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 of the research project COOLSKIN

Facade integrated cooling (heating) system

- Heat pump cycle
- Electric circuit

Outdoor test facility

First field test results

- PV system characteristic
- Heating characteristic
- Cooling characteristic
- Direct vs. indirect cooling

Conclusion and Outlook

Introduction of the research project COOLSKIN

The objective of the research project COOLSKIN (funded by the FFG) is the investigation of façade-integrated systems for space-cooling.

The solar irradiation onto the façade is converted directly or time-delayed to electrical energy in order to cool the adjacent room.

Energy supply is energetically autonomous and not dependent on energy from external sources.

The project is based on elaborated system simulations and experimental work with a functional model of the system as well as field tests under real operating conditions.

Introduction of the research project COOLSKIN

Project partner

- 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

Introduction of the research project COOLSKIN

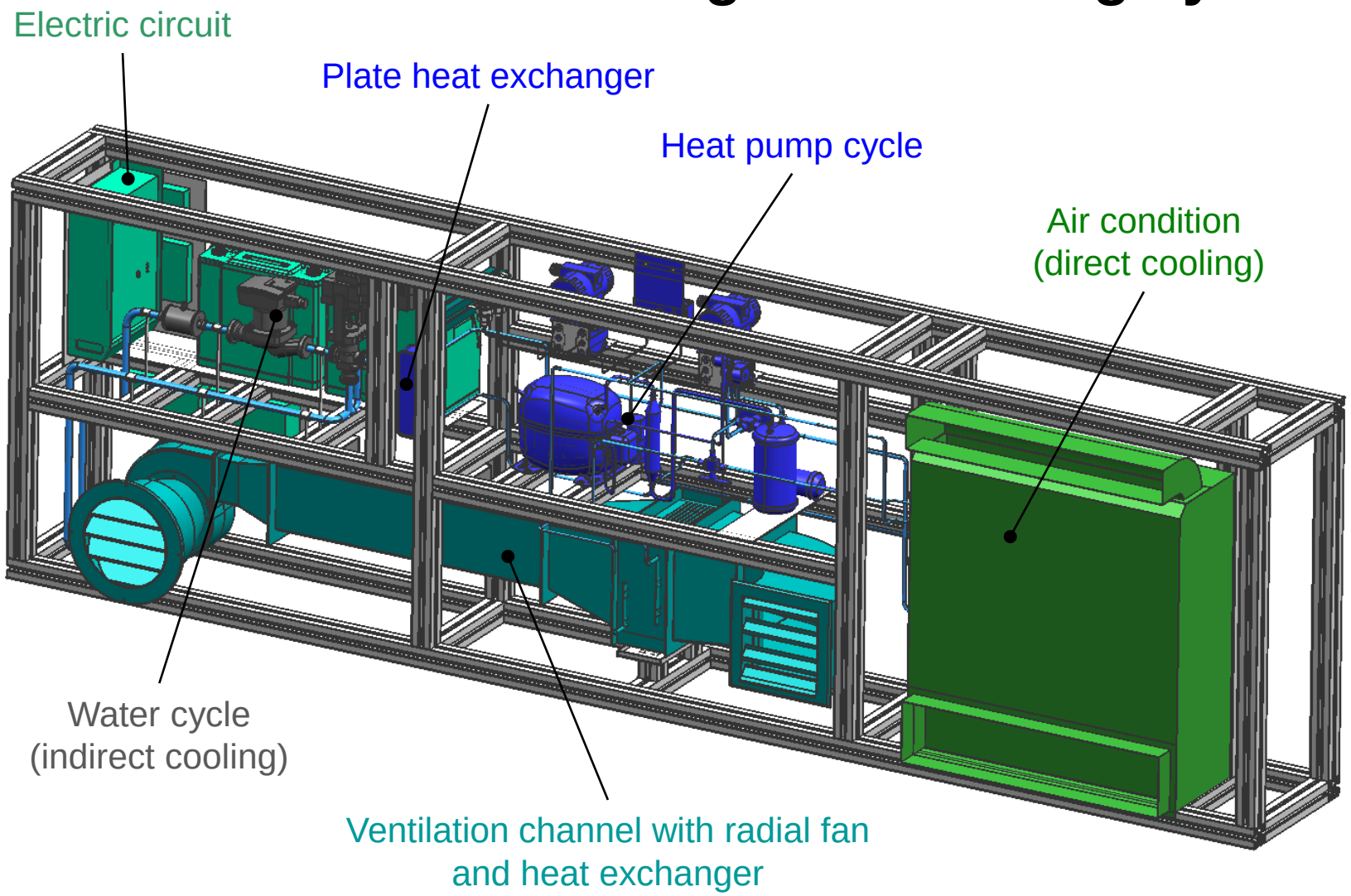
Project idea

- To cover the increasing cooling demand in buildings using regenerative energy sources
- To be independent from energy imports
- To avoid additional space requirement for energy conversion systems
- To ensure a good thermal comfort
- To ensure visual comfort due to architectural integration

The results provide

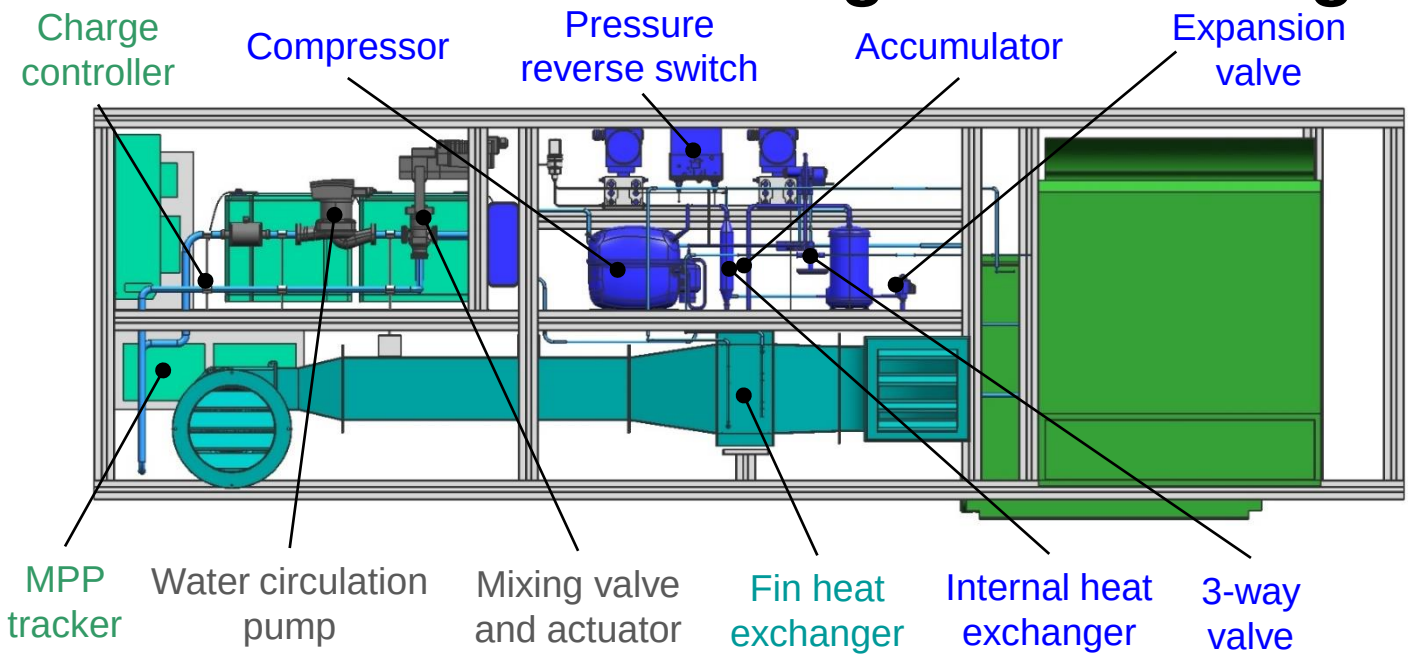
- Documentation and analysis for technical possible system configurations
- Experimental and numerical characterization of promising system configurations
- Adaptation of system configuration for façade integration (from the technical as well as the architectural point of view)

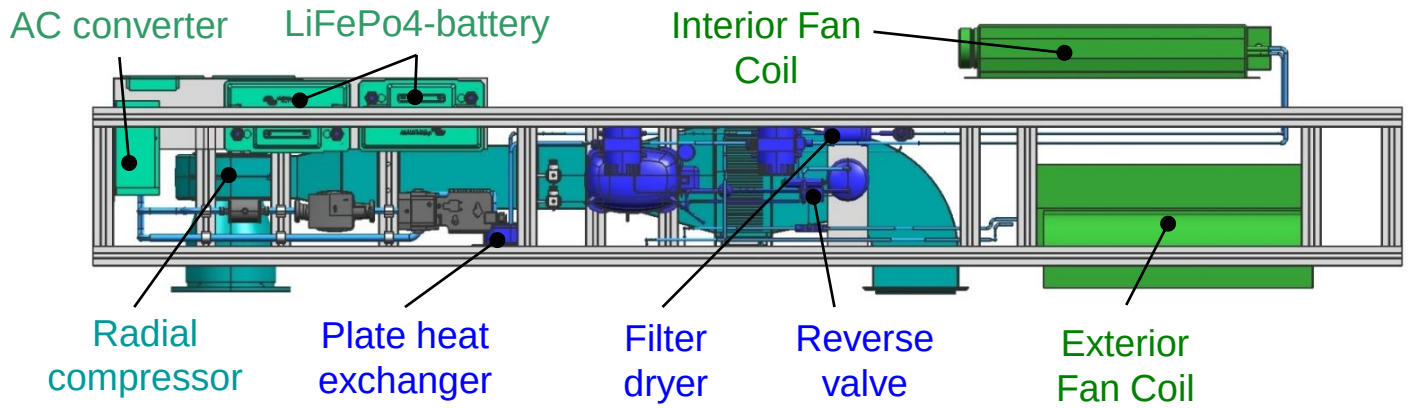
Facade integrated cooling system (Coolskin)



- Aluminium framework with main dimensions of 2.97 x 0.89 x 0.36m
- Five main units
- Heat pump cyle
  - R134A as refrigerant
  - Cooling capacity 1 - 2 kW
- Compressor
  - speed 2000 - 4500 min^{-1}
  - electricity consumption 200 - 450 W
- 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)
- Can also be used for heating

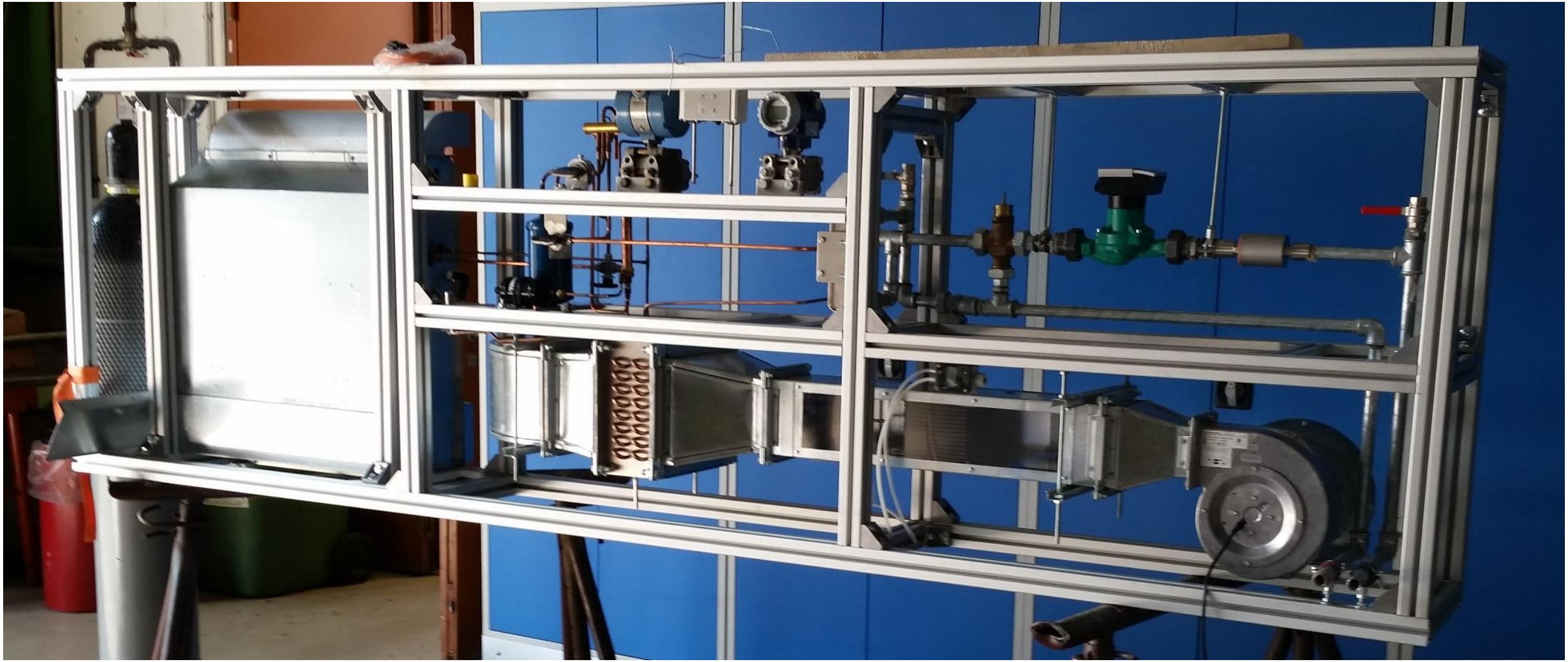
Facade integrated cooling system (Coolskin)



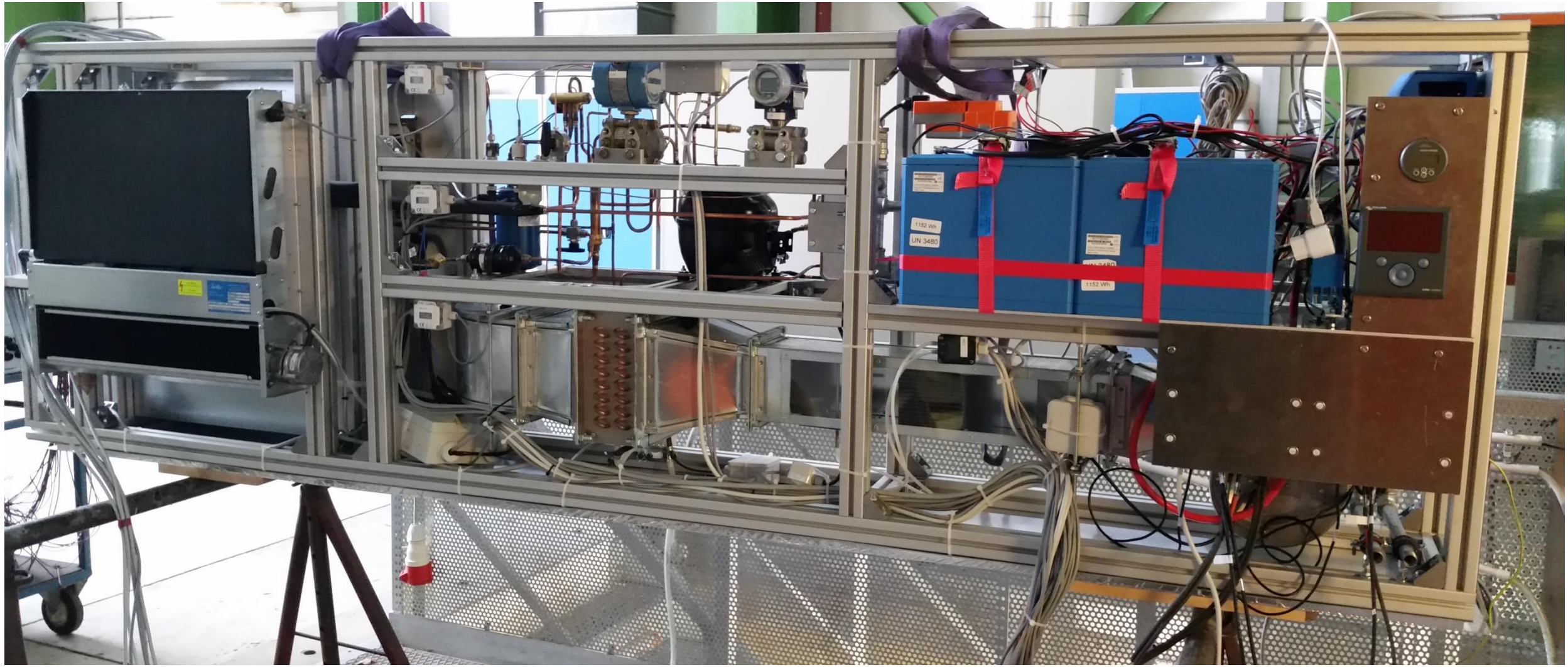


- Aluminium framework with main dimensions of 2.97 x 0.89 x 0.36m
- Five main units
- Heat pump cyle
  - R134A as refrigerant
  - Cooling capacity 1 - 2 kW
- Compressor
  - speed 2000 - 4500 min^{-1}
  - electricity consumption 200 - 450 W
- Direct cooling
  - Interior Fan coil with 0.35 - 1.28 kW cooling power
- Indirect cooling
  - Thermal activation of the concrete ceiling or floor (water cycle)
- Can also be used for heating

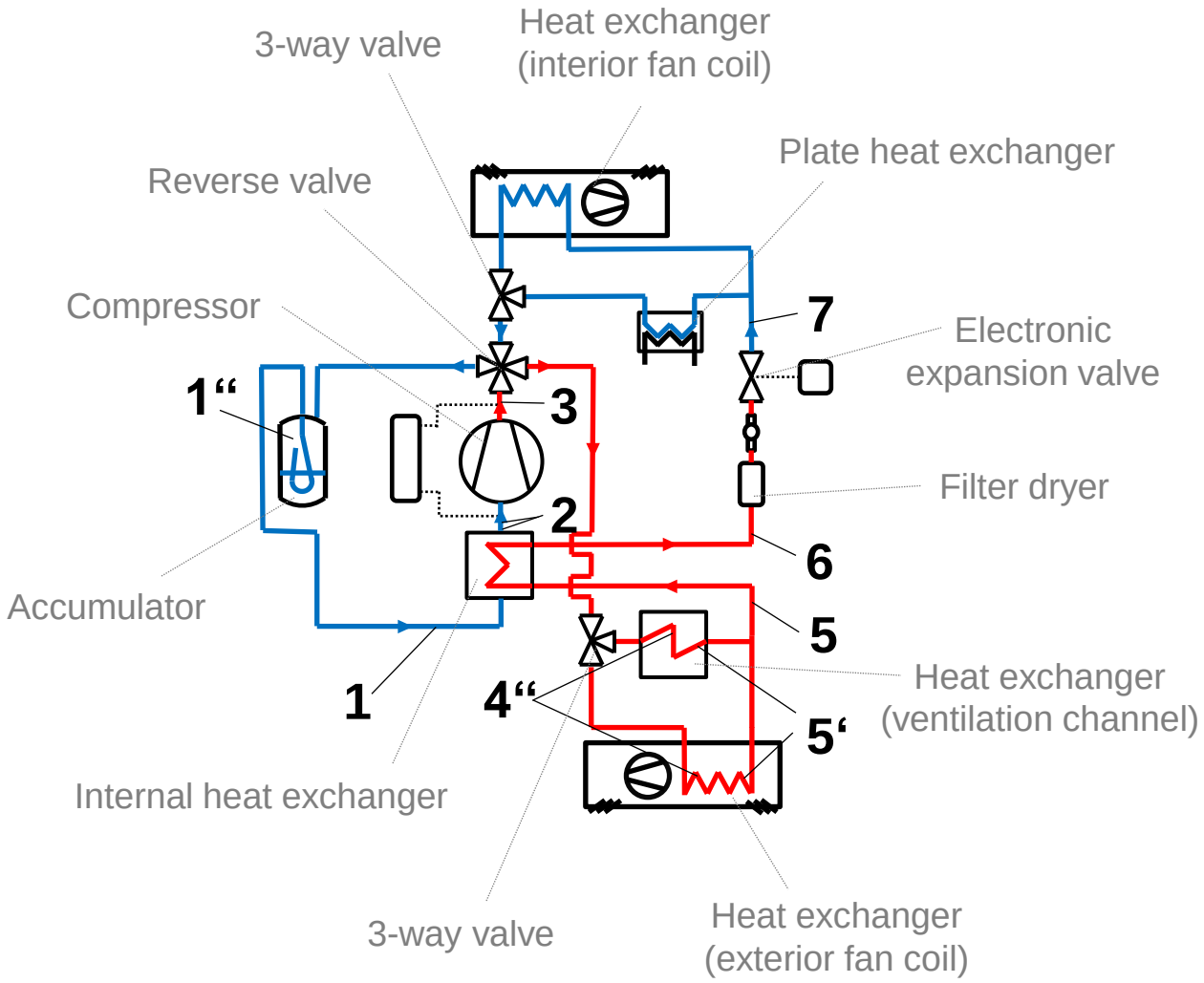
Facade integrated cooling system (fotos)

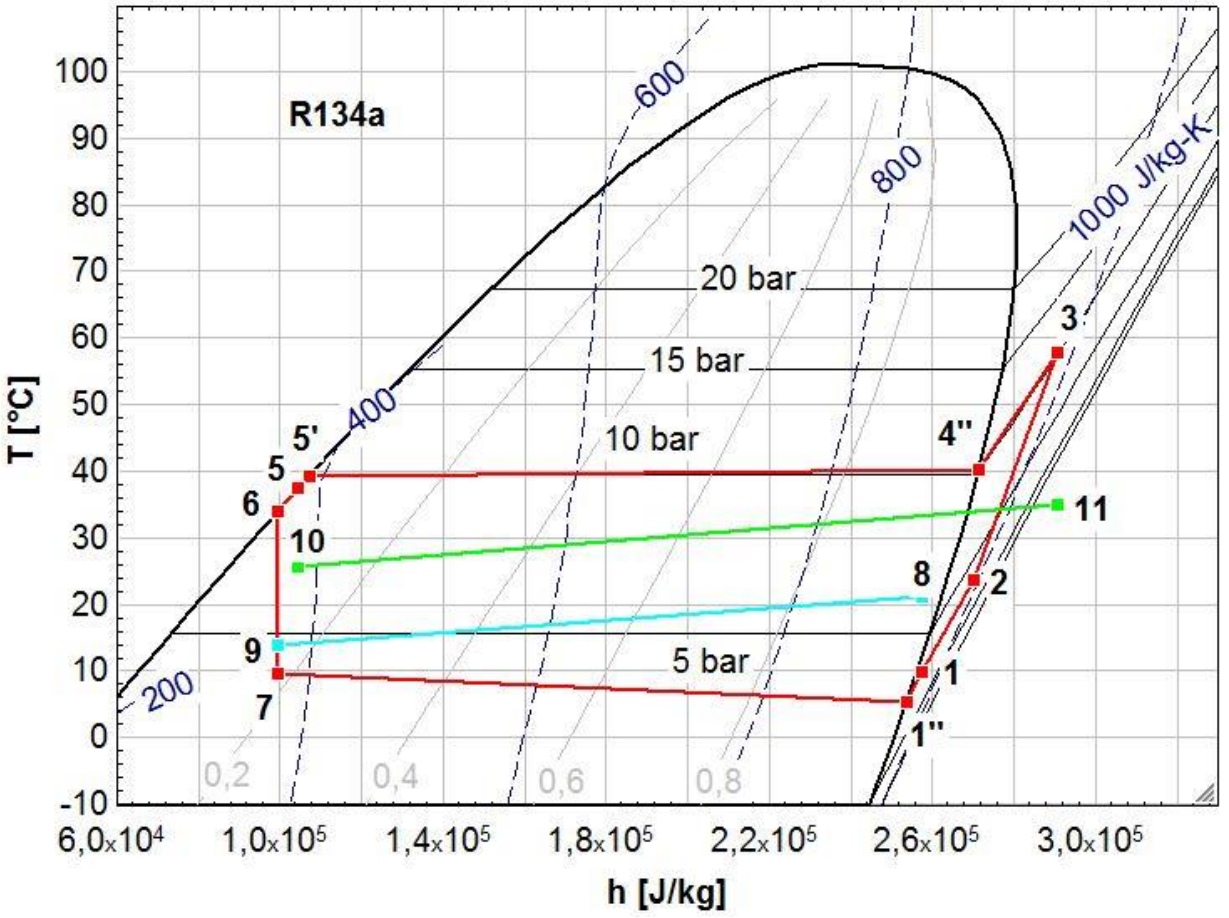


Facade integrated cooling system (fotos)



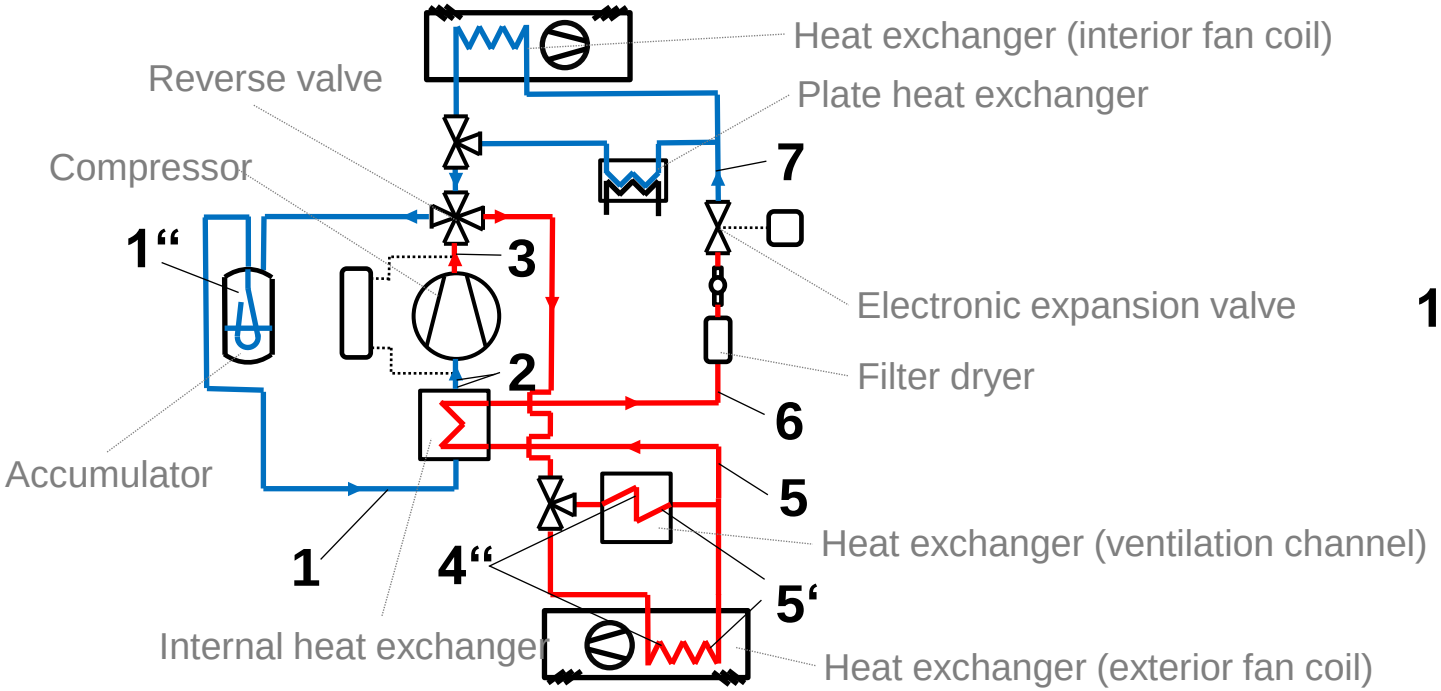
Heat pump cycle



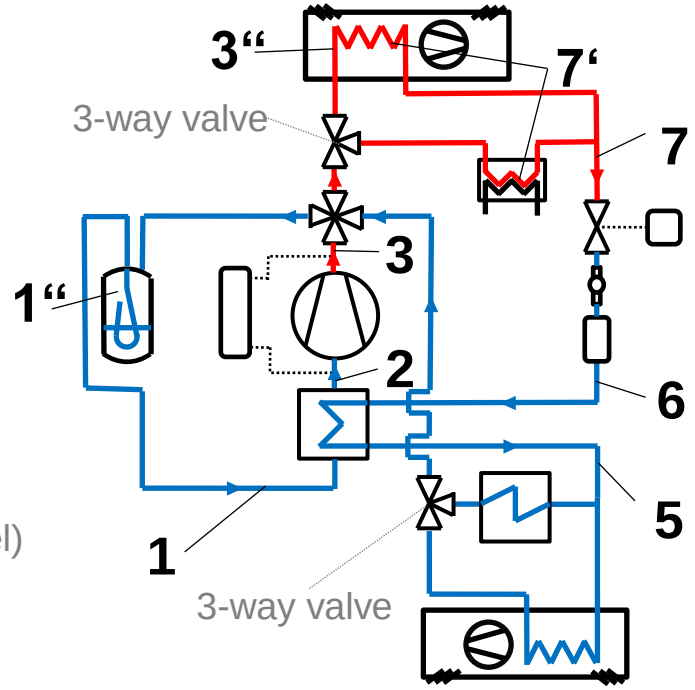


Heat pump cycle

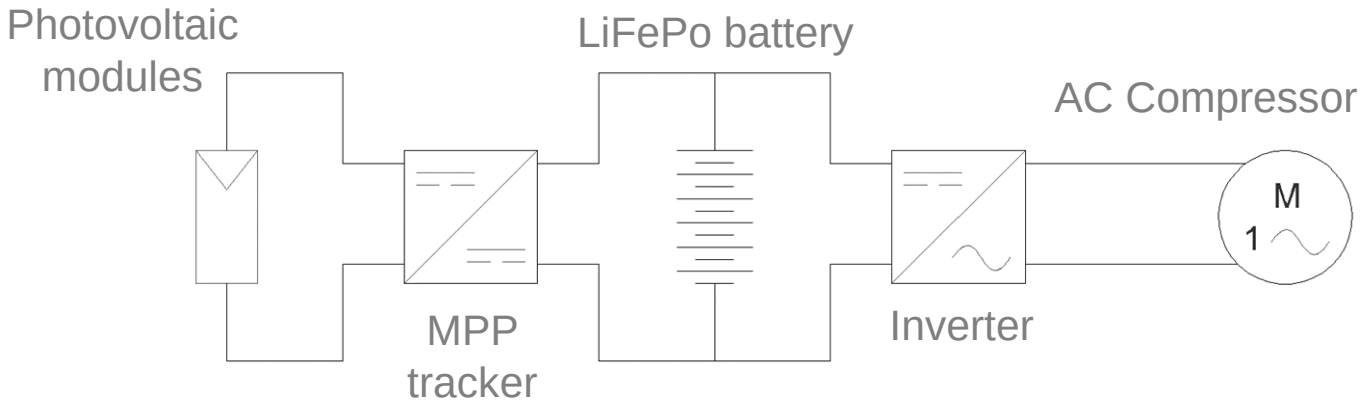
Cooling

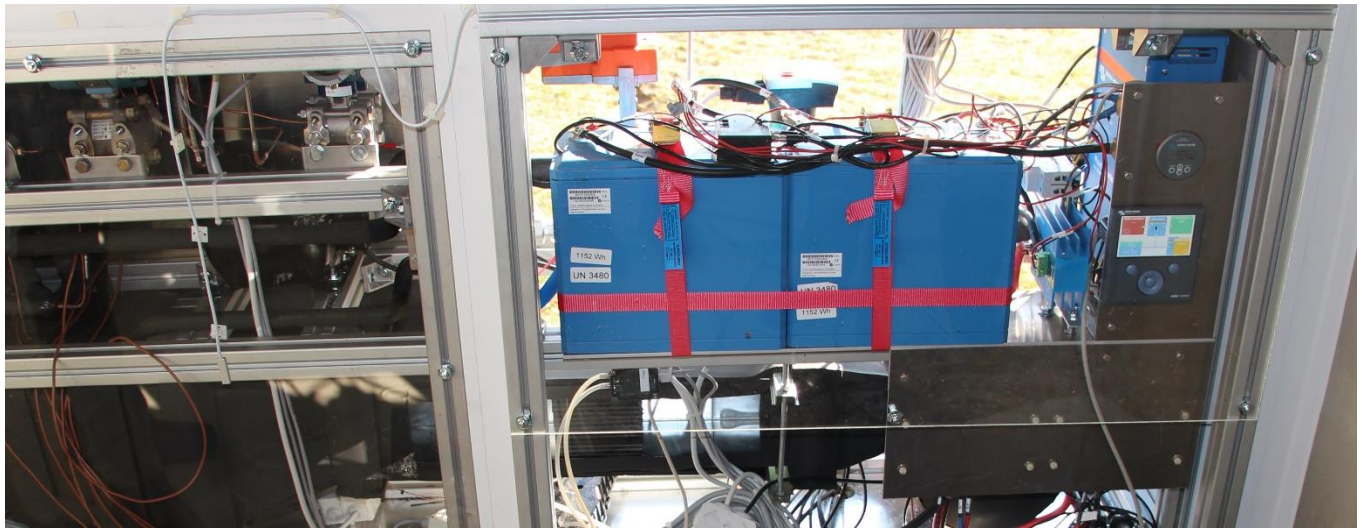


Heating



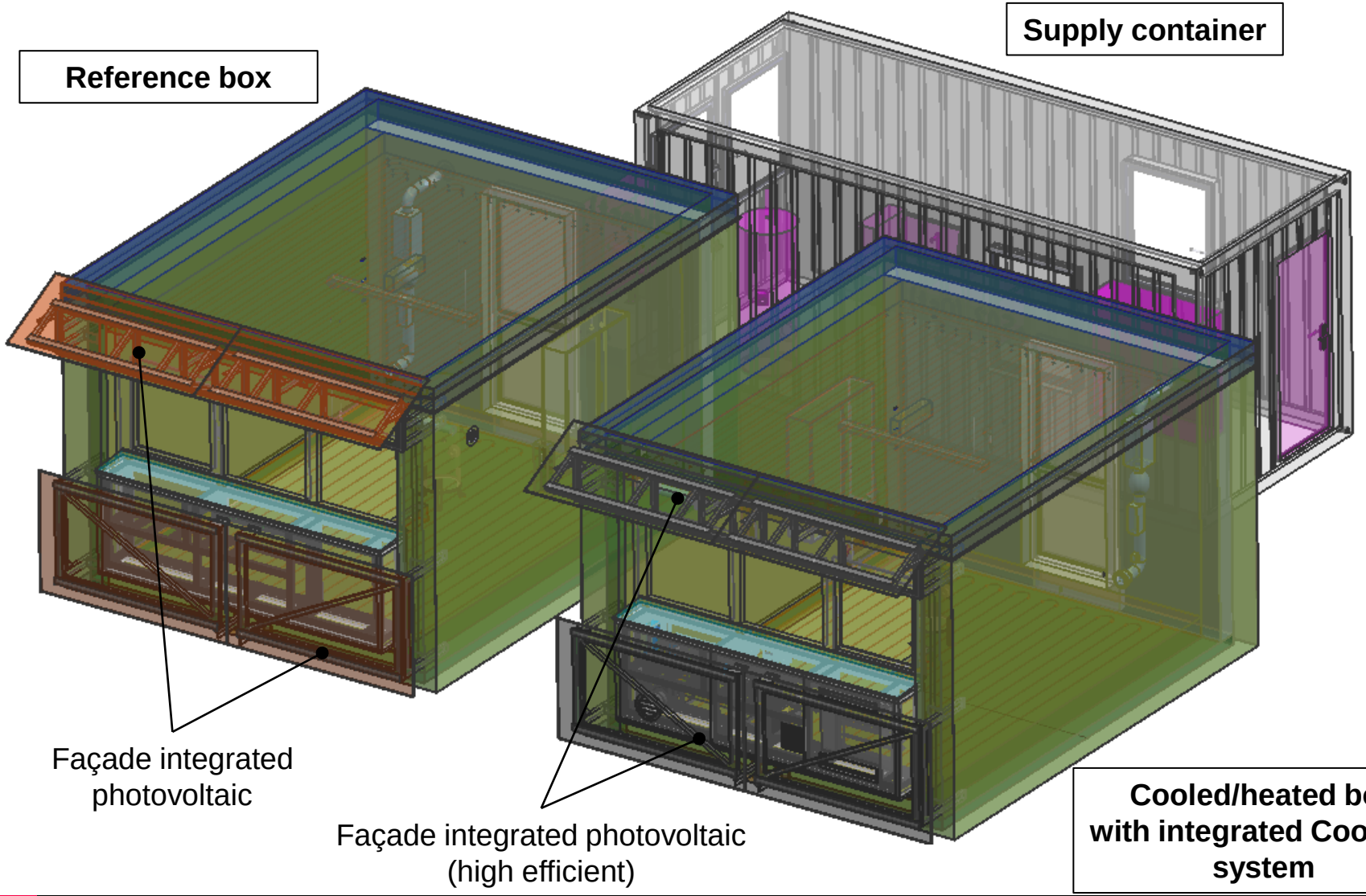
Electric circuit





- PV modules
  - High efficiency
  - 4.14 m² (facade integrated)
  - Nominal power of 1170 W
- Batteries (LiFePO4)
  - connected in series
  - capacity of 2300 Wh
- Inverter
  - 25.6 V DC -> 230 V and 50 Hz AC
  - Efficiency of 85% at peak load

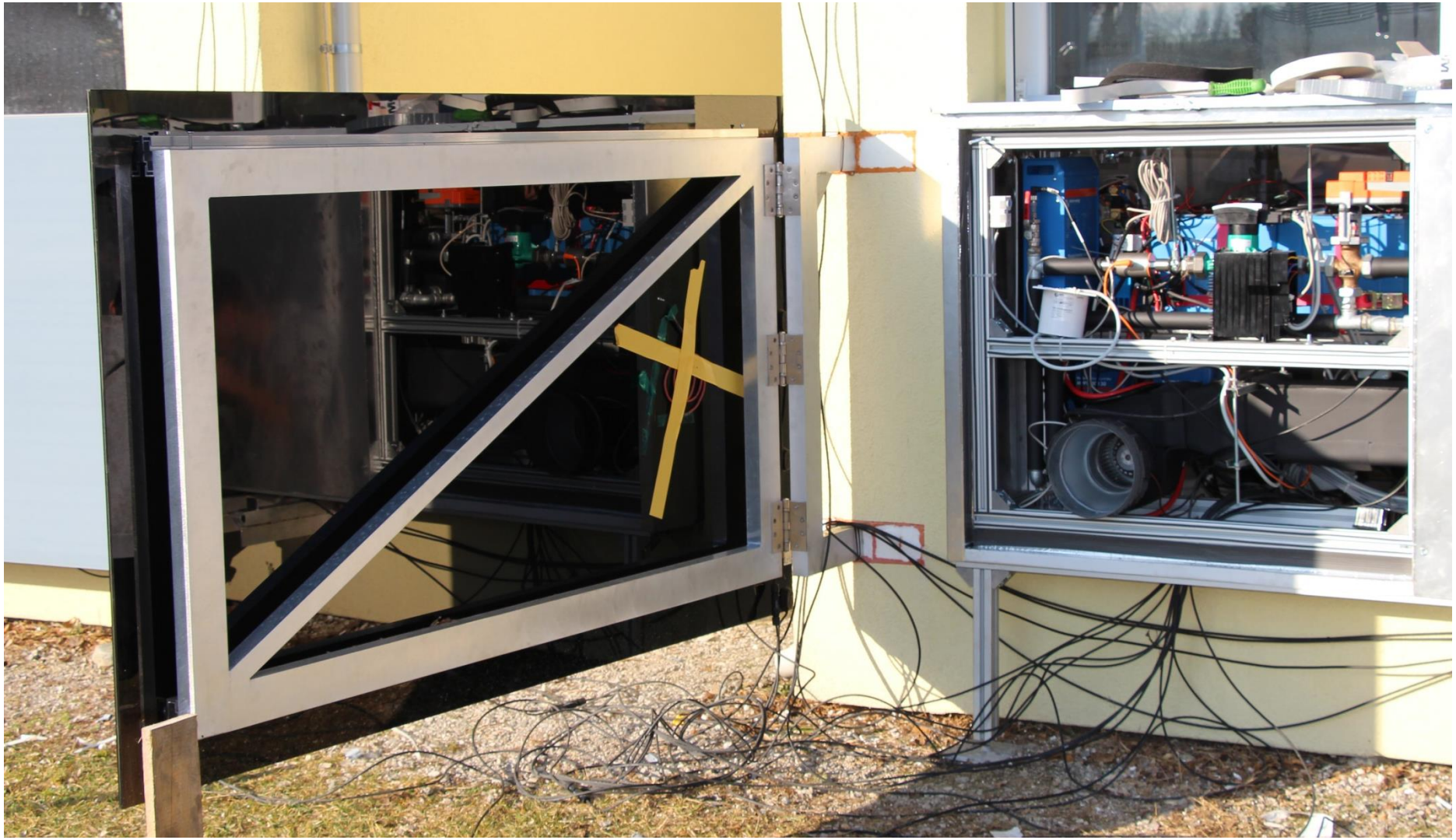
Outdoor test facility



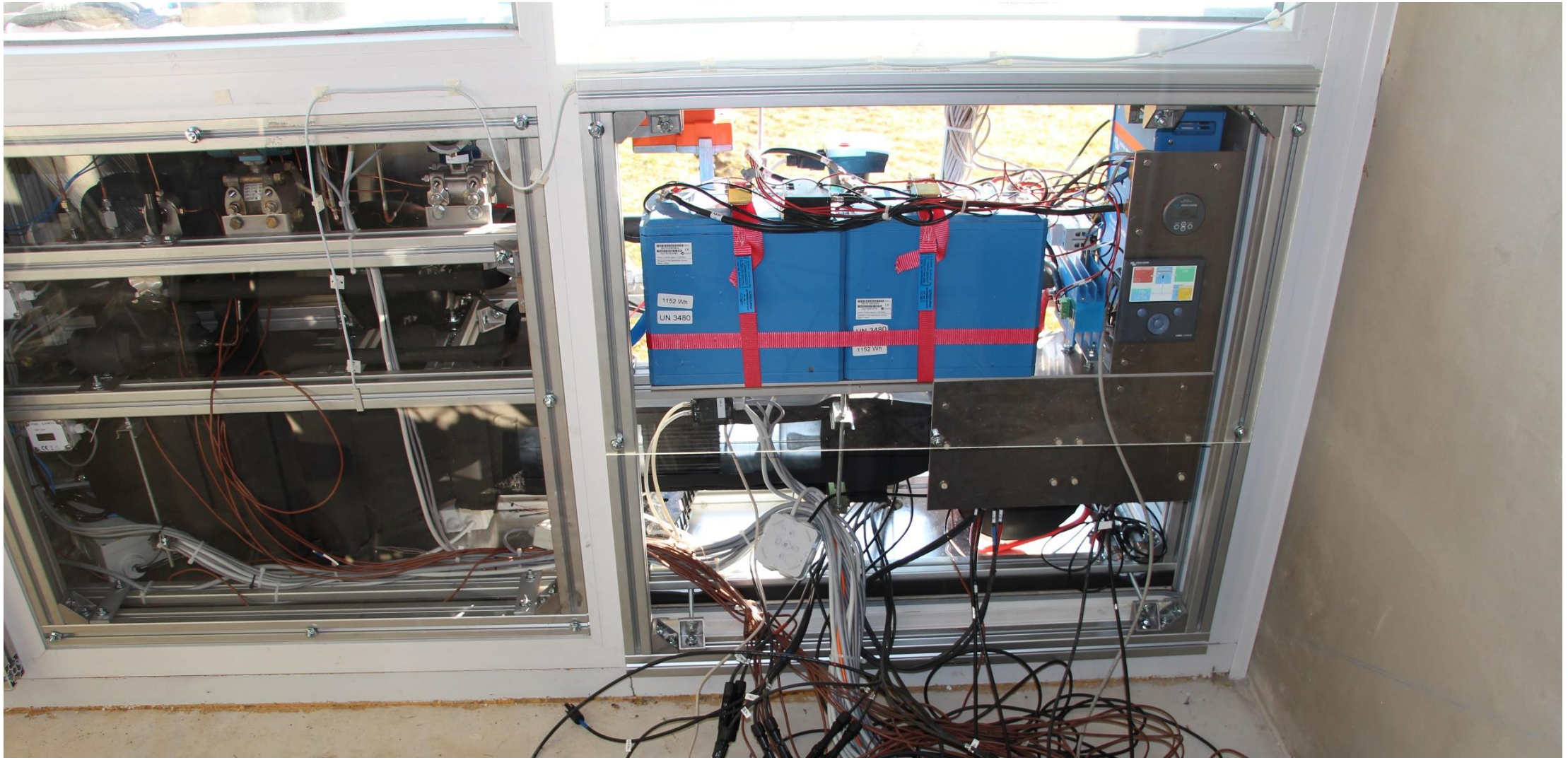
- Two equal boxes
  - 13.42 m² effective floor area
  - Internal thermal loads of 300 W over 8 hours per working day
  - Air exchange of 60 m³/h over the whole working period
- Facade integrated Coolskin
  - below the window
  - Behind the PV modules
- PV modules
  - Black coloured (high efficiency)
  - Grey coloured (78% power of black coloured)
- ZAMG climate station
  - Solar radiation
  - Exterior temperature
  - Pressure
  - Humity

Outdoor test facility (fotos)

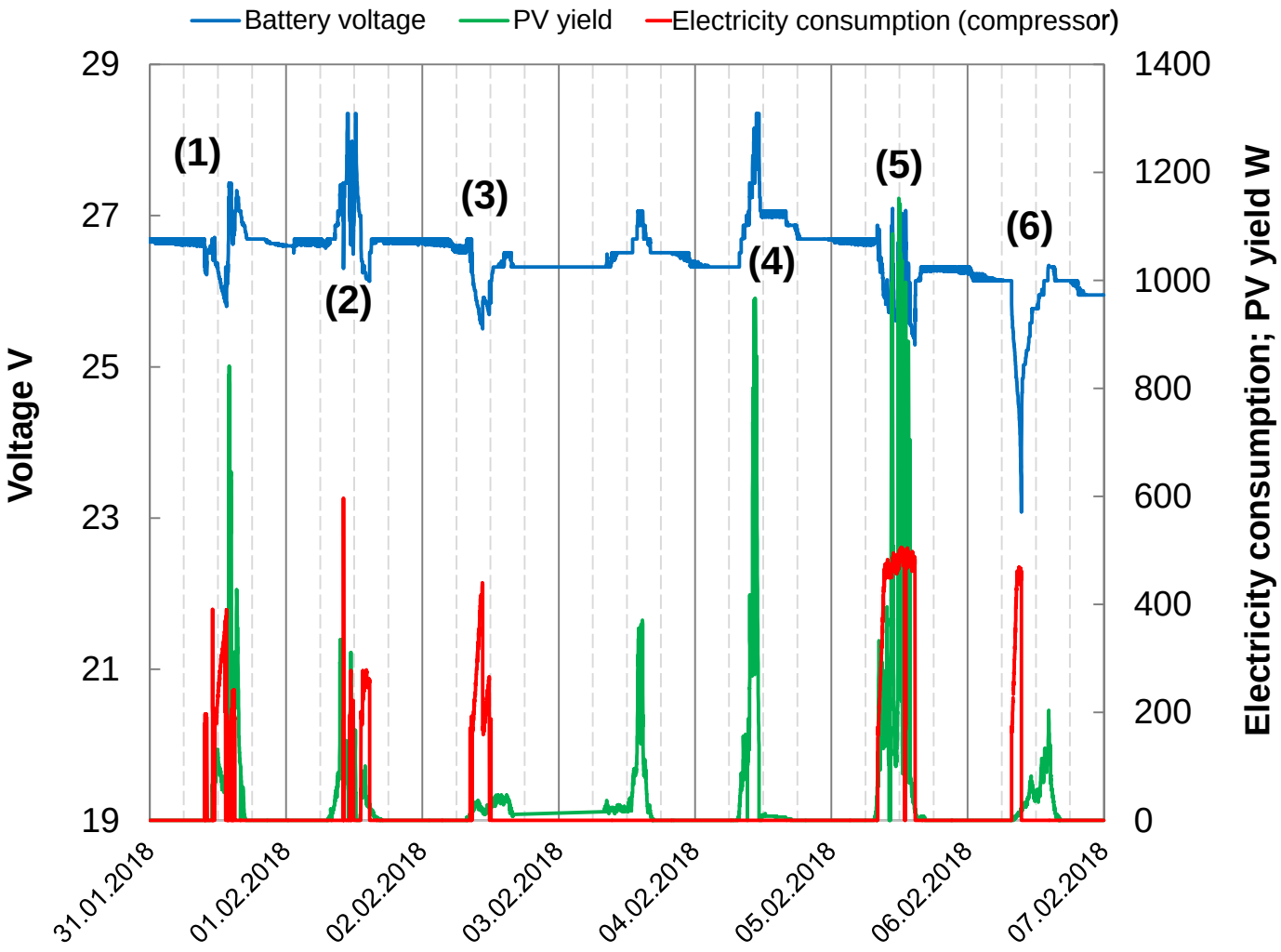
Outdoor test facility (fotos)



Outdoor test facility (fotos)



PV system characteristic



(1) Load is equal to the PV yield: Battery voltage is stable and load can be covered.

(2) Load is temporarily switched off: Battery is charged or discharged according to the PV yield.

(3) Low PV yield with load: Battery voltage decreases

(4) PV yield without load: Battery is fully charged

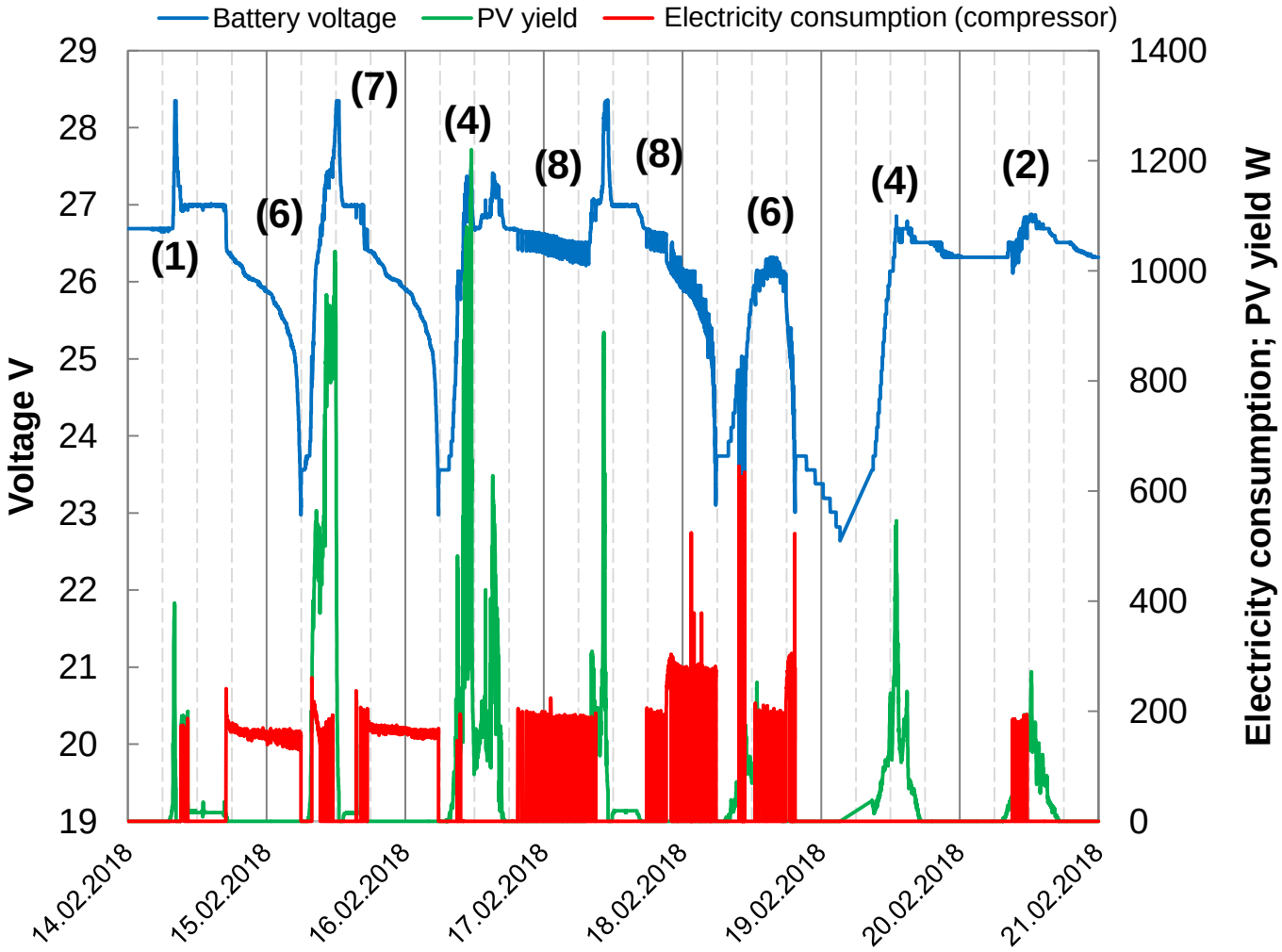
(5) High irradiation: Load is covered by the PV yield

(6) Low irradiation: Load is disconnected when the battery voltage decreases to the cut off voltage.

(7) PV yield higher than load: Battery is charged while the load is covered

(8) Fluctuating load: continuous operation in charging and discharging mode.

PV system characteristic



(1) Load is equal to the PV yield: Battery voltage is stable and load can be covered.

(2) Load is temporarily switched off: Battery is charged or discharged according to the PV yield.

(3) Low PV yield with load: Battery voltage decreases

(4) PV yield without load: Battery is fully charged

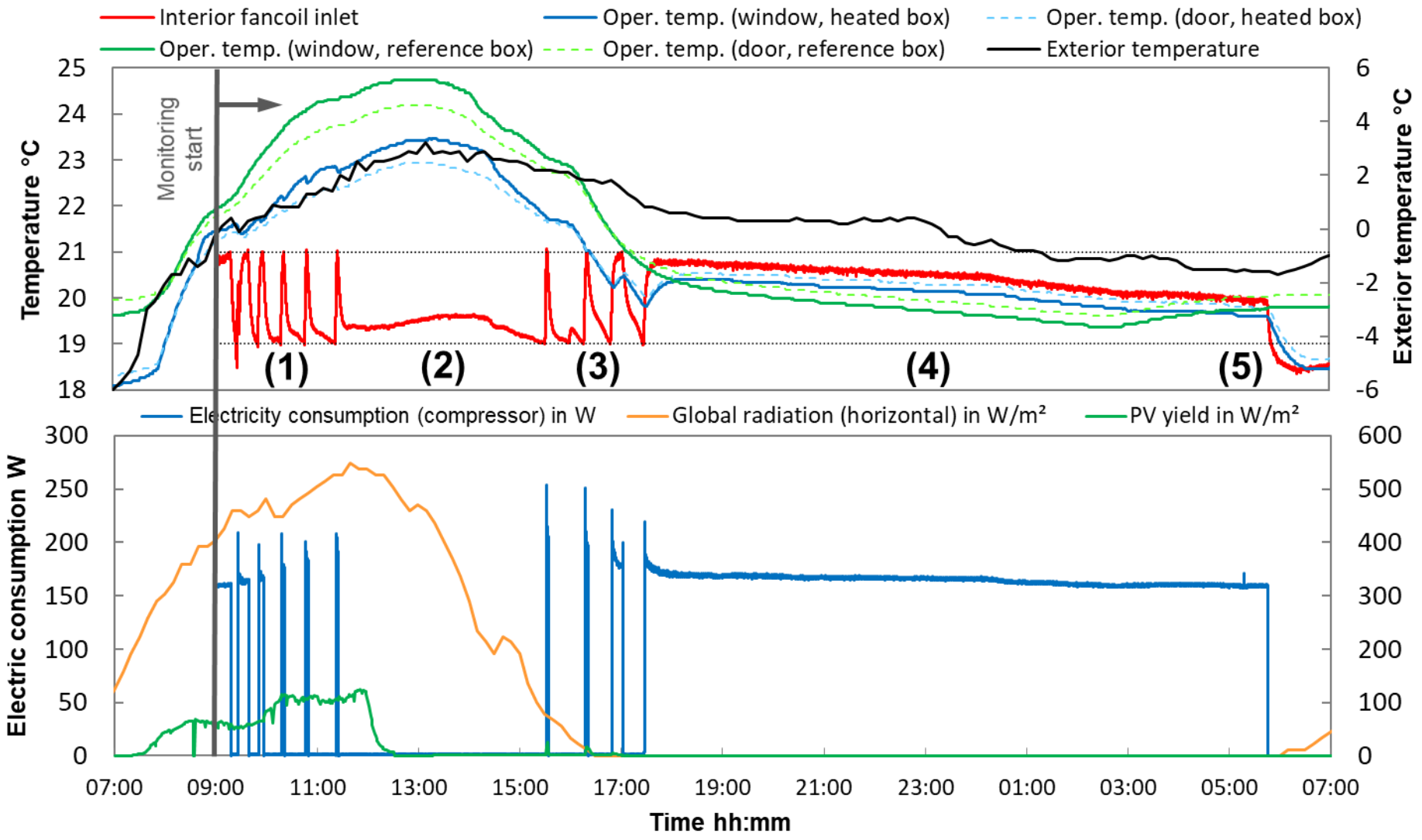
(5) High irradiation: Load is covered by the PV yield

(6) Low irradiation: Load is disconnected when the battery voltage decreases to the cut off voltage.

(7) PV yield higher than load: Battery is charged while the load is covered

(8) Fluctuating load: continuous operation in charging and discharging mode.

Heating characteristic



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

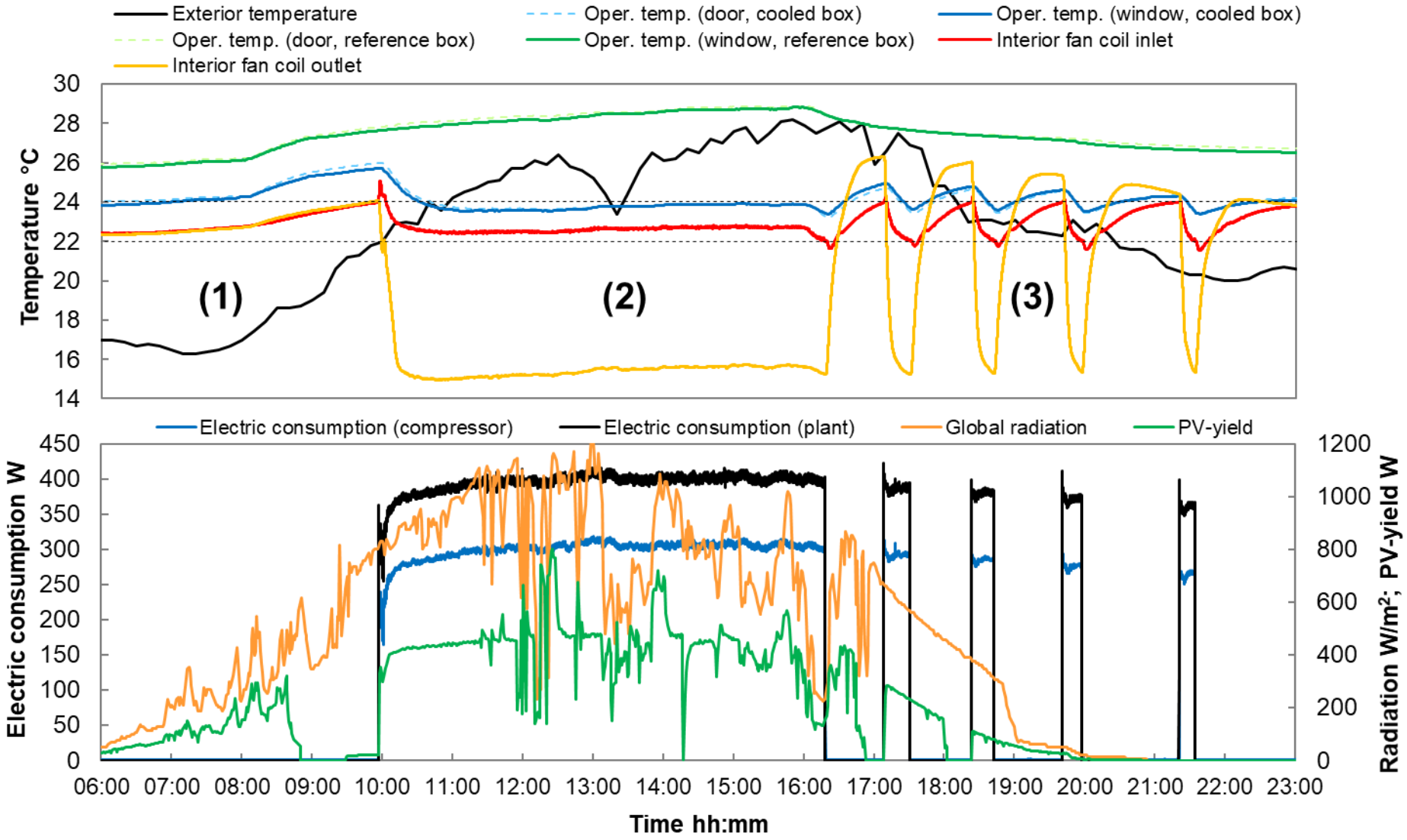
(2) 11:30 - 15:30
- inactive

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

(4) 17:30 - 5:00
- Continous mode

(5) 5:30
- Battery was discharged

Cooling characteristic for indirect cooling



(1) 6:00 - 10:30

- Turned off because room temperature is below the upper temperature limit

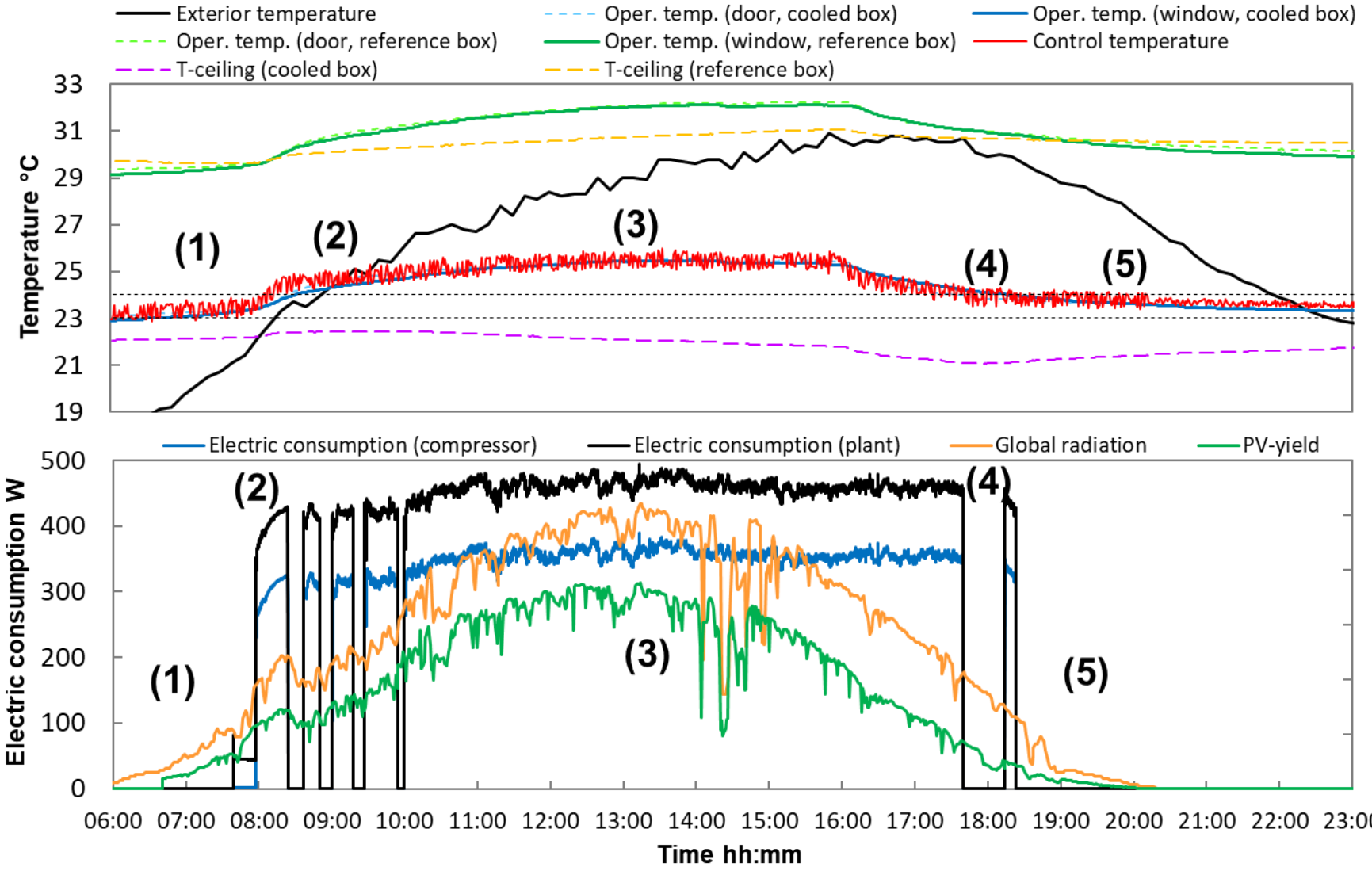
(2) 10:30 - 16:20

- Continous mode

(3) 16:20 - 22:00

- Alternating characteristic (on/off mode)

Cooling characteristic for direct cooling



(1) 6:00 - 8:00

- Turned off because room temperature is below the upper temperature limit

(2) 8:00 - 10:00

- Alternating characteristic (on/off mode) because batteries have not enough power

(3) 10:20 - 17:40

- Continous mode

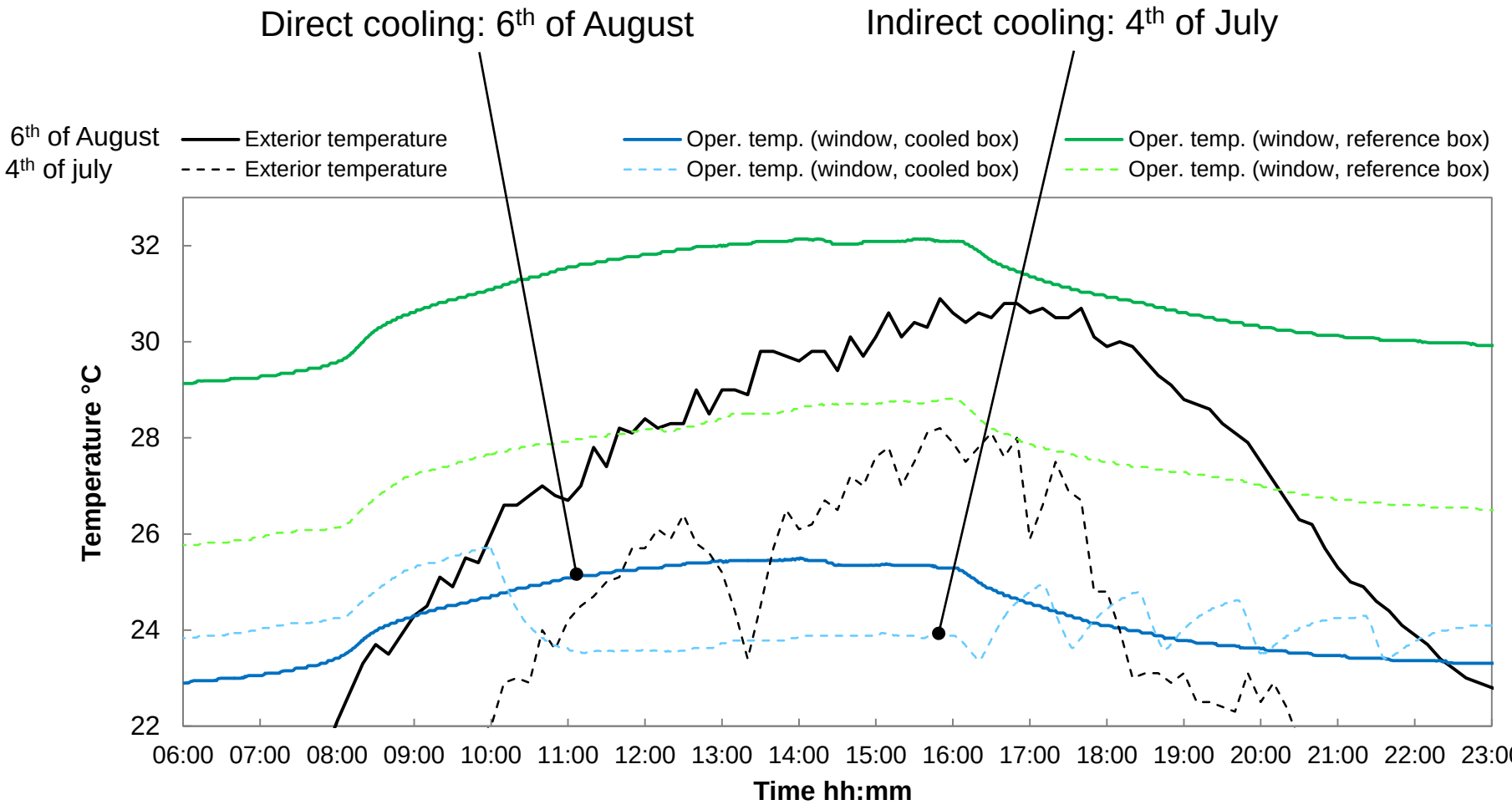
(4) 17:40 - 18:20

- Alternating characteristic (on/off mode) because batteries have not enough power

(5) 18:20

- Batteries are discharged again

Comparison between direct and indirect cooling



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

Conclusion

A facade-integrated heating and cooling system called “COOLSKIN” was developed, built and successfully put into operation at the campus of Graz University of technology

The expected power of 1 kW was achieved and partly exceeded

First 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

The results from field tests indiacte that the indierect 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)

Adaptation of the system for prototyping (IWT, AIT)

Design possible systems which are conform with the OIB standards (SFL)


Thank you for your attention