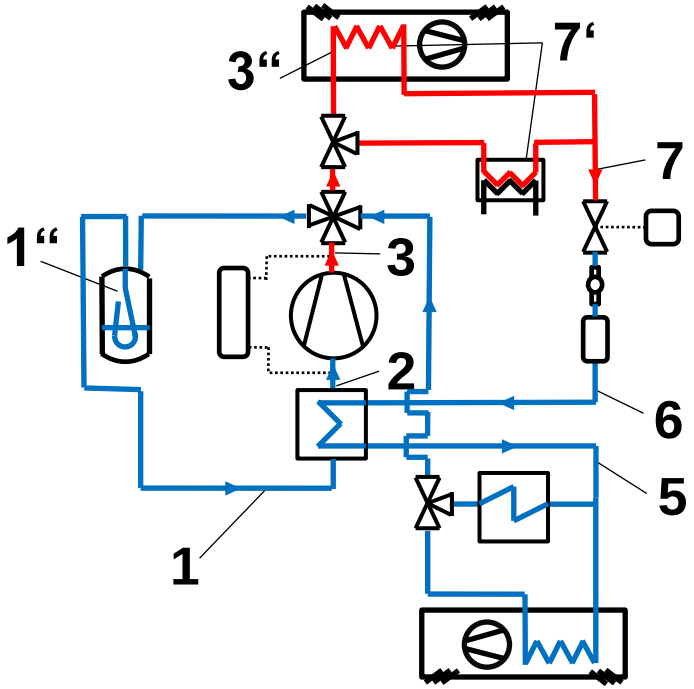


Heat pump cycle

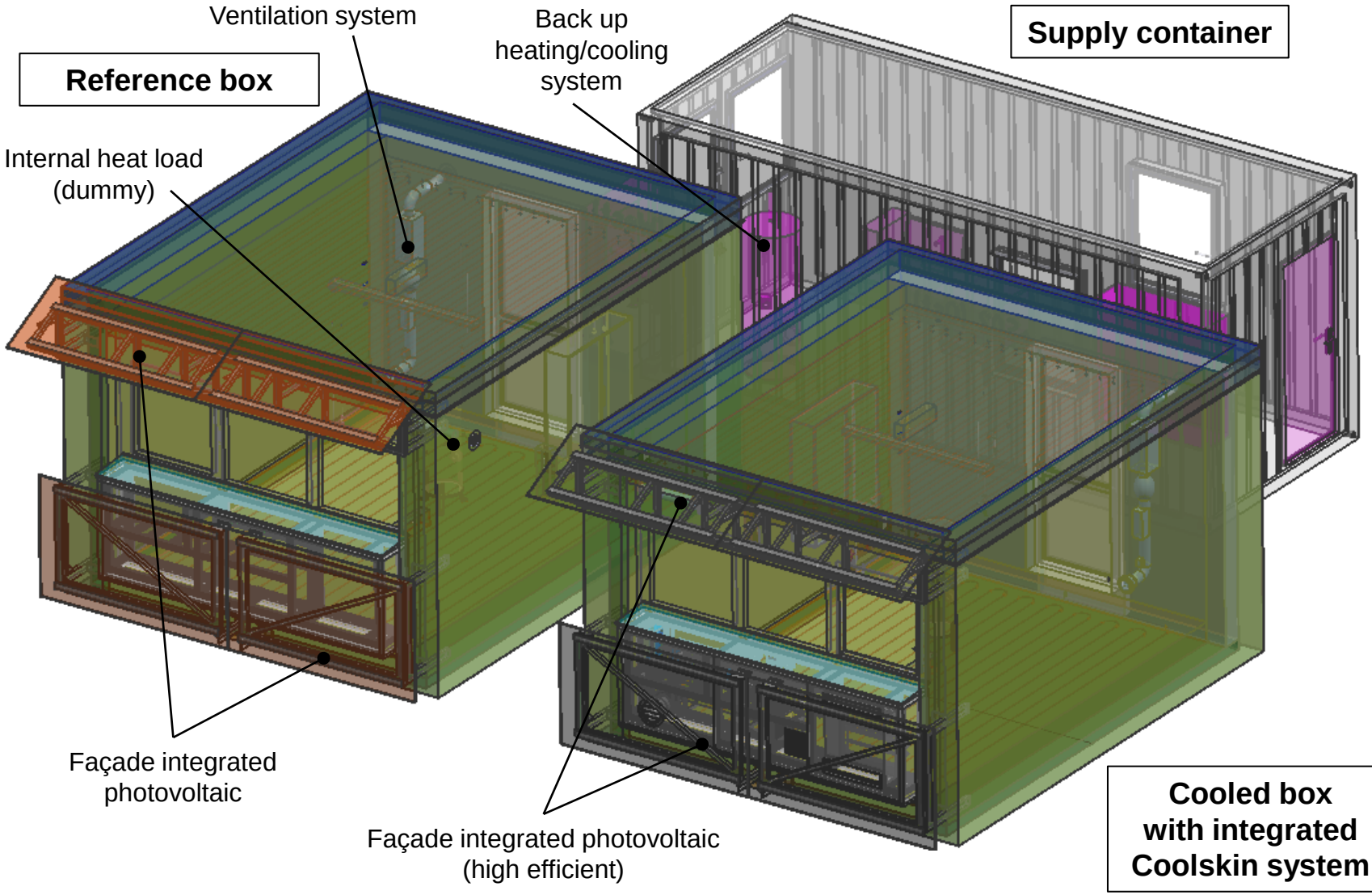
Cooling mode (Primary)



Heating mode



Outdoor test facility

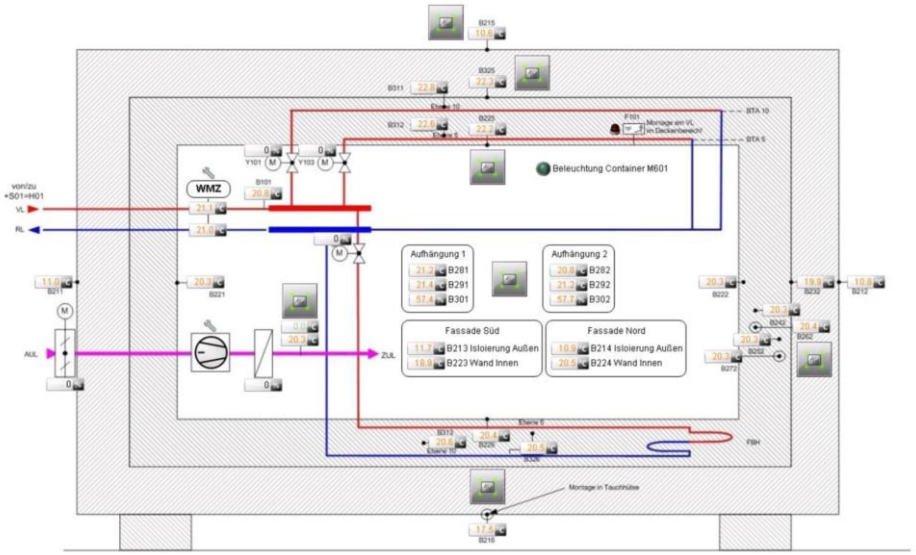


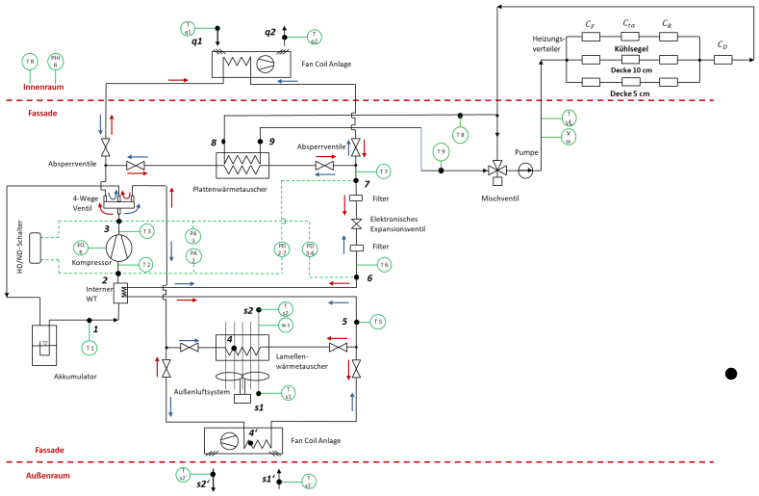
- Two equal boxes
  - Concrete Walls with 200 mm EPS
  - Cooled box
  - Reference box
  - 13.42 m² effective floor area
  - Internal thermal load of 300 W between 8:00 - 16:00 on working days
  - Air exchange of 60 m³/h during working period
- Supply container
  - Includes data acquisition and storage of all measurement systems
  - Supplies the measurement systems with electricity
  - Serves as backup system for the reference box
- COOLSKIN system
  - Integrated below the south oriented window
  - Thermal insulated with 50 mm XPS
  - Additional ventilation to prevent overheating inside the COOLSKIN

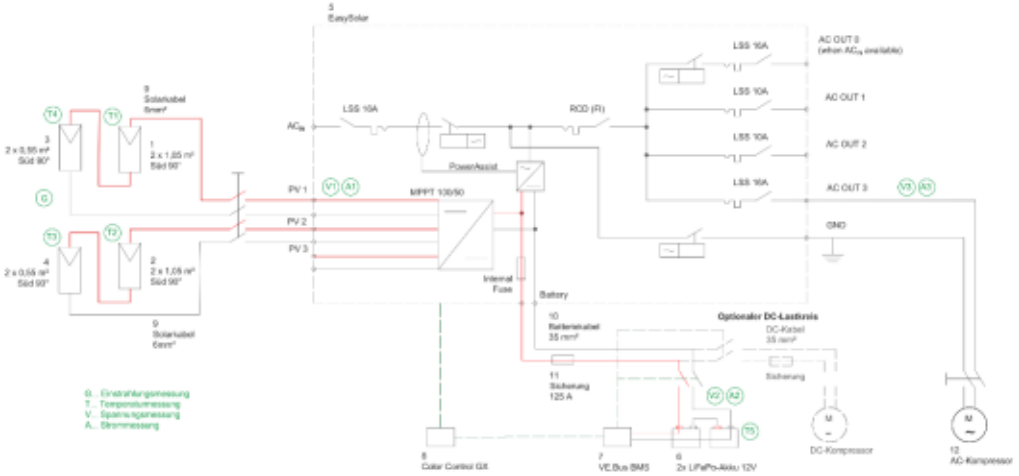
Outdoor test facility

- PV modules (BIPV)
  - Glass-glass modules
  - Black coloured with an efficiency of app. 14%
  - Grey coloured with an efficiency of app. 11.5%
  - Variable combination of modules
  - Variable angle for PV above the window
- ZAMG climate station
  - Solar radiation
  - Exterior temperature
  - Humidity
  - Barometric pressure

Outdoor test facility

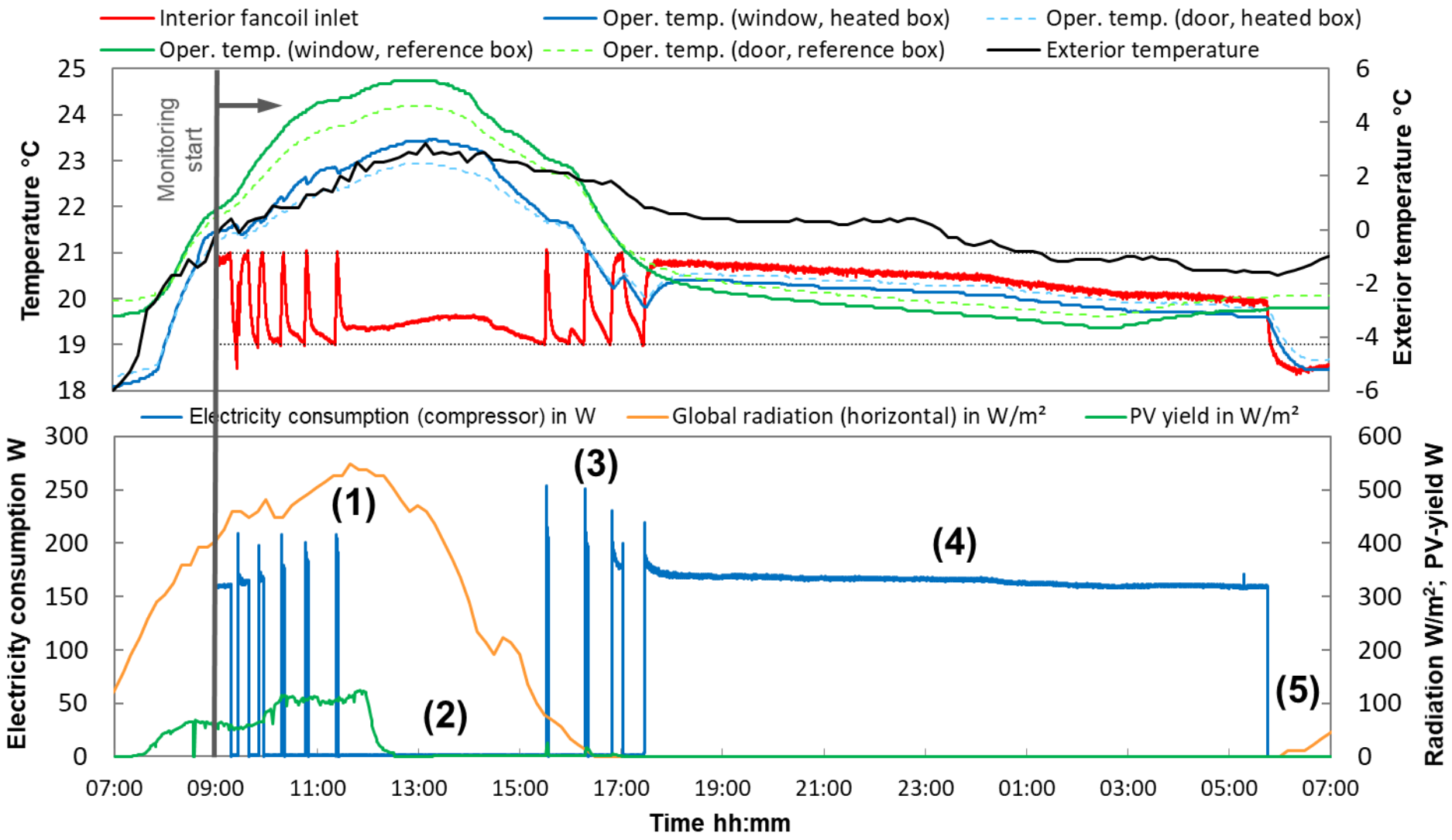






- Box measurement system
  - More than 30 sensors per box
  - Installed and supported EAM Systems GmbH
  - Surface temperatures
  - Air temperature
  - Operative room temperature
  - Thermal comfort analysis
- Coolskin measurement system
  - More than 40 sensors
  - State points of the T-h diagram
  - Electricity consumption of the compressor
  - Electricity consumption of the cooling plant
  - Determination of the COP
- Electric circuit measurement system
  - PV yield
  - Battery voltage
- Long run tests from mid of June 2018 to June 2019

Heating characteristic (direct heating)



15th of February

T_{ext} between -6.2 and 3.2 °C
I_{sol} max. of 550 W/m²

(1) 9:00 - 11:30
- Alternating mode (on/off mode)

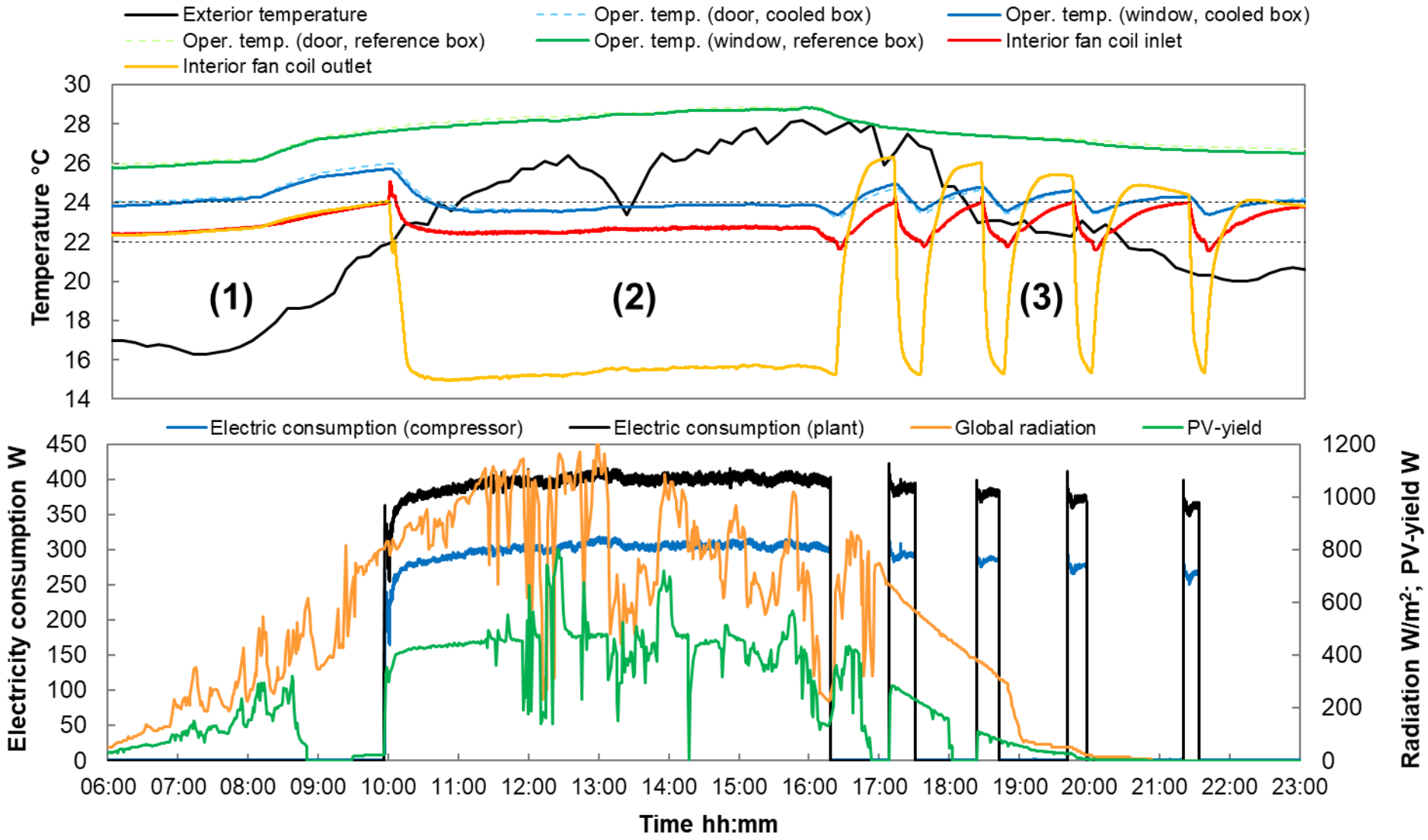
(2) 11:30 - 15:30
- inactive

(3) 15:30 - 17:30
- Alternating mode (on/off mode)

(4) 17:30 - 5:00
- Continuously in operation

(5) 5:30
- Battery was discharged

Cooling characteristic (direct cooling)



4th of August

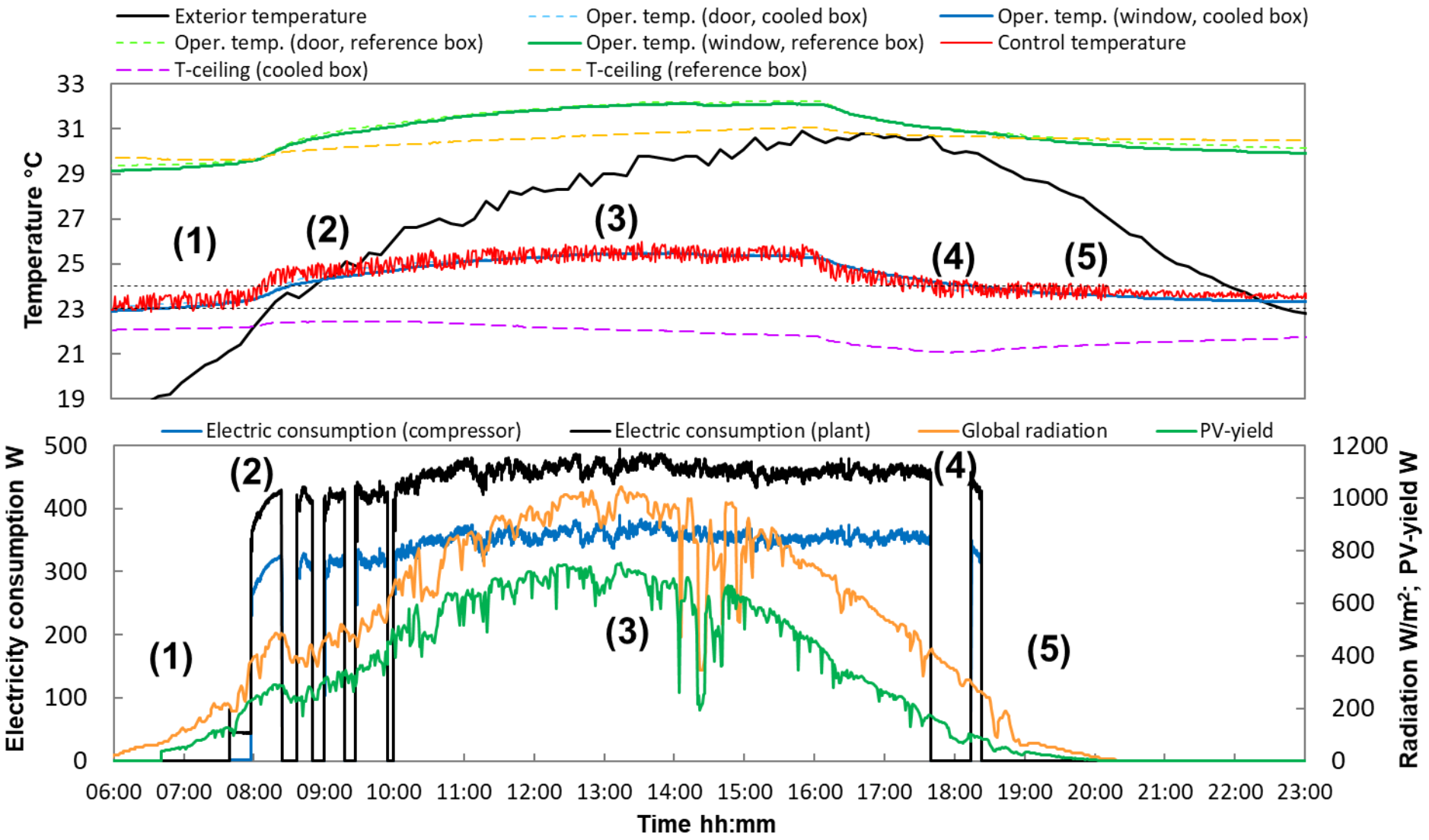
T_{ext} between 16.3 and 28.2 °C
I_{sol} max. of 1200 W/m²

(1) 6:00 - 10:30
- Turned off because room temperature is below the upper temperature limit

(2) 10:30 - 16:20
- Continuously in operation

(3) 16:20 - 22:00
- Alternating mode (on/off mode)

Cooling characteristic (indirect cooling)



6th of August

T_{ext} between 18.5 and 30.9 °C
I_{sol} max. of 1050 W/m²

(1) 6:00 - 8:00
- Turned off because room temperature is below the upper temperature limit

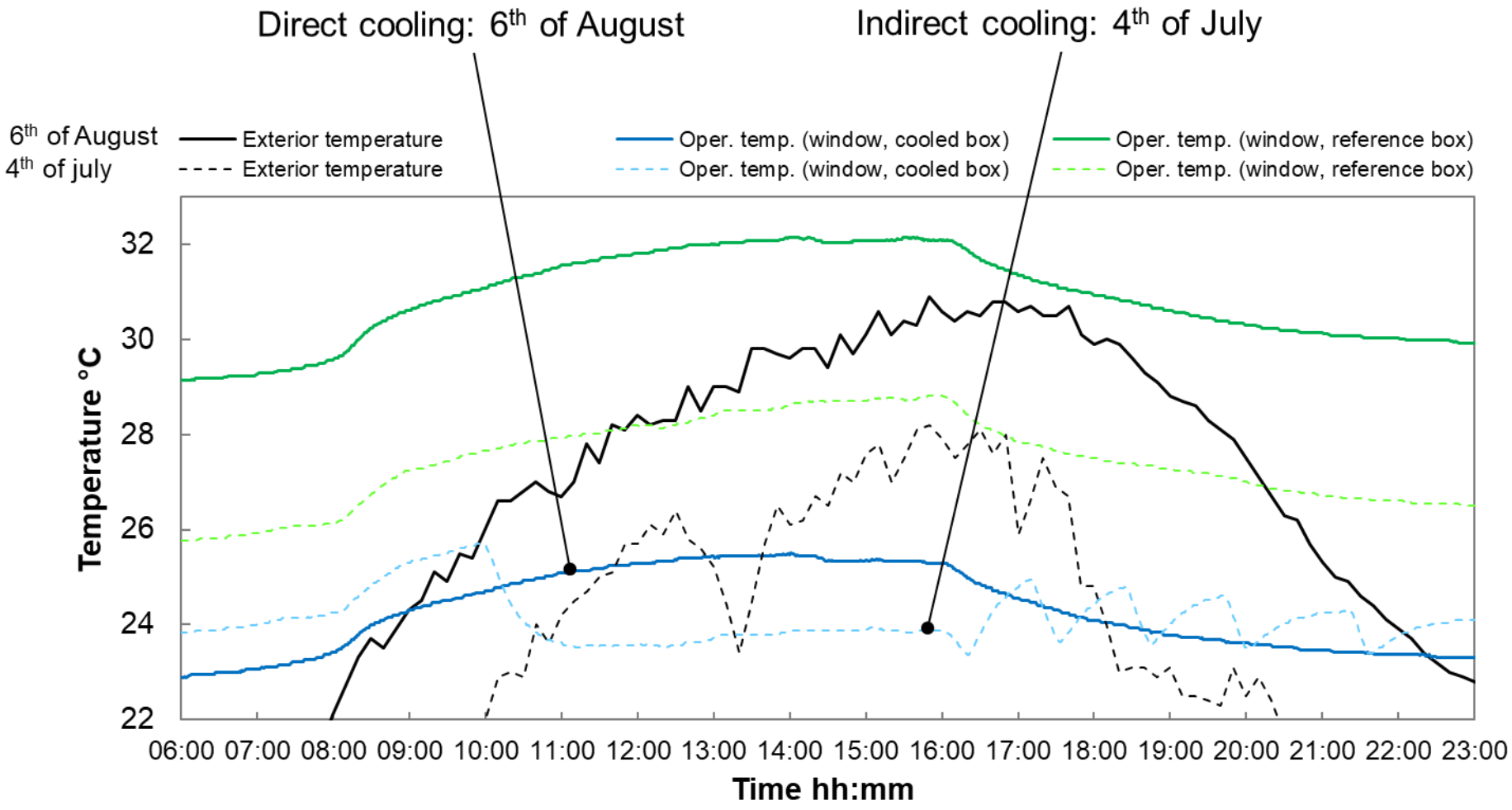
(2) 8:00 - 10:00
- Alternating mode (on/off mode) because batteries have not enough power

(3) 10:20 - 17:40
- Continuously in operation

(4) 17:40 - 18:20
- Alternating mode (on/off mode) because batteries have not enough power

(5) 18:20
- Batteries are discharged

Comparison between direct and indirect cooling



- Similar radiation
- Exterior temperature difference = 2.9 K
- Reference box temperature difference = 3.4 K
- Cooled box temperature difference = - 0.2 K

Conclusion

- Results from first field tests showed that the system works well in both heating and cooling mode, where the expected cooling power of 1 kW was achieved and partly exceeded.

- The results imply that the battery capacity and PV power is undersized for a continuous heating operation in winter times, as it was expected from the beginning.

- Furthermore, the results indicate that the indirect cooling seems to be more efficient as well as more comfortable than the direct cooling.

Outlook

- Optimization of the heat pump cycle, especially for heating (IWT)
- Numerical simulation of thermal comfort (q-punkt)
- Determination of the best configuration for the COOLSKIN system (in terms of efficiency and comfort) by analysing the measurement results from long term runs (IWT, AIT)
- Design of a façade integrate able version of the chosen cooling system configuration according to the building standards (SFL)

Thank you for your attention