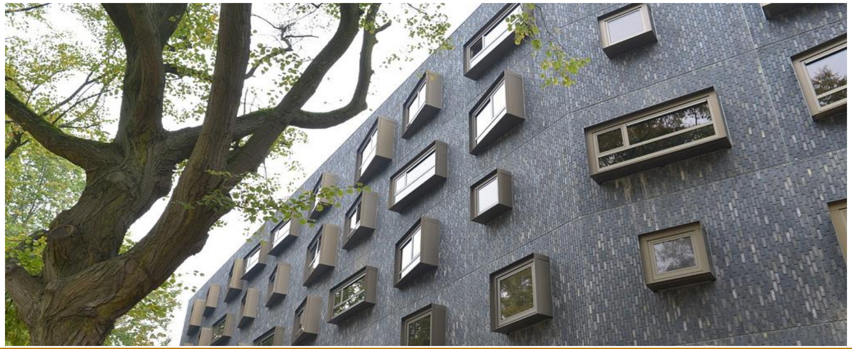
Atic for HVAC professionals

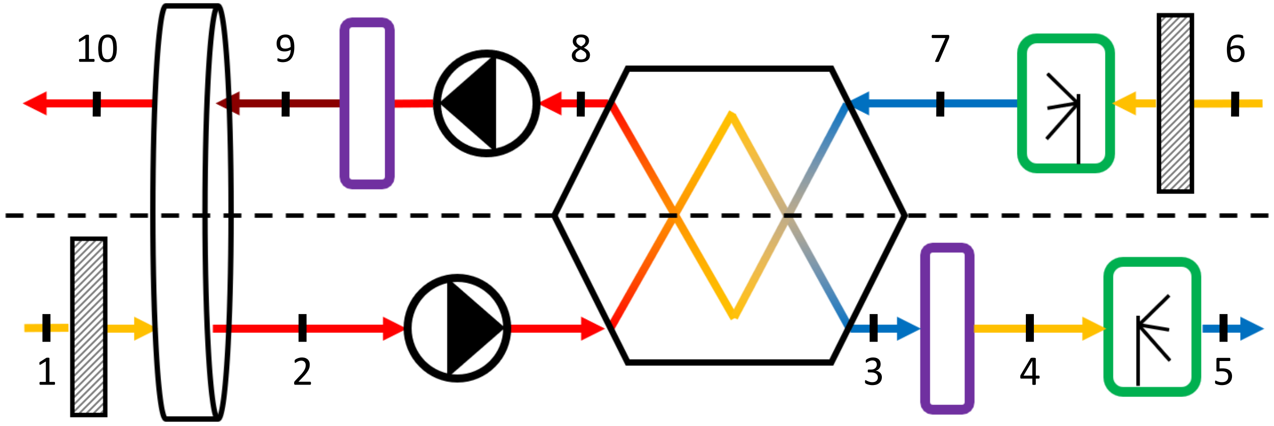
VUB



16-11-2023 – 12H15 – 19H – VUB BRUSSELS

CASE STUDY OF A DESICCANT EVAPORATIVE COOLING SYSTEM IN DENMARK

ZEOLI Alanis, JOHRA Hicham, GENDEBIEN Samuel, LEMORT Vincent



LIÈGE université

Presentation Outline

- Introduction to the IDCS Project
- Description of the Case Study
- System Monitoring and Operation
- Performance Analysis

The IDCS project

Instant District Cooling System (IDCS) project:

- Minimal heating demand in summer : the district heating network (DHN) is almost not used
- De-electrification of the cooling load
- Coupling of the cooling production and the waste heat management
- Connection to DHN to reduce the load on electrical network
- Optimization of the existing DHN
- Enhancement of the heat market

Figure 1 – Principle of a DHN.

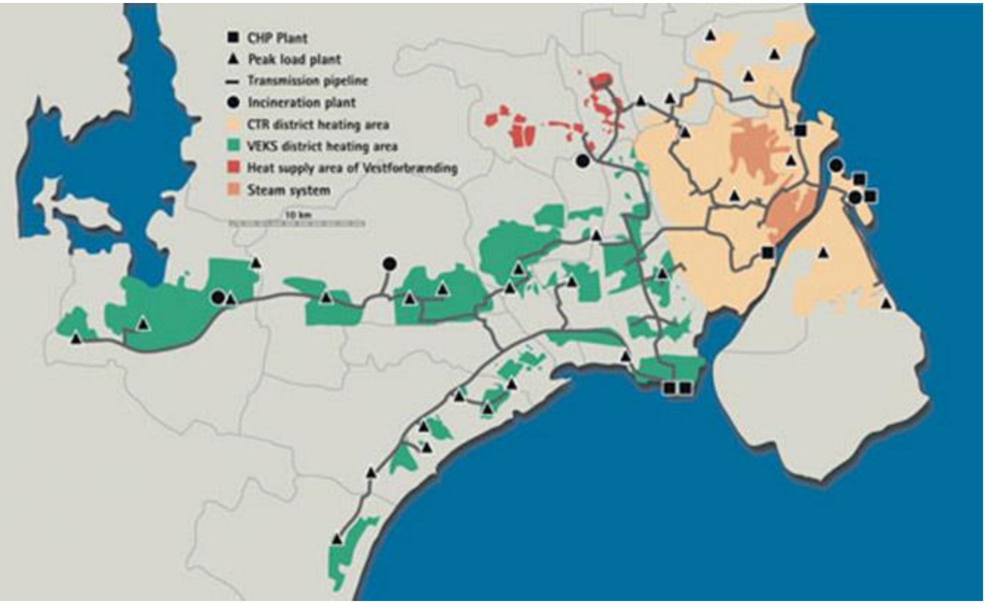


Figure 2 – DHN in Denmark.

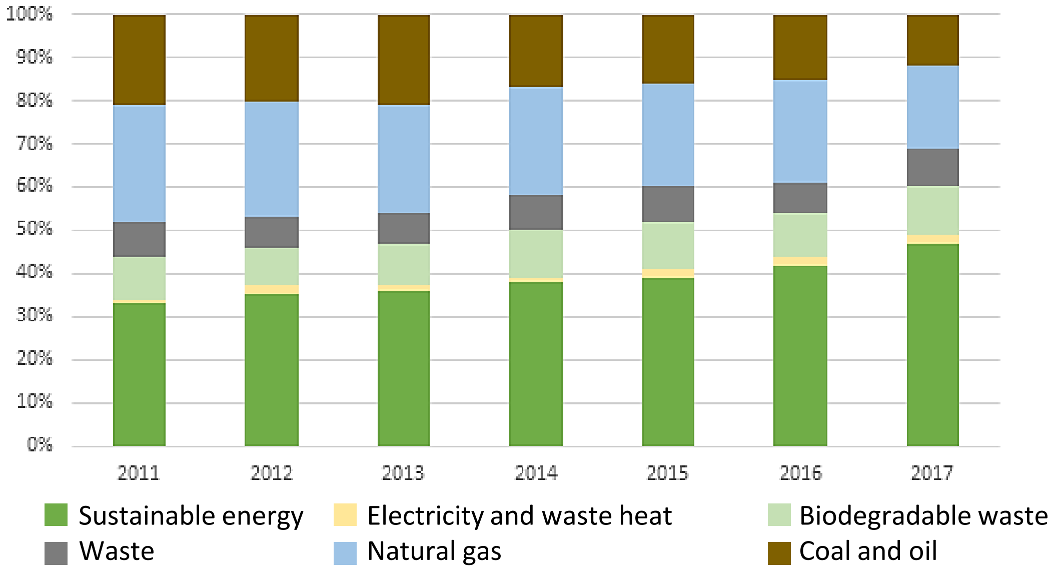


Figure 3 – Heat sources of the DHN.
source: *Danish District Heating Association*.

The IDCS project

First prototype of the IDCS project:

- Performance evaluation of an AHU in a large building
- Connection with the district heating network
- University building suffering from overheating in summer

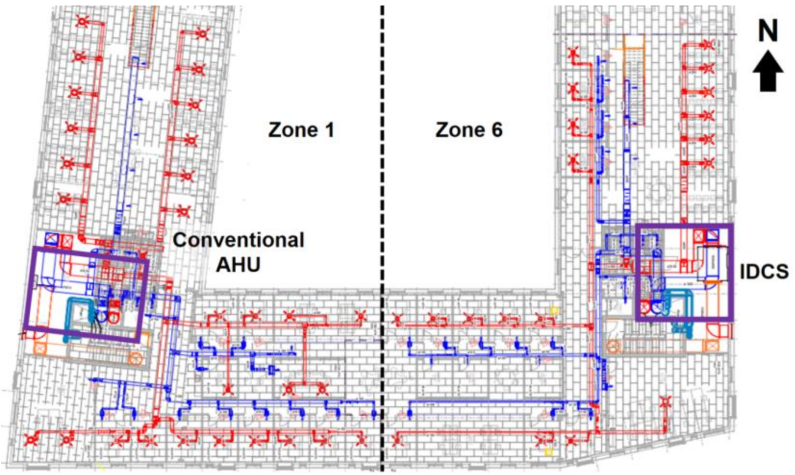
Zone 6
Test zone with new AHU installed

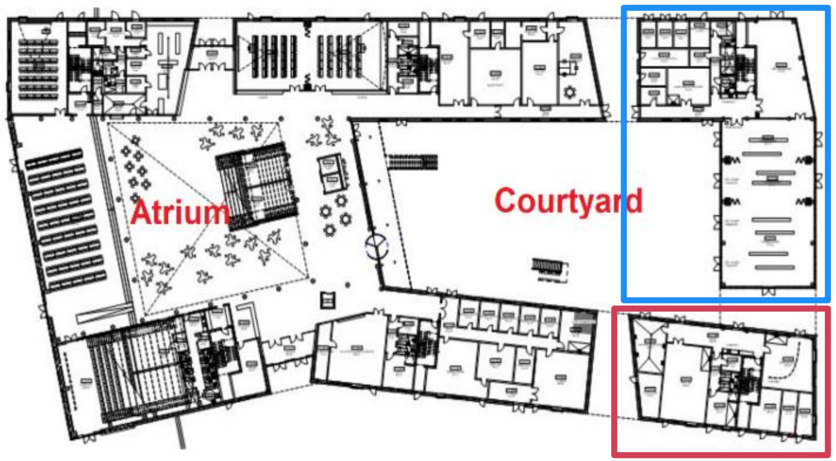
Zone 1
Reference zone with conventional ventilation system

Atic
for HVAC professionals

Description of the building test case

Building regulation energy class	
• Maximum infiltration rate	1.5 L/s.m²
• Maximum losses through building envelope	7 W/m²
• Maximum total primary energy demand	71.4 kWh/year.m²
Construction	
• Year of construction	2014
• Number of floors	5
• Ground surface area of the building	5 036 m²
Building operation	
• Maximum occupancy	4 450
• Ventilation requirements	~ 3 m³/h.m²





Atic
for HVAC professionals

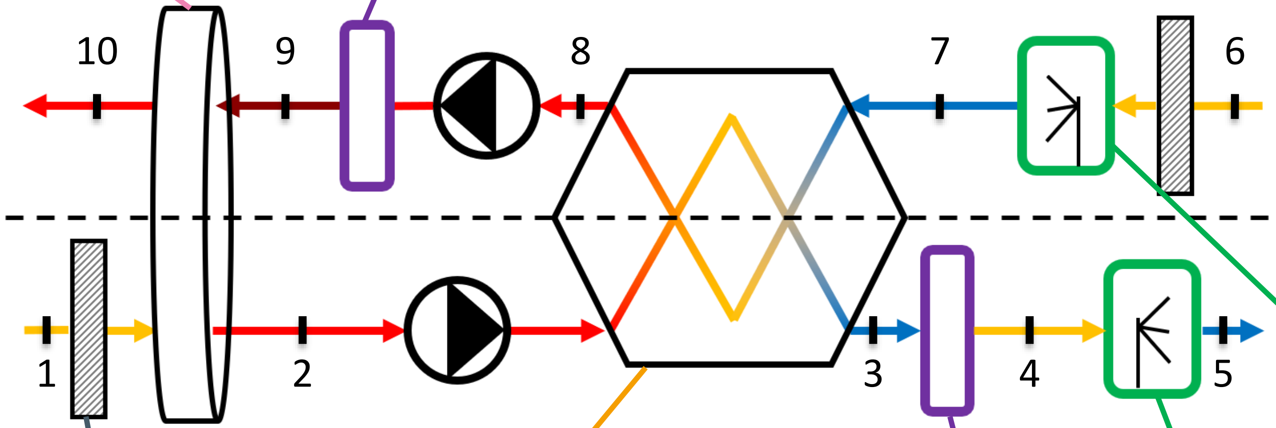
Desiccant Evaporative Cooling System – DECS

DW

- Dehumidification of primary air
- Regeneration energy required

Regenerator

- Increase temperature of secondary air before entering the wheel to ensure regeneration
- Heat source: district heating



Air filter

HEX

- Sensible air-air heat exchanger

Additional HEX for winter operation

(not used in cooling mode)

DEC
(Direct Evaporative Cooler)

Direct humidification of air

- Before entering HEX
- Before room supply

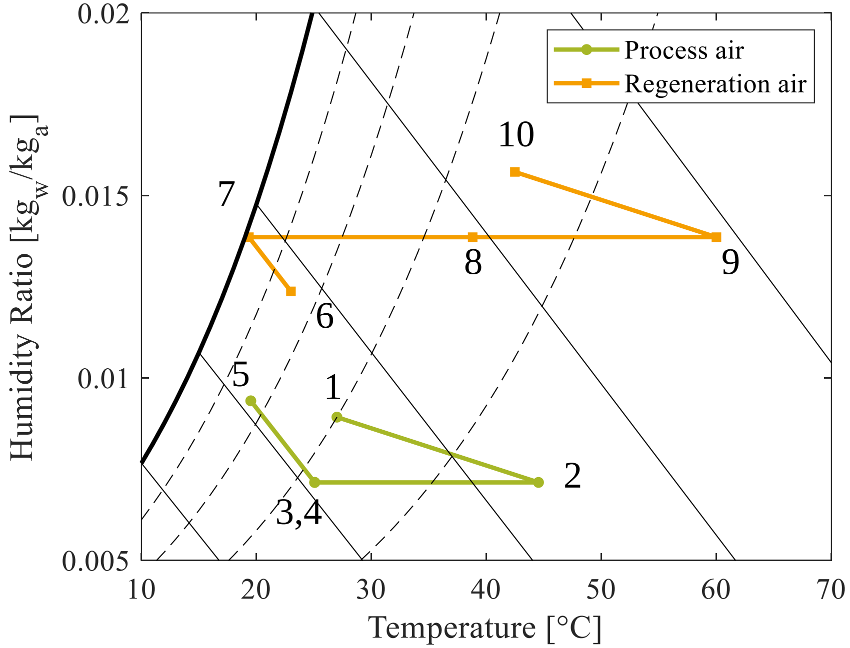
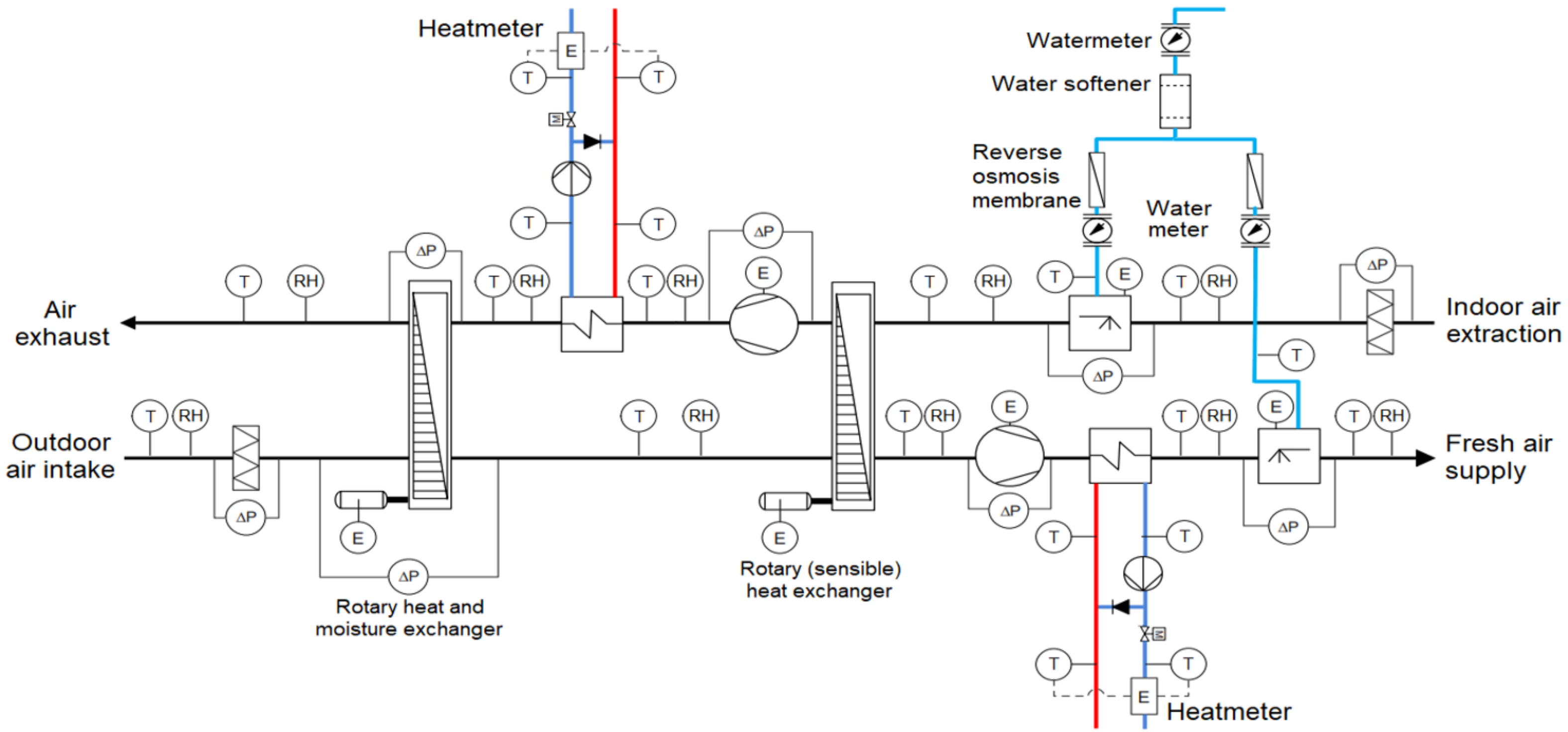


Figure 4 – Representation of the process in the psychrometric chart.

Atic for HVAC professionals

System Monitoring

- Installation with complete instrumentation and constant monitoring
- Data collection for **summer** 2021, 2022 and 2023 (May – September)
- Recording every 30 seconds
- Data for temperature, humidity and system consumption: electricity, heat and water.



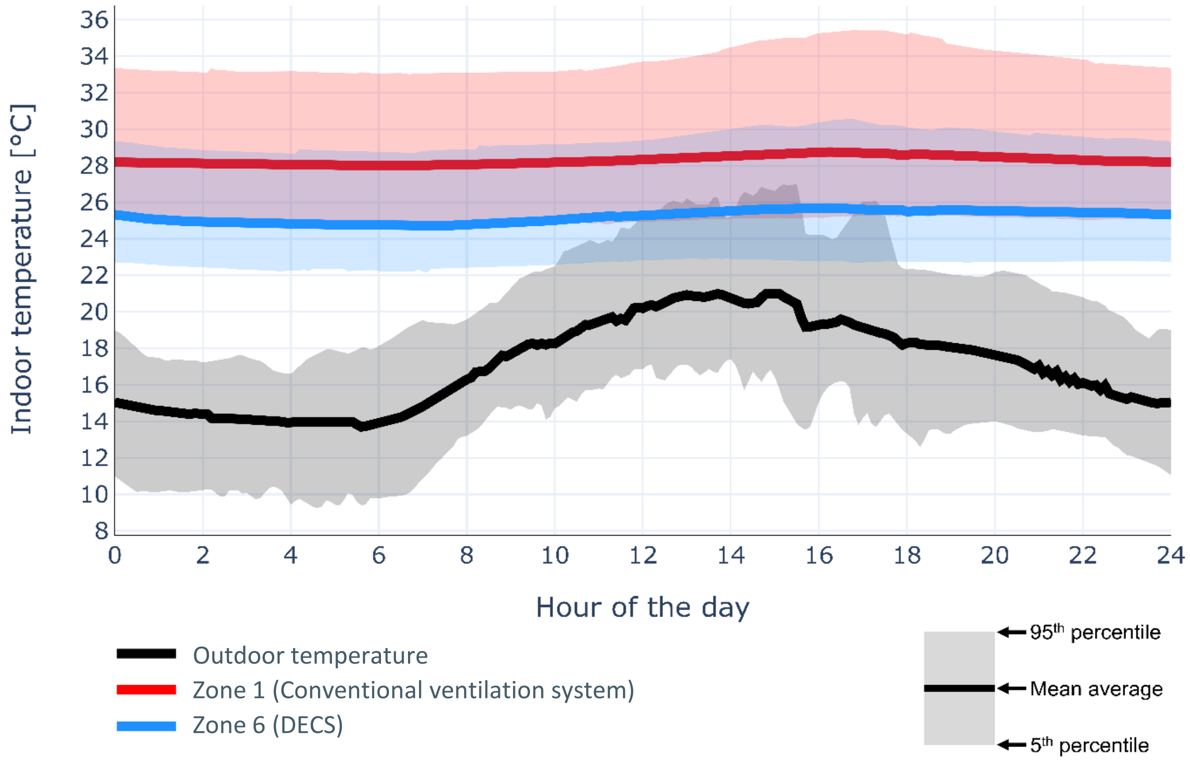
Average daily indoor temperature over a warm period

Comparison of the daily indoor temperature in two zones of the same building:

- Zone 1 has a conventional ventilation system
- Zone 6 is equipped with DECS

Analysis of the daily temperature over a warm summer period (20th July – 3rd August 2021):

- High overheating risk in non ventilated zone due to high insulation level and South exposition
- Average temperature reduced by more that 2 K with DECS

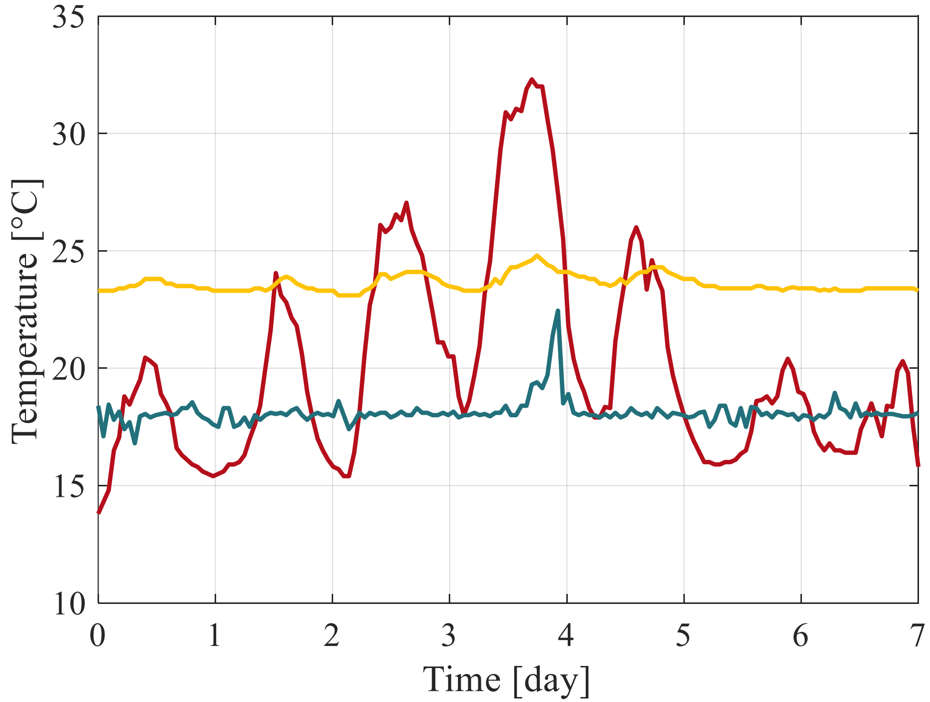


Atic
for HVAC professionals

Temperature and humidity control during a warm summer week

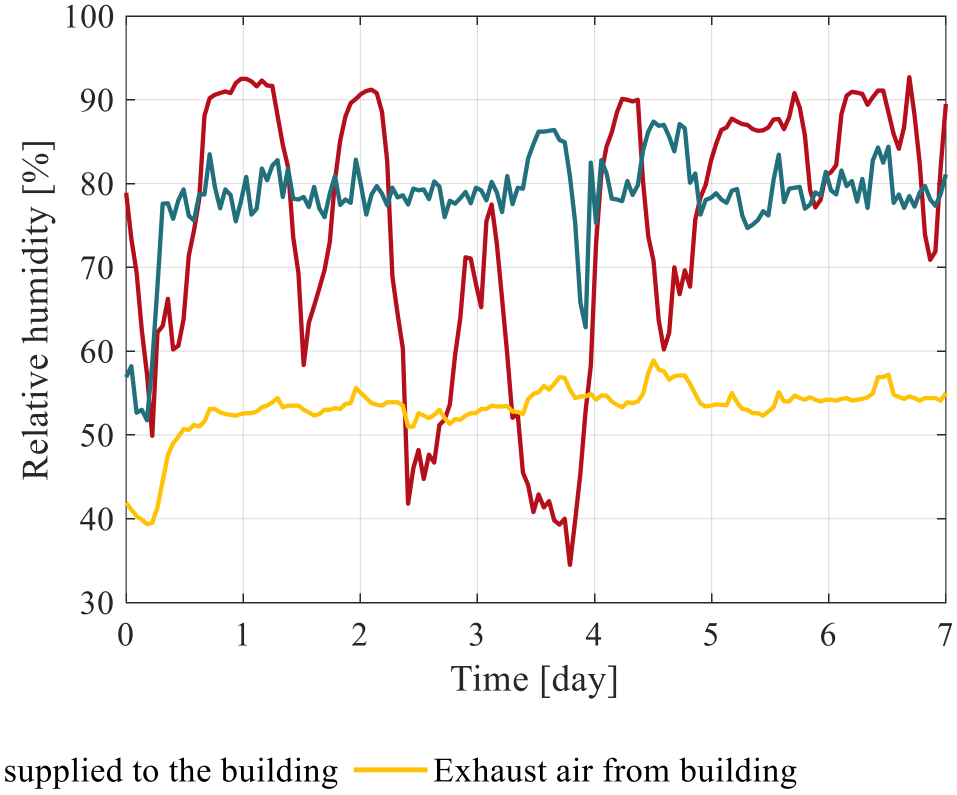
TEMPERATURE

- Supply temperature almost constant at 17°C
- Outdoor temperature as high as 32°C
- Indoor temperature never exceeds 25°C



RELATIVE HUMIDITY

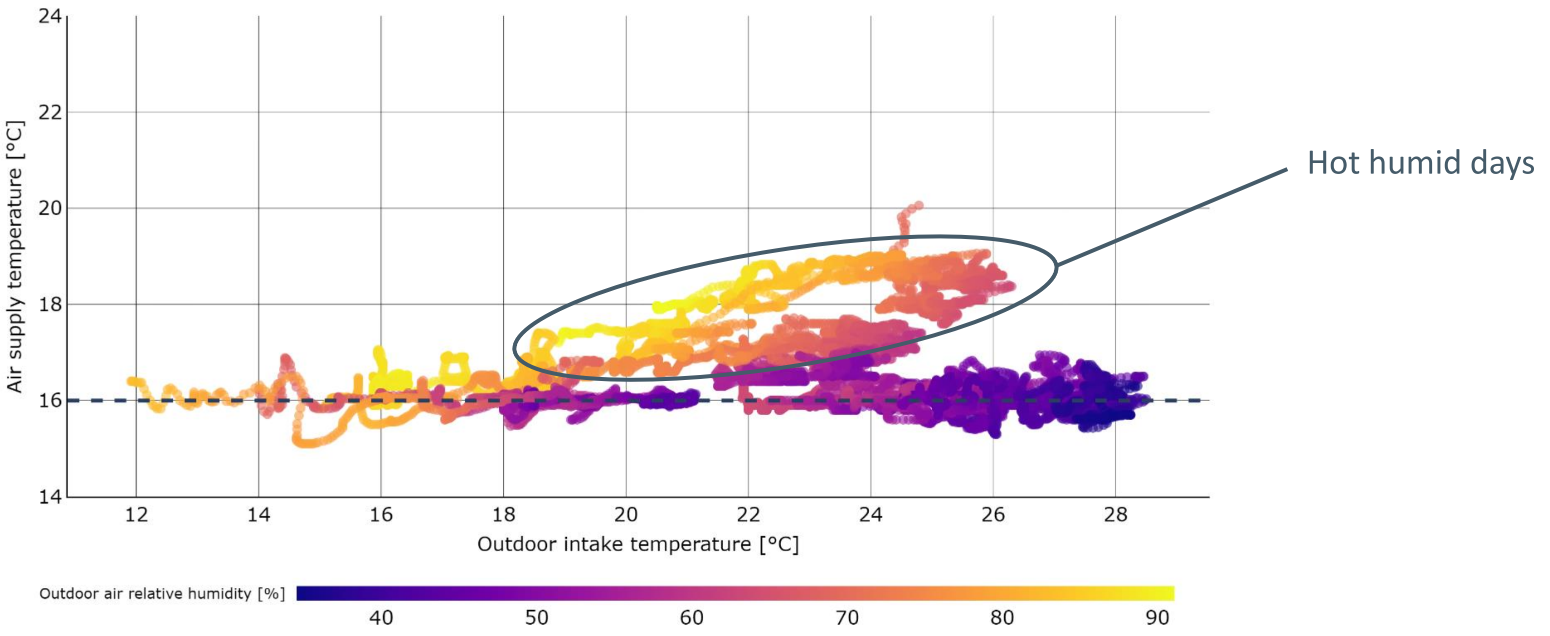
- Supply RH around 80%
- Outdoor RH between 40 and 90%
- Indoor RH kept in an acceptable range



Atic
for HVAC professionals

System limitations with outdoor conditions

- Temperature set point of the system : 16°C
- Set point temperature is not achievable for hot and humid days : outdoor relative humidity of 70-90%
- During hot and humid days, the supply temperature can still be as low as 18-19°C
- Performance limitation when the boundary conditions (outdoor air intake) reach critical heat and moisture content.

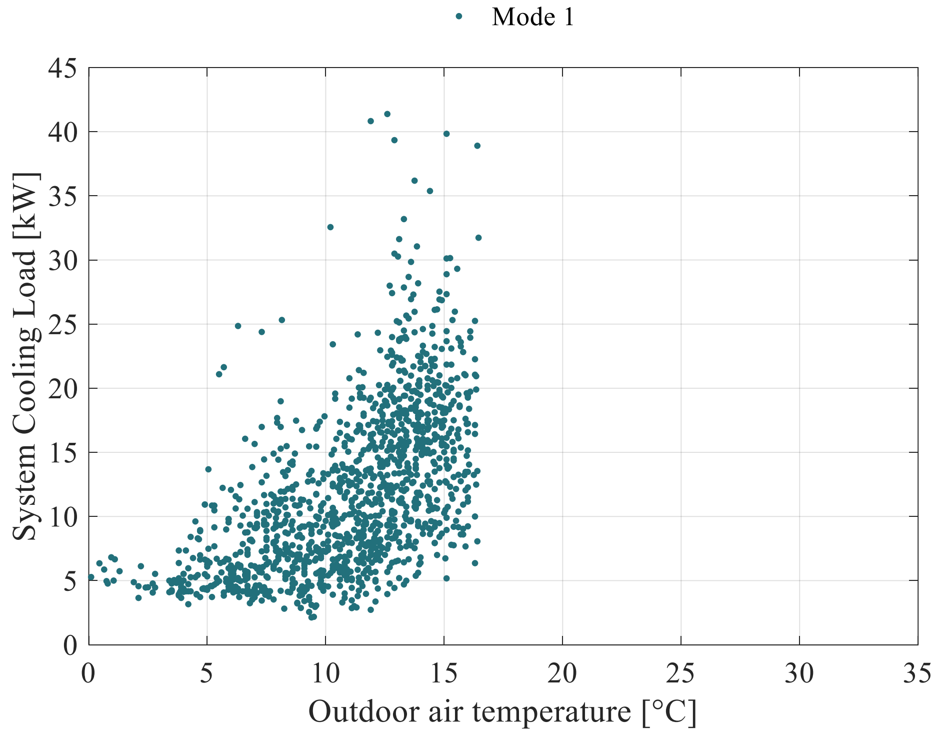


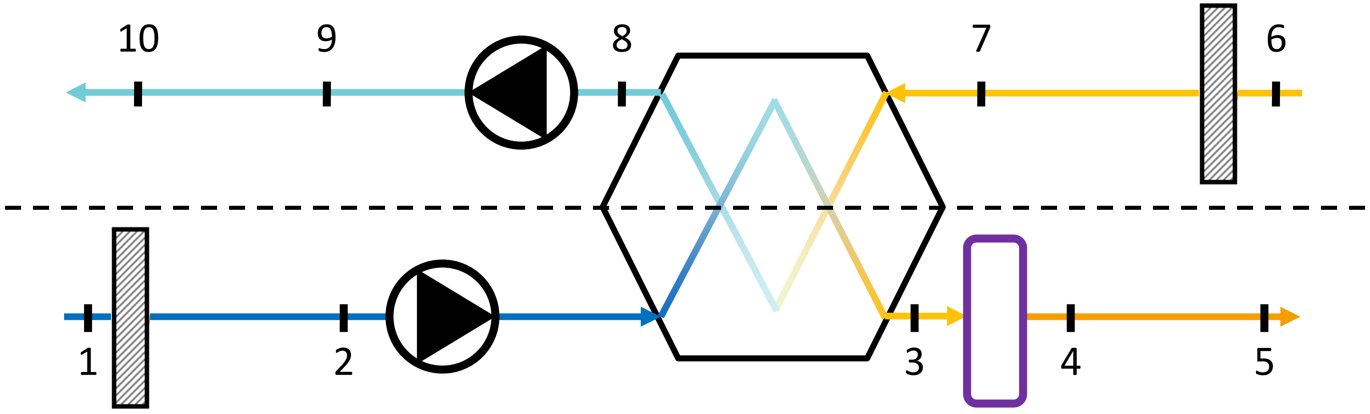
Atic
for HVAC professionals

System control strategy

- Control of temperature and humidity in the building
- **Sequential** control strategy :

Mode 1 – If T_{out} is too low, heat recovery.





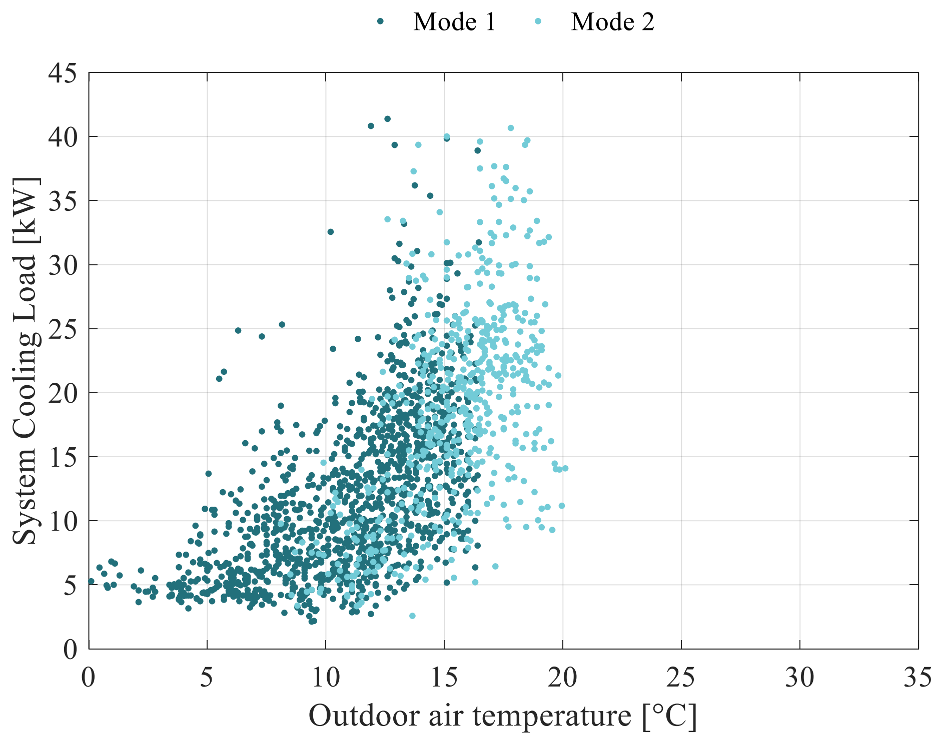
$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$

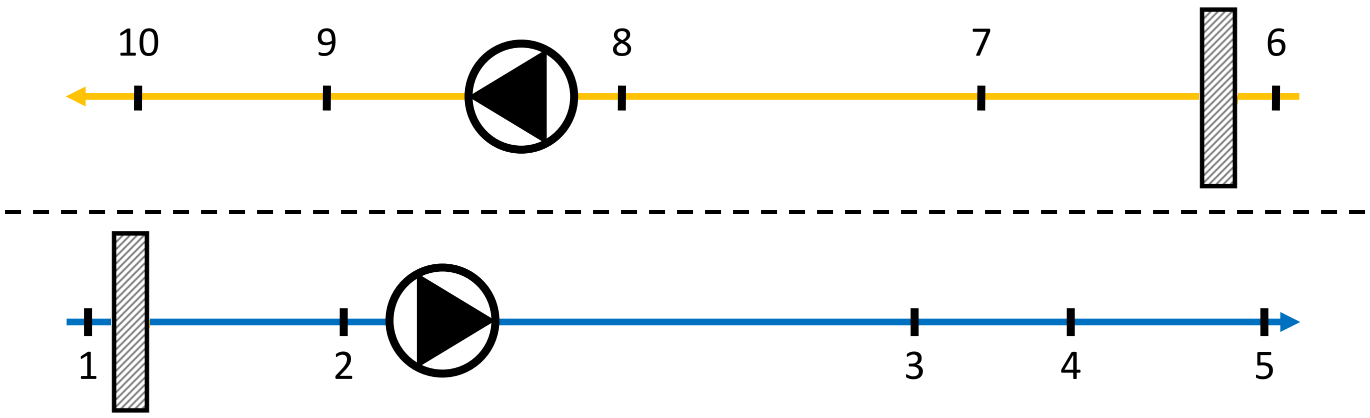
System control strategy

- Control of temperature and humidity in the building
- **Sequential** control strategy :

Mode 1 – If T_{out} is too low, heat recovery.

Mode 2 – If $T_{in} < T_{setpoint}$, system acts as a ventilation system.





$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$

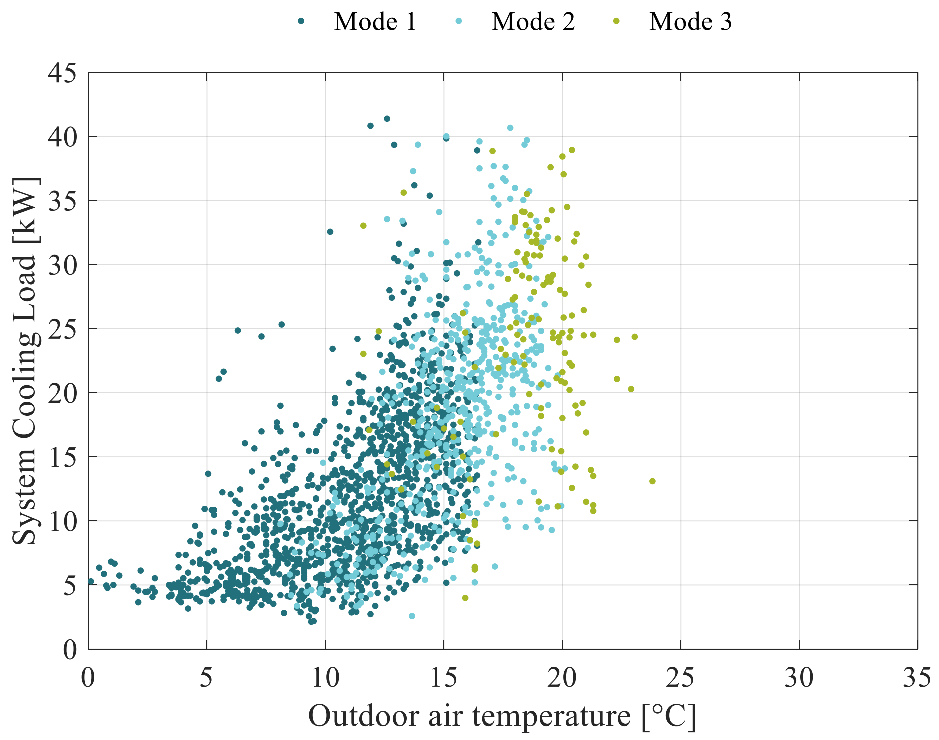
System control strategy

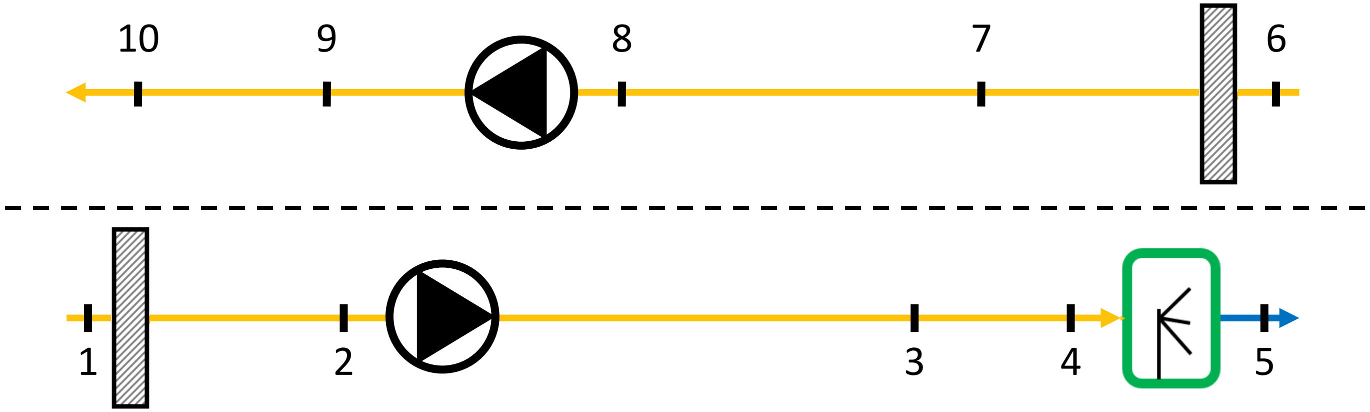
- Control of temperature and humidity in the building
- **Sequential** control strategy :

Mode 1 – If T_{out} is too low, heat recovery.

Mode 2 – If $T_{in} < T_{setpoint}$, system acts as a ventilation system.

Mode 3 – If $T_{in} > T_{setpoint}$, activation of DEC on process side.





$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$

System control strategy

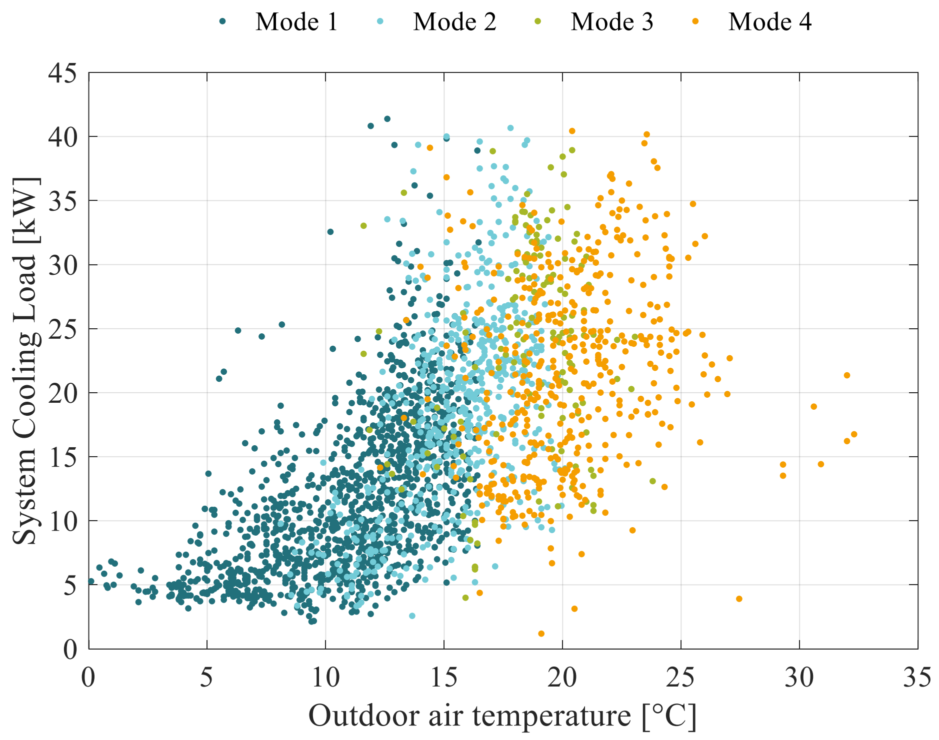
- Control of temperature and humidity in the building
- **Sequential** control strategy :

Mode 1 – If T_{out} is too low, heat recovery.

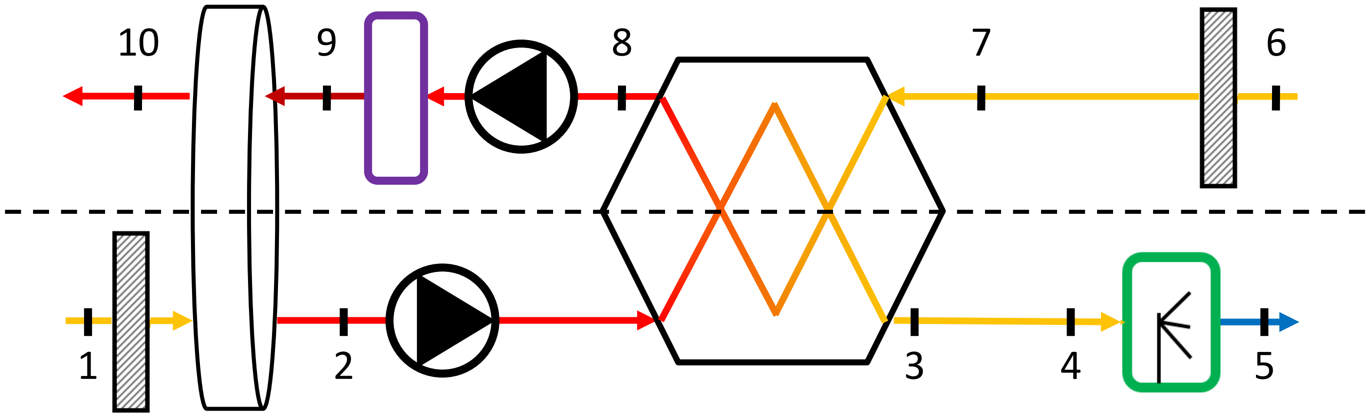
Mode 2 – If $T_{in} < T_{setpoint}$, system acts as a ventilation system.

Mode 3 – If $T_{in} > T_{setpoint}$, activation of DEC on process side.

Mode 4 – If $RH_{in} > RH_{max}$, activation of DW and HEX.



$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$



System control strategy

- Control of temperature and humidity in the building
- **Sequential** control strategy :

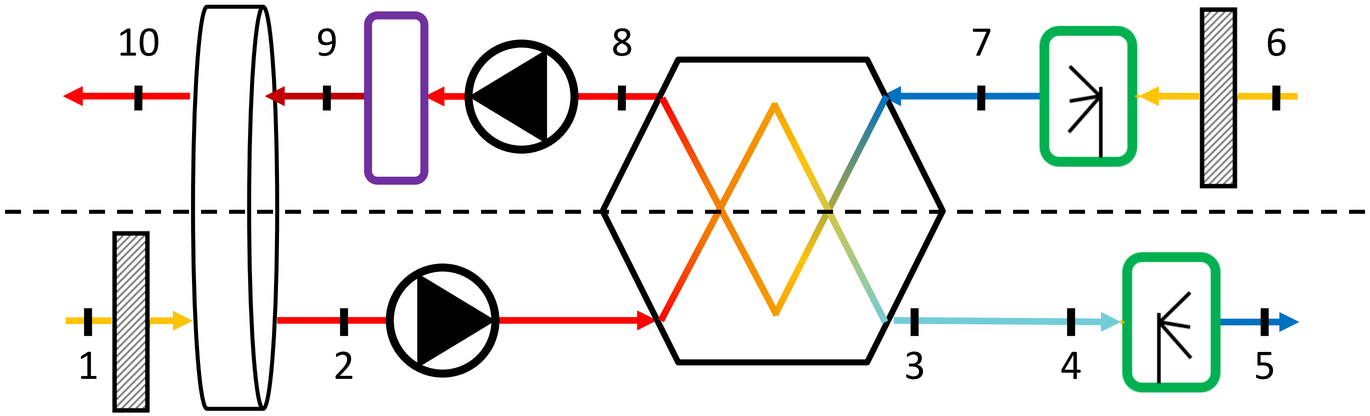
Mode 1 – If T_{out} is too low, heat recovery.

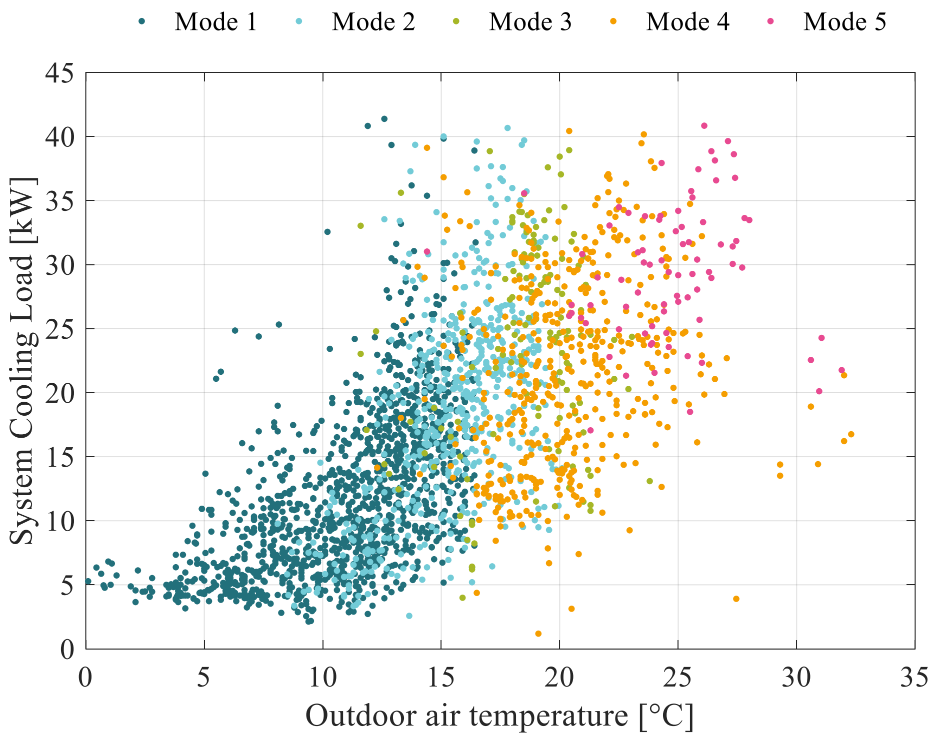
Mode 2 – If $T_{in} < T_{setpoint}$, system acts as a ventilation system.

Mode 3 – If $T_{in} > T_{setpoint}$, activation of DEC on process side.

Mode 4 – If $RH_{in} > RH_{max}$, activation of DW and HEX.

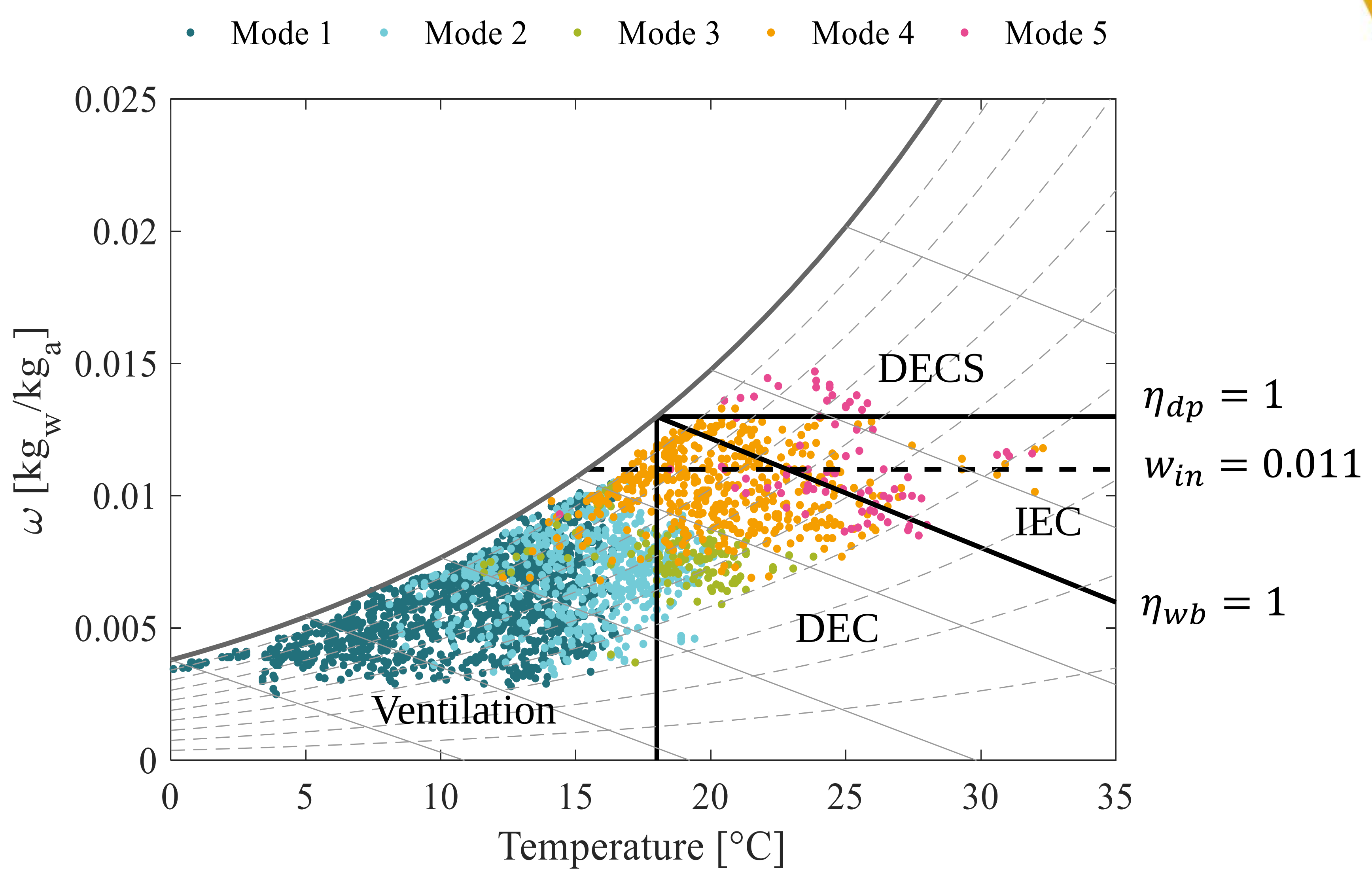
Mode 5 – If $T_{in} > T_{setpoint}$, activation of DEC on regeneration side (IEC mode).





$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$

Feasibility Analysis vs System Operation



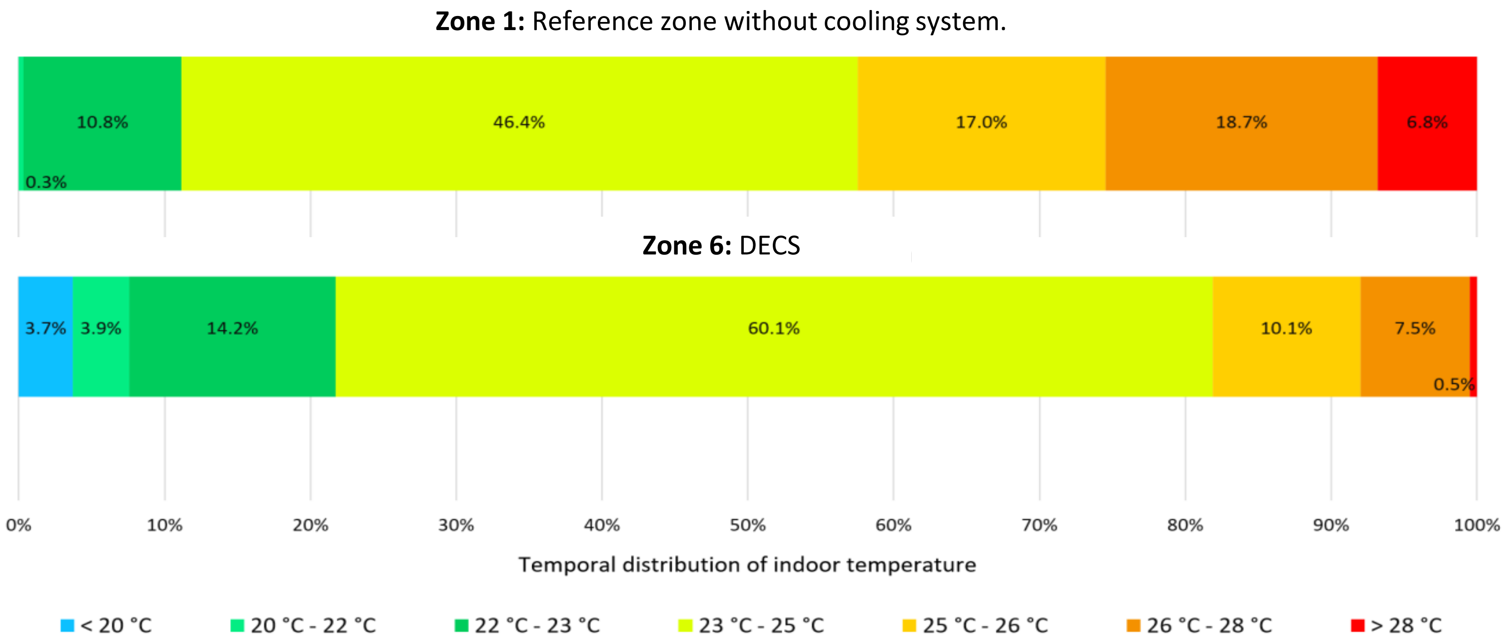
Legend	
DECS	Desiccant Evaporative Cooling System
DEC	Direct Evaporative Cooling
IEC	Indirect Evaporative Cooling

Atic for HVAC professionals

Indoor thermal comfort

- Thermal comfort in zone equipped with DECS has been significantly improved.
- Indoor temperature is above 26°C less than 10% of the time during whole summer.

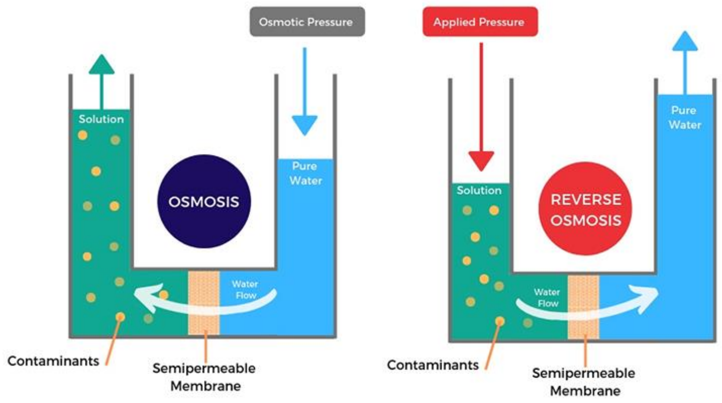
Yearly overheating hours	Above 26°C	Above 27°C
Regulation limit in Denmark for office buildings	100	25
Without cooling system	281	144
With DECS	88	33

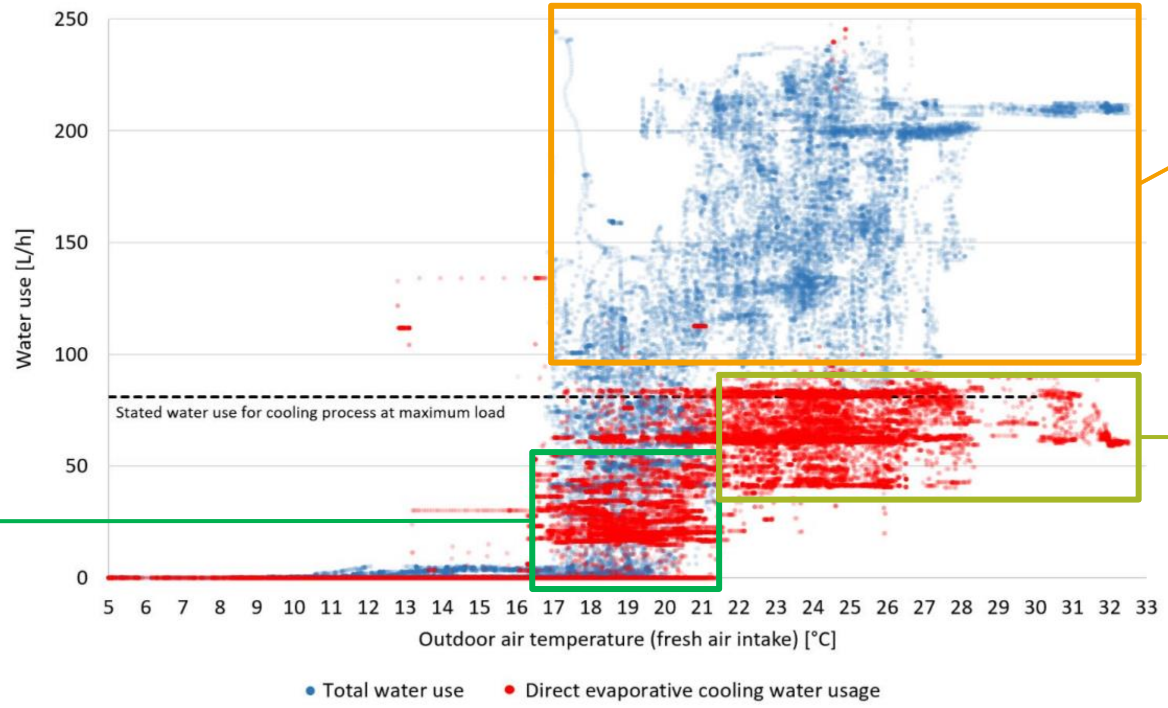


Atic for HVAC professionals

Water consumption analysis

- Water treatment is necessary due to high content in limestone
- Water treatment through reverse osmosis
- Additional water consumption required to clean the filters
- Water treatment could be improved





Atic for HVAC professionals

Performance analysis

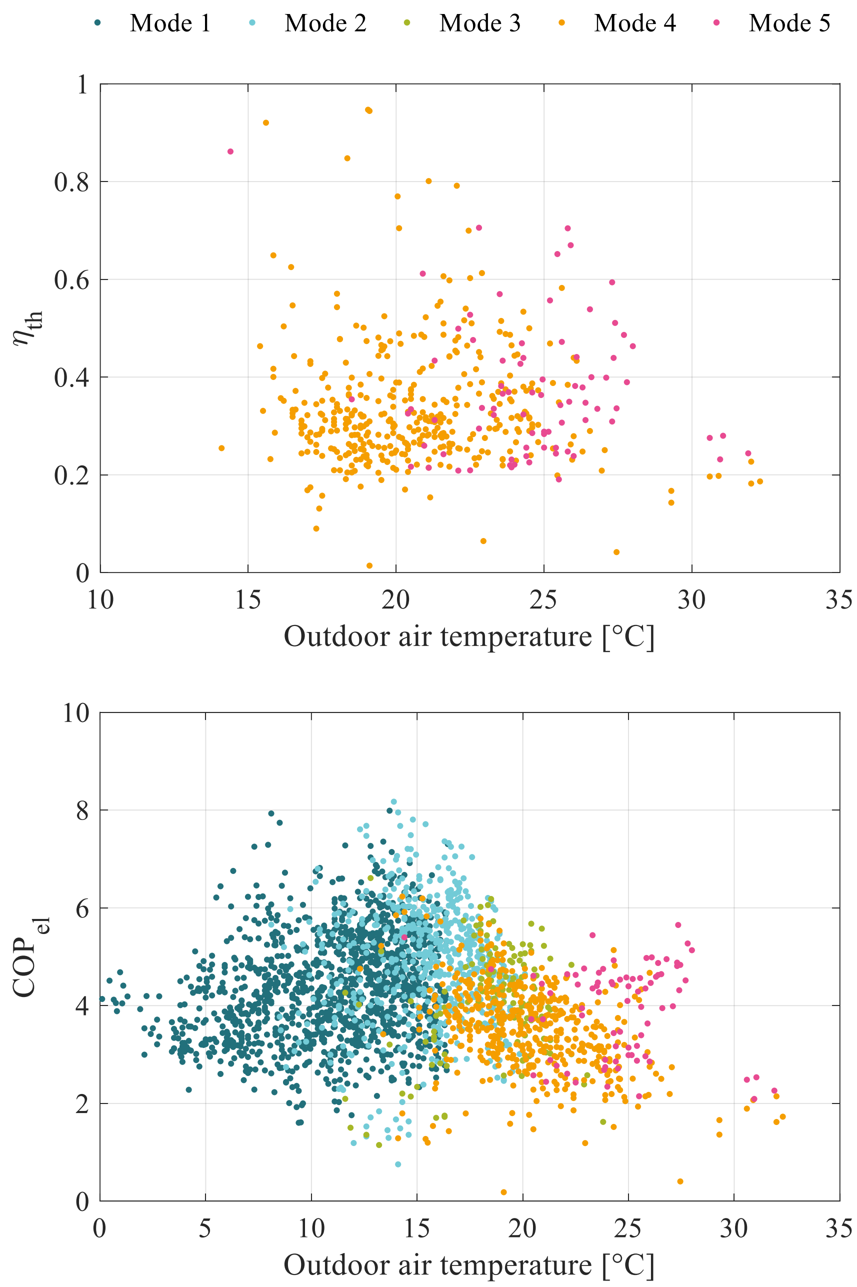
- Cooling load produced by the system and provided to the building

$$\dot{Q}_{cool} = \dot{m}_{vent} \cdot (h_6 - h_5)$$

- Calculation of thermal efficiency and electrical COP

$$\eta_{th} = \frac{\dot{Q}_{cool}}{\dot{Q}_{th}} \quad \text{and} \quad COP_{el} = \frac{\dot{Q}_{cool}}{\dot{W}_{el}}$$

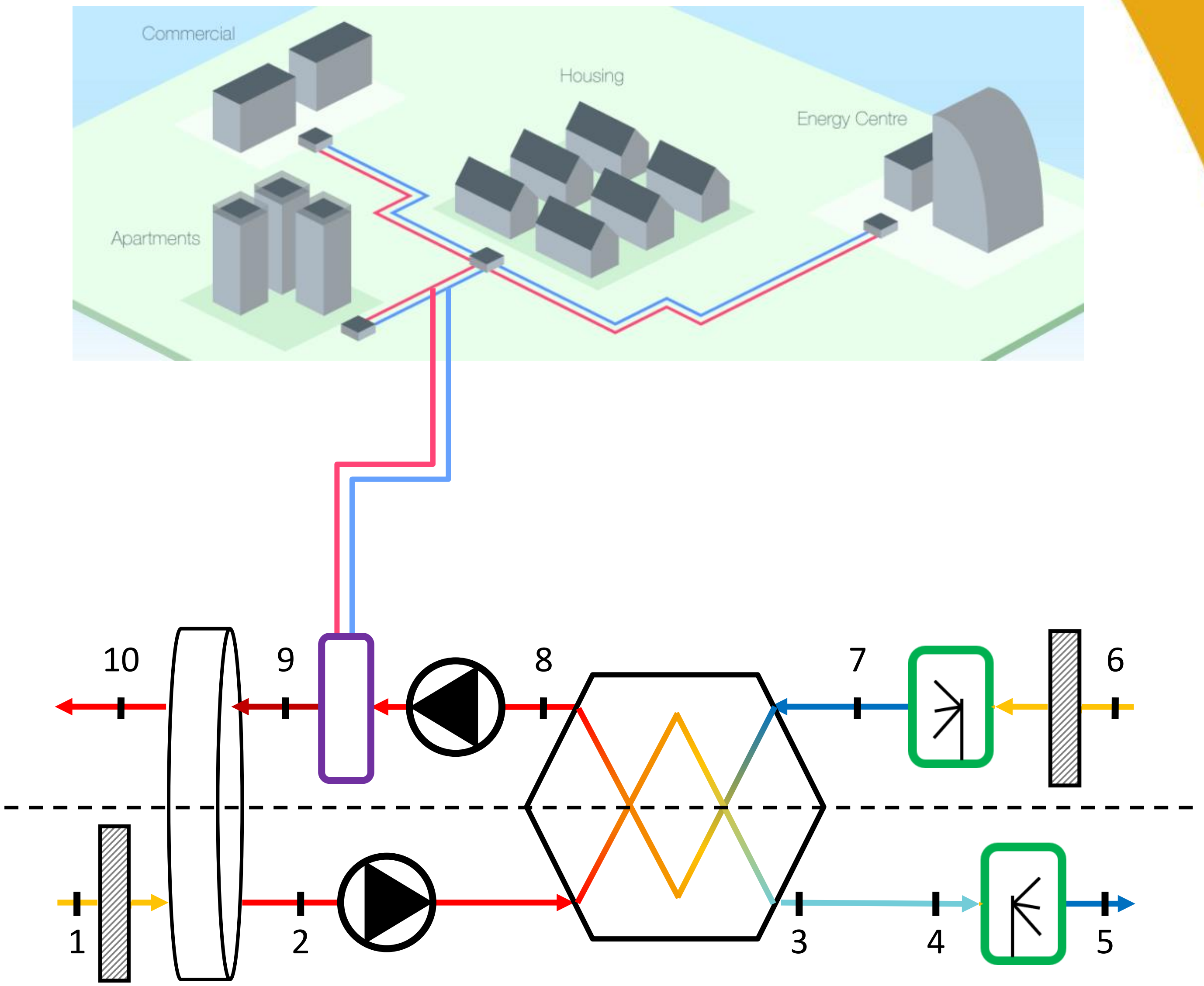
- The electrical energy consumption includes the electricity consumption of auxiliaries
- The electrical COP is higher than a standard air-conditioning system
- The consumption of the cooling system is shifted to a thermal energy consumption
- There is an additional water consumption



Atic for HVAC professionals

The IDCS project

Average values during the cooling period	
Total cooling load	41 MWh_{th}
Electricity consumption	10 MWh_{el}
Thermal energy consumption	40 MWh_{th}
Water consumption	44 m^3
Average COP	4.12
Average thermal efficiency	31%
Thermal comfort increase	44%



Thank you for your attention

Atic
for HVAC professionals