KATEDRA TECHNICKÝCH ZAŘÍZENÍ BUDOV

FAKULTA STAVEBNÍ ČVUT V PRAZE

Optimization of operational energy efficiency and indoor environment quality in research facility buildings – Analytical section

Final report on contract research

Prague, September 2025

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Imprint
Final report on contract research Optimization of operational energy efficiency and indoor environment quality in research facility buildings - Analytical section
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Date: September 2025

Contents

1 Order identification

Client:

Extreme Light Infrastructure | ELI Beamlines Facility Za
Radnicí 835, 252 41 Dolní Břežany
Company ID: 10974938
VAT number: CZ10974938
represented in contractual matters by:
Veronika Záchová

in technical matters:
Václav Bernášek Order No.
25911002

Contractor:

ČVUT in Prague, Faculty of Civil Engineering
Department of Building Services
Engineering Address: Thákurova 7, 160 00
Prague 6
Company ID: 68407700 VAT ID: CZ 68407700

Contractor's responsible representative:
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Prepared by:
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Zuzana Veverková, Ph.D.

2 Subject of the contract

The subject of the contract research is an analysis of the operational energy intensity and indoor environment quality of the laboratories at the ELI Dolní Břežany research facility. The results of the analysis will form the basis for the next phase of research focused on identifying opportunities to reduce operational energy consumption and subsequently recommending technical measures for building components, technical heating, cooling, ventilation, air treatment, hot water preparation, and measurement and control systems, including energy sources for equipment technologies. As part of the contractual research, a survey of the building was carried out, a reference zone was identified, data on energy consumption supplied by the client was analyzed and evaluated, operational data supplied by the client was analyzed, selected indoor environment parameters (air temperature, relative humidity, CO2 concentration, sound pressure level) were measured over the medium term, and a summary report was prepared. Detailed documentation and source files are stored in the contractor's archive.

3 Supporting documents

The research was based on files and information provided by the client:

- Project documentation for the structural and technical design of the building
- Selected data from the building's MaR system provided by the client
- Local surveys on July 1, 2025, and July 30, 2025
- Own measurements of selected indoor environment parameters in the period from January 1, 2025, to August 26, 2025

4 Methodology

The analysis of indoor environmental quality and subsequent evaluation was performed using applicable procedures from the CTU HAIEQ (Holistic Assessment of Indoor Environmental Quality) methodology selected for this case. The HAIEQ methodology evaluates the indoor environment in eight categories: LS Location and location of the building in terms of the external environment and social ties; STI Structural and technical design and interior of the evaluated zone; TCW Thermal comfort in cold weather; TCS Thermal comfort in warm weather; IAQ Air quality; LC Lighting environment; AC Acoustic environment; and EC Electromagnetic, ion, and static fields. Each category has 5-8 evaluation criteria. The basis for the evaluation is

- a detailed survey of the building by CTU staff;
- indicative measurements of physical quantities in the indoor environment;
- subjective evaluation from the perspective of the building user.

The output is a report containing a comprehensive holistic view of the evaluated building in terms of individual components of the indoor environment, including information on whether the building meets the requirements in a given category.

- is designed in line with the current state of knowledge
- has the potential to improve the quality of the environment,

- shows deficiencies in terms of indoor environmental quality.

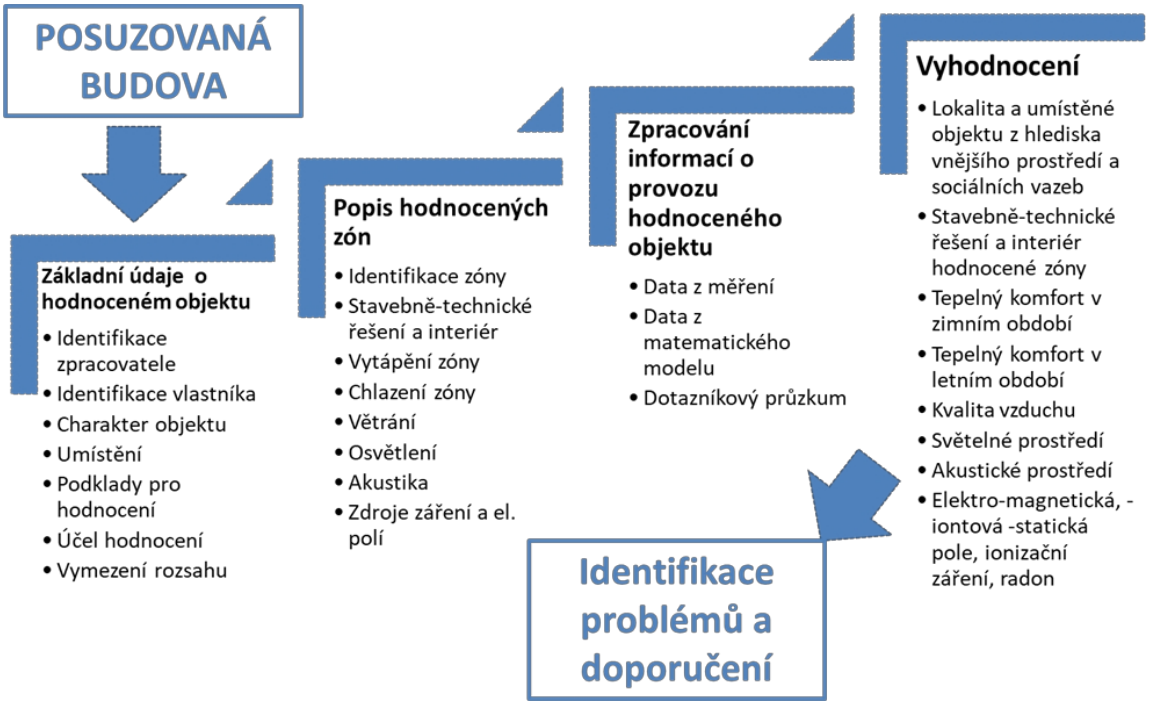


Fig. 1 HAIEQ methodology

At this stage of the contract research, the first part of the building analysis was carried out, focusing on mapping the building's technical equipment systems and performing medium-term measurements of selected indoor environment parameters in nine zones of the building in question, with a focus on the thermal and humidity microclimate. At the client's request, the analysis focused primarily on the area of energy use to ensure the required microclimatic conditions in the laboratories and halls of the assessed building.

5 Survey of the building and description of the HVAC solution concept, identification of the reference zone

The building survey was carried out on the basis of the project documentation provided for the buildings in question, a site survey, operational data, and consultations with the client's representatives. For this phase of the solution, the following spaces were selected as reference spaces for medium-term measurement of selected indoor environment parameters: halls L1, L2, L3, L4b, L4c, E1, E2, E3, E5. For organizational reasons, the measurements were carried out in two stages, in July 2025 for halls L1 to L3 and in August 2025 for the remaining halls. At the same time, a block diagram of the cooling system (Fig. 2) was created in cooperation with the client to identify energy flows into individual spaces. Given the nature of the operation, no changes were made to the system at this stage, and data on energy consumption and system temperatures were taken from the building control system provided by the client for this initial analysis.

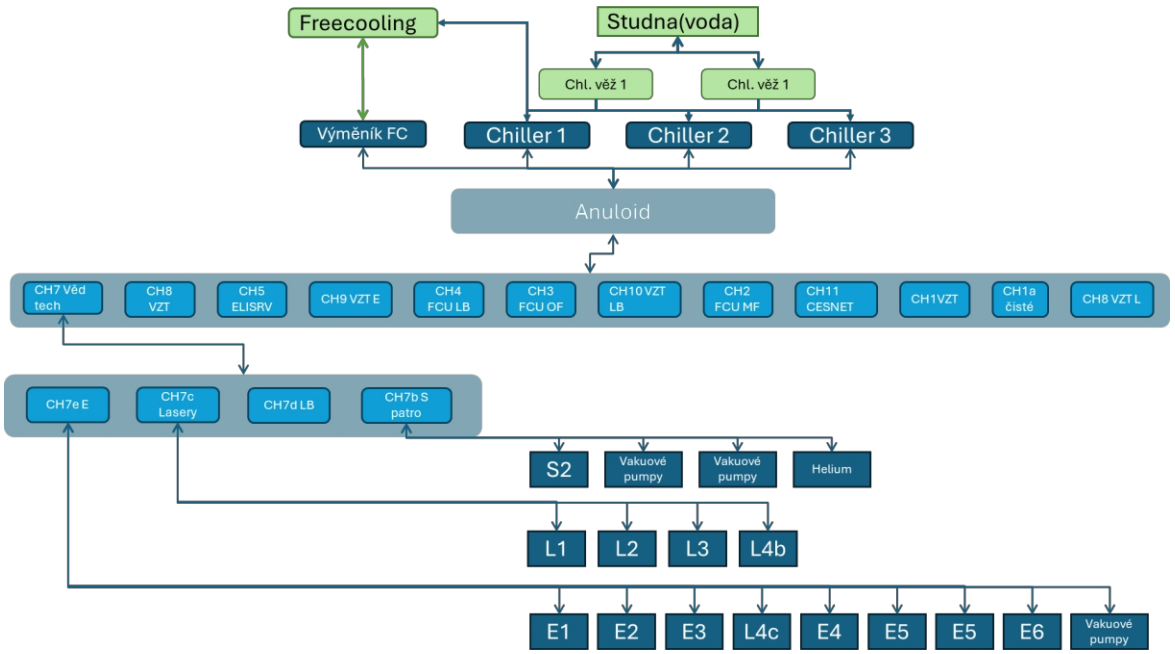


Fig. 2 Block diagram of the cooling principle

6 Medium-term measurement of selected indoor environment parameters

The COMET U3120M temperature and humidity data logger measuring system was used to measure selected indoor environment parameters. The measurements were taken between June 30, 2025, and August 26, 2025, in selected halls; for details, see Table 1. The placement of COMET U3120M data loggers for halls L1, L2, and E1 is shown in Fig. 3. Location of the COMET TZB101 data logger in hall L1 Fig. 4. Location of COMET TZB101 data loggers in hall L2 Fig. 5. Location of the COMET TZB101 data logger in hall E1

Hall	Number of data logger	Measured period	System System	System System	Full operation
L1	101	June 30–July 29	June 30–July 14	July 4-July 6	July 21–August 26
L2	104	June 30–July 29	June 30–July 14	July 4–6	July 21–August 26
L3	105	June 30–July 29	June 30–July 14	July 4–6	July 21–August 26
L4b	101	July 30–August 26	-	-	July 21–August 26
L4c	105	July 30–August 26	-	-	July 21–August 26
E1	103	July 30–August 26	-	-	July 21–August 26
E2	102	July 30–August 26	-	-	July 21–August 26
E3	104	July 30–August 26	-	-	July 21–August 26
E5	106	July 30–August 26	-	-	July 21–August 26

Table 1 Measured halls and measurement periods, including shutdowns 2025

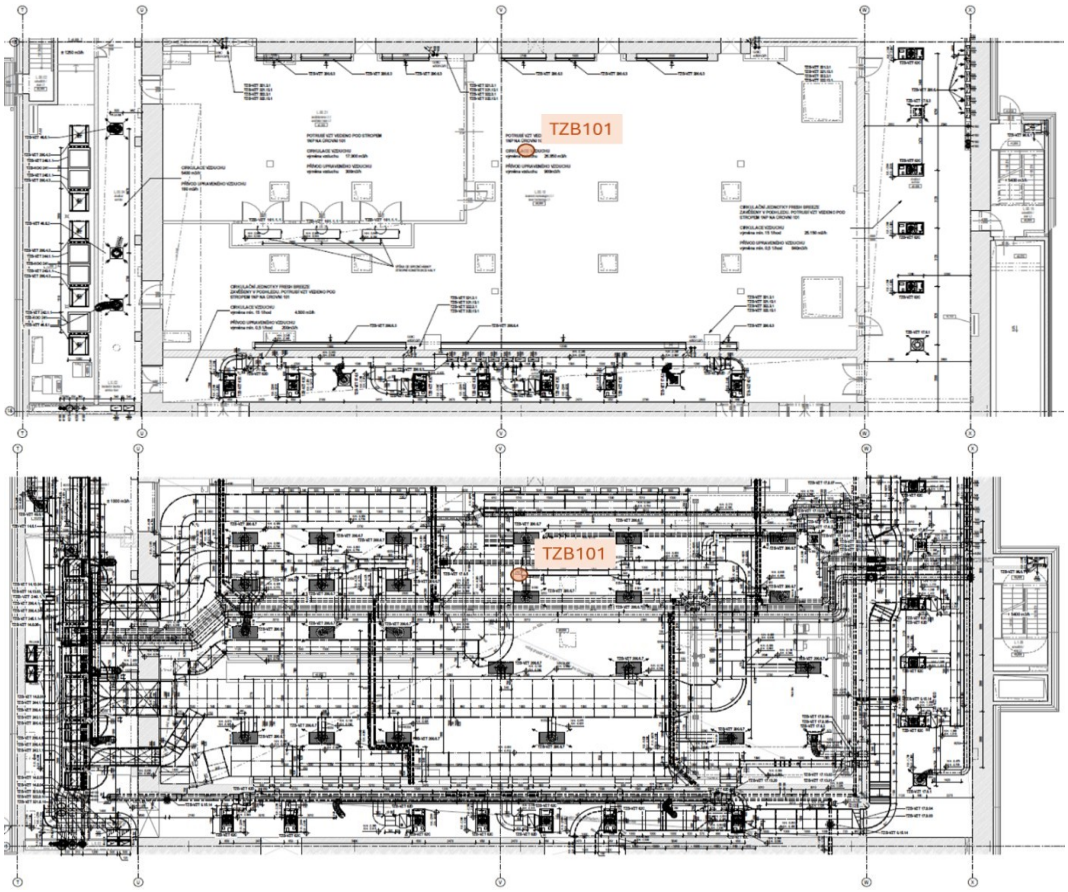


Fig. 3 Location of the COMET TZB101 data logger in hall L1

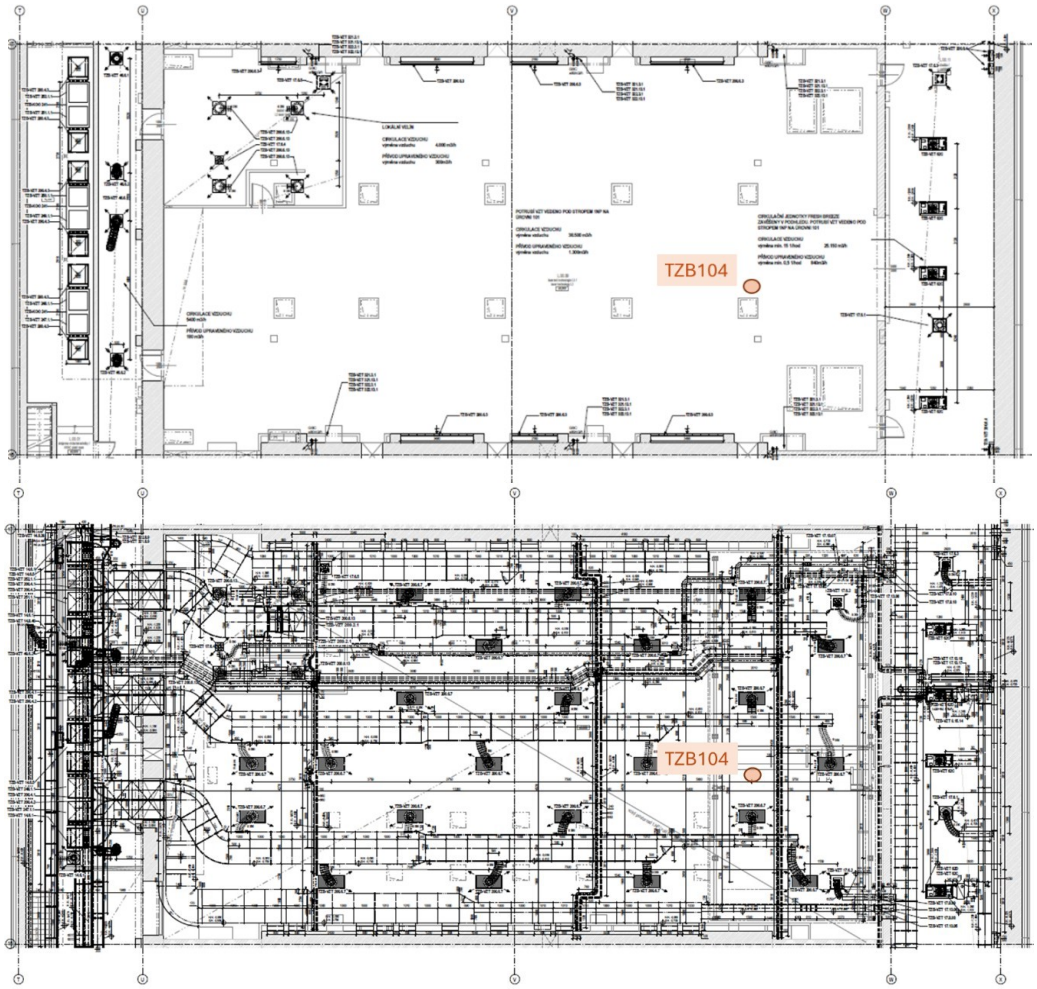


Fig. 4 Location of the COMET TZB101 data logger in hall L2

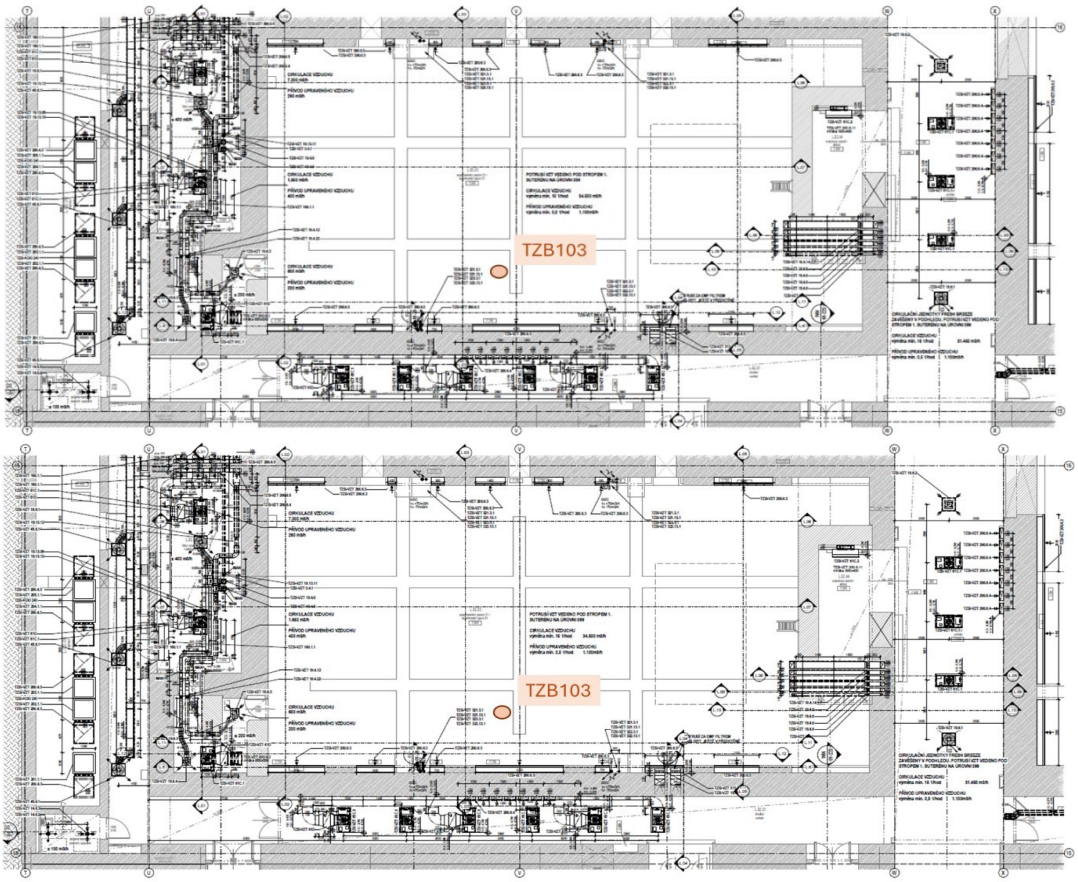


Fig. 5 Location of the COMET TZB101 data logger in hall E1

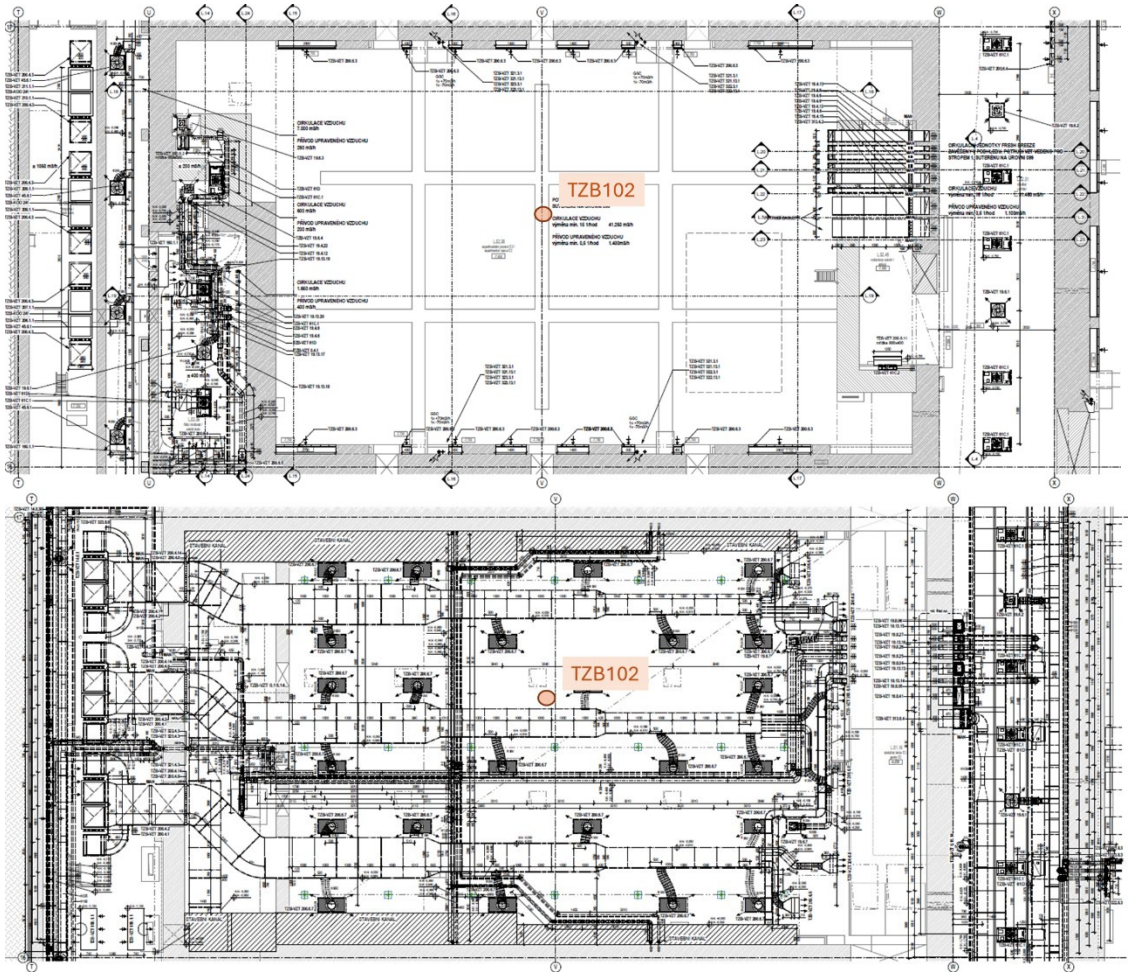


Fig. 6 Location of the COMET TZB102 data logger in hall E2

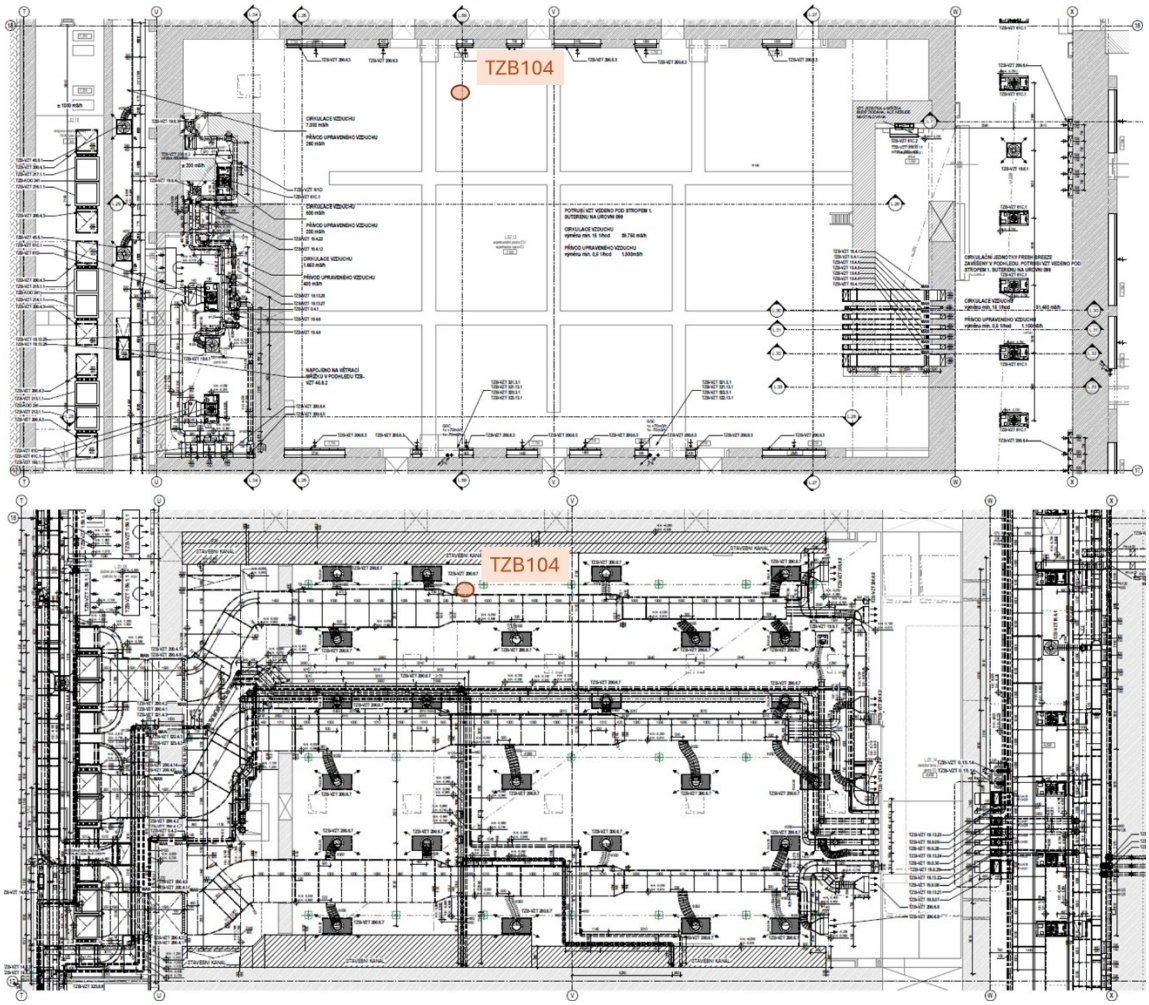


Fig. 7 Location of the COMET TZB104 data logger in hall E3

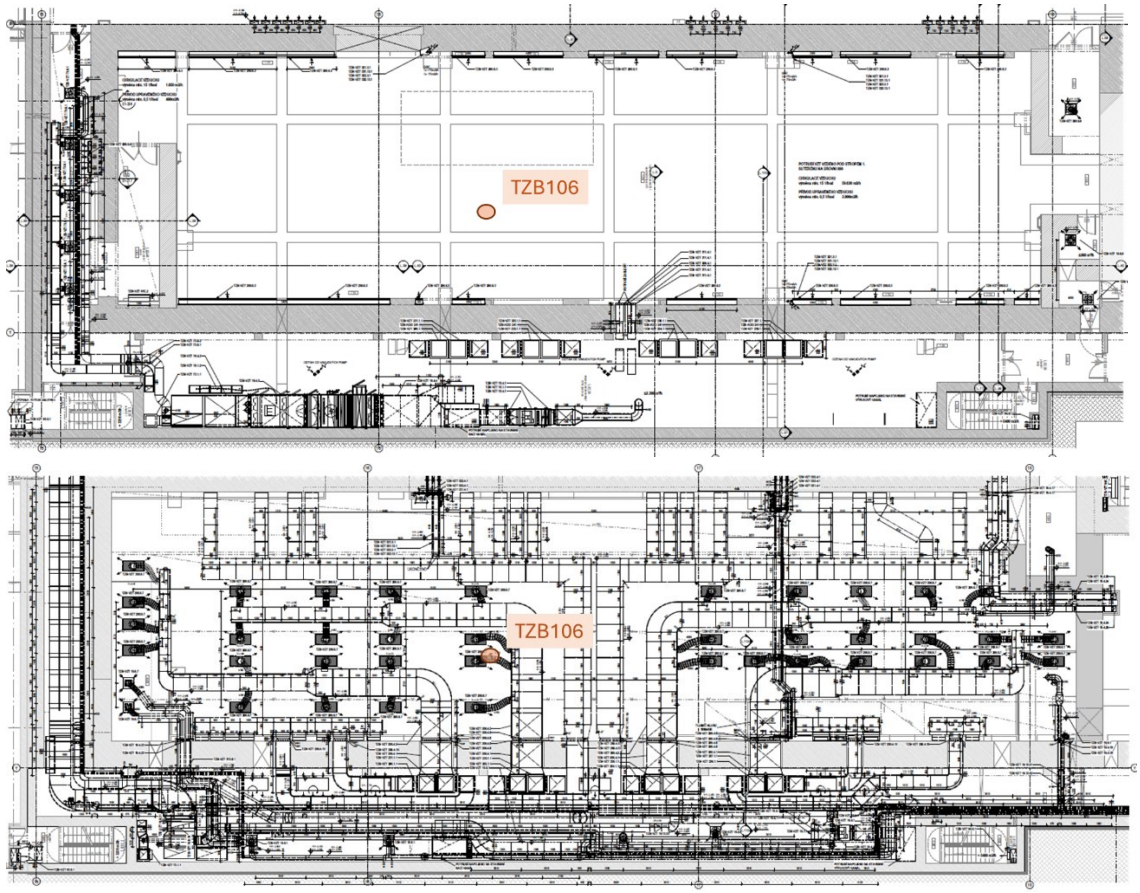


Fig. 8 Location of the COMET TZB106 data logger in hall E5

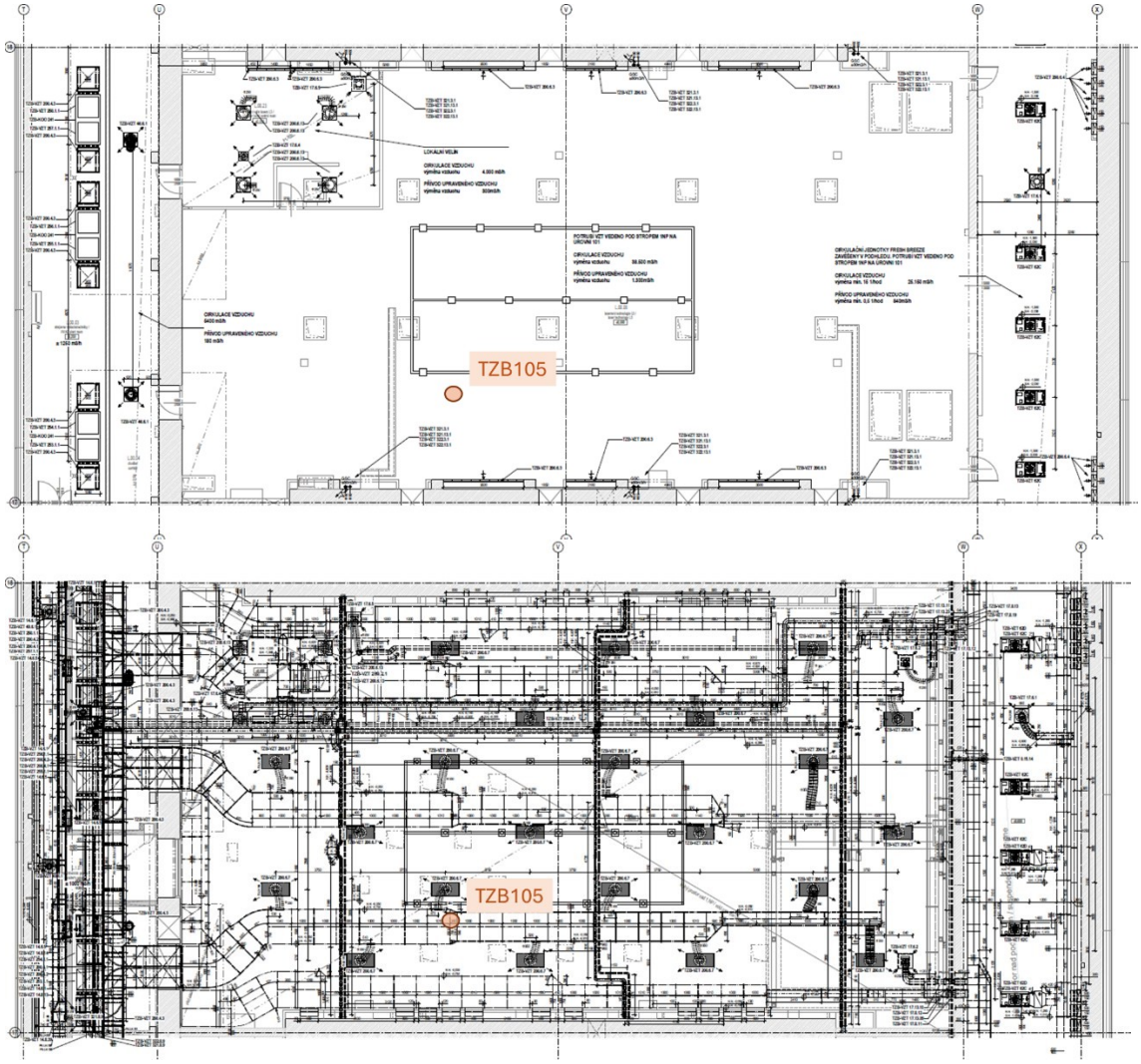


Fig. 9 Location of the COMET TZB105 data logger in hall L3

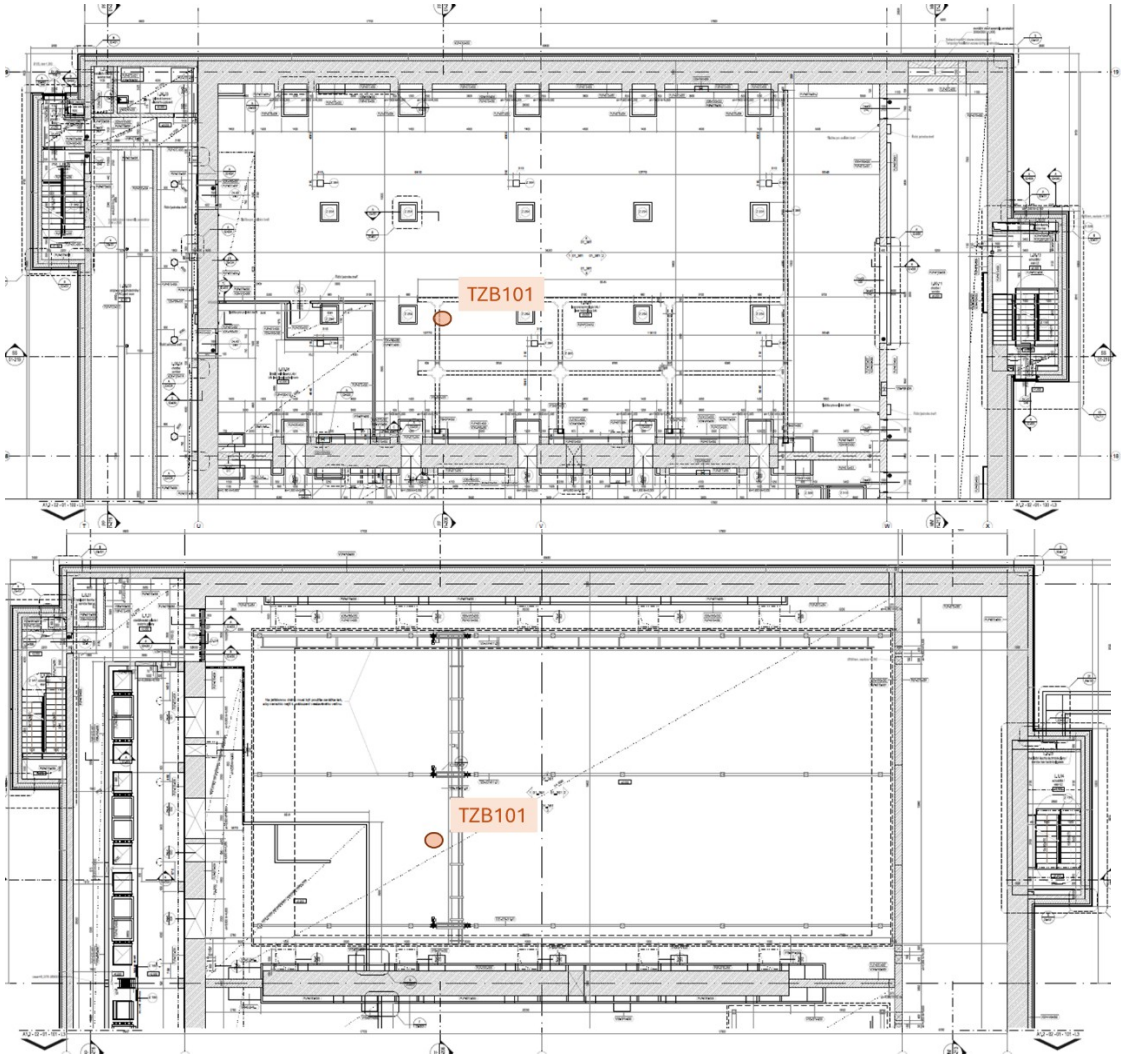


Fig. 10 Location of the COMET TZB101 data logger in hall L4b

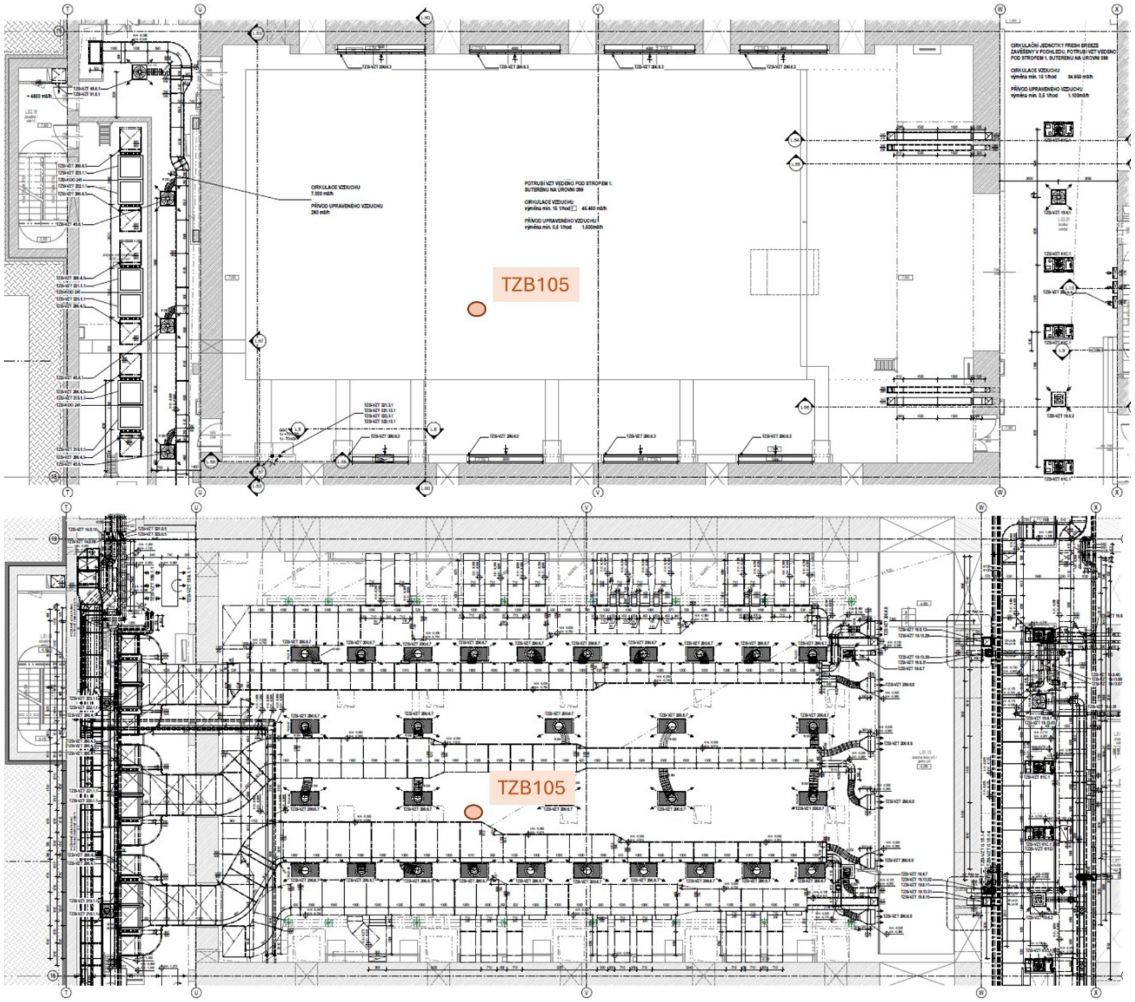
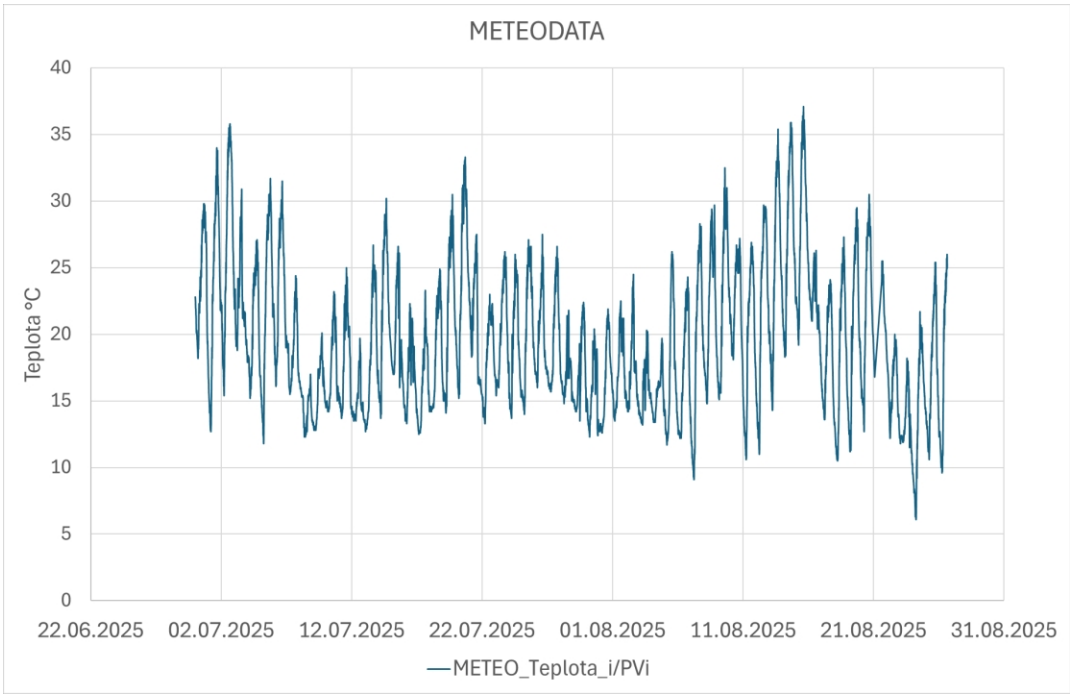


Fig. 11 Location of the COMET TZB105 data logger in hall L4c

7 Data analysis and evaluation

7.1 Analysis of climate data for the monitored period



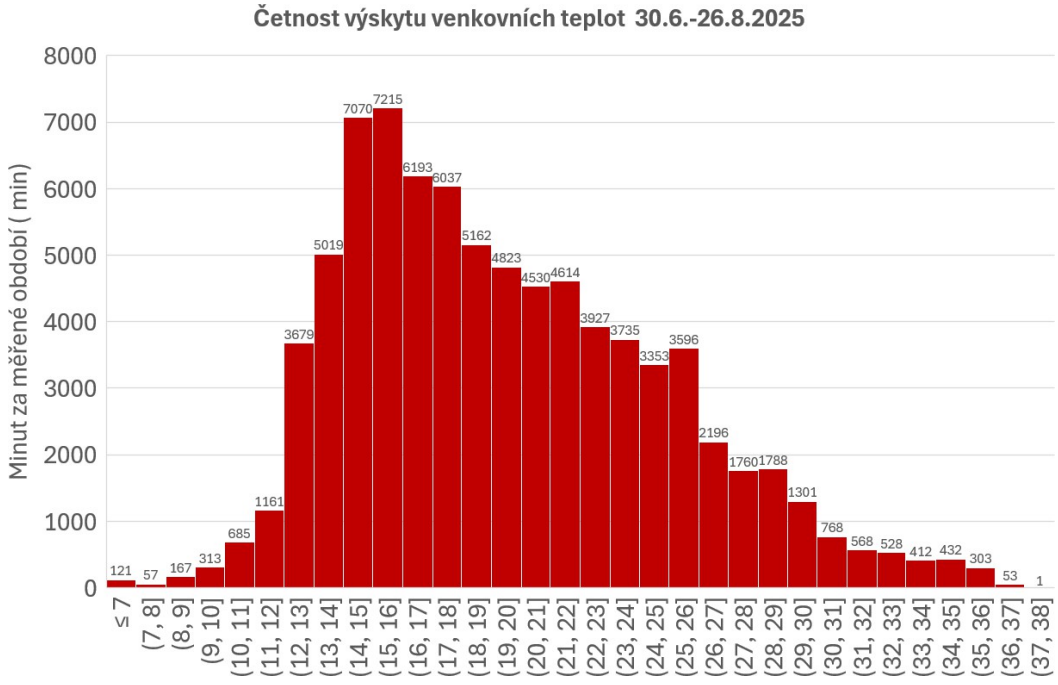
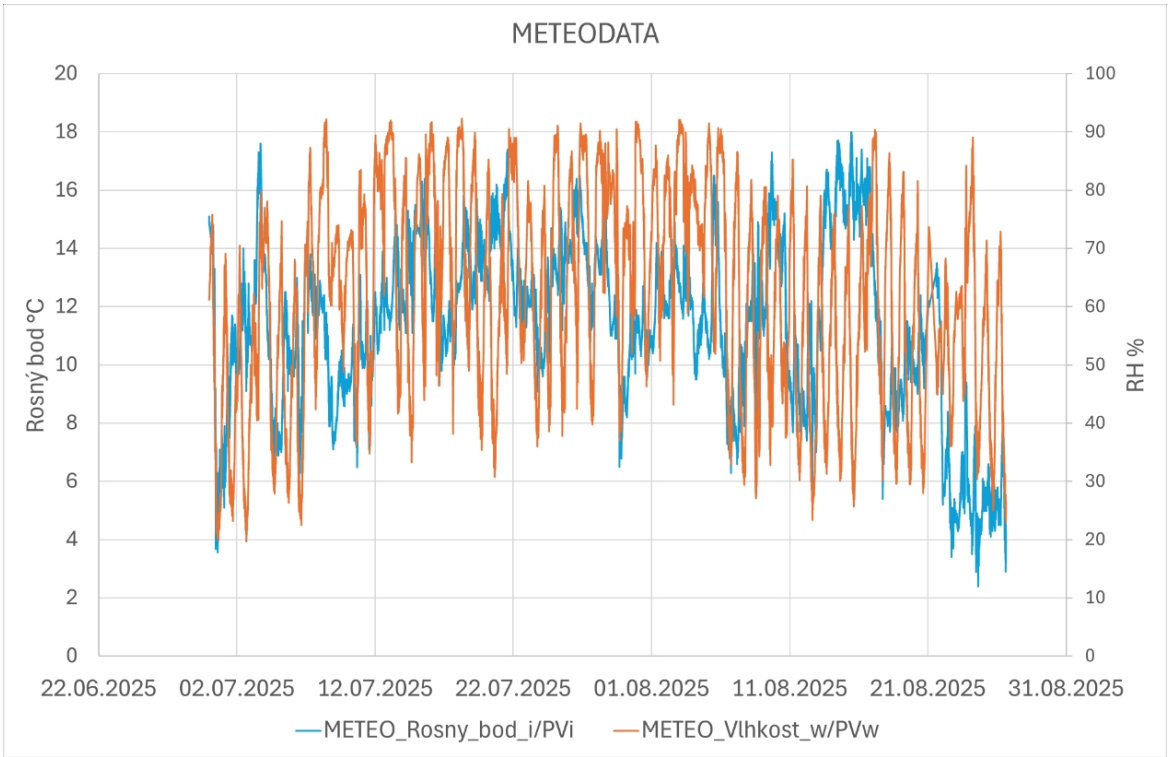


Fig. 12 Weather data – Temperature



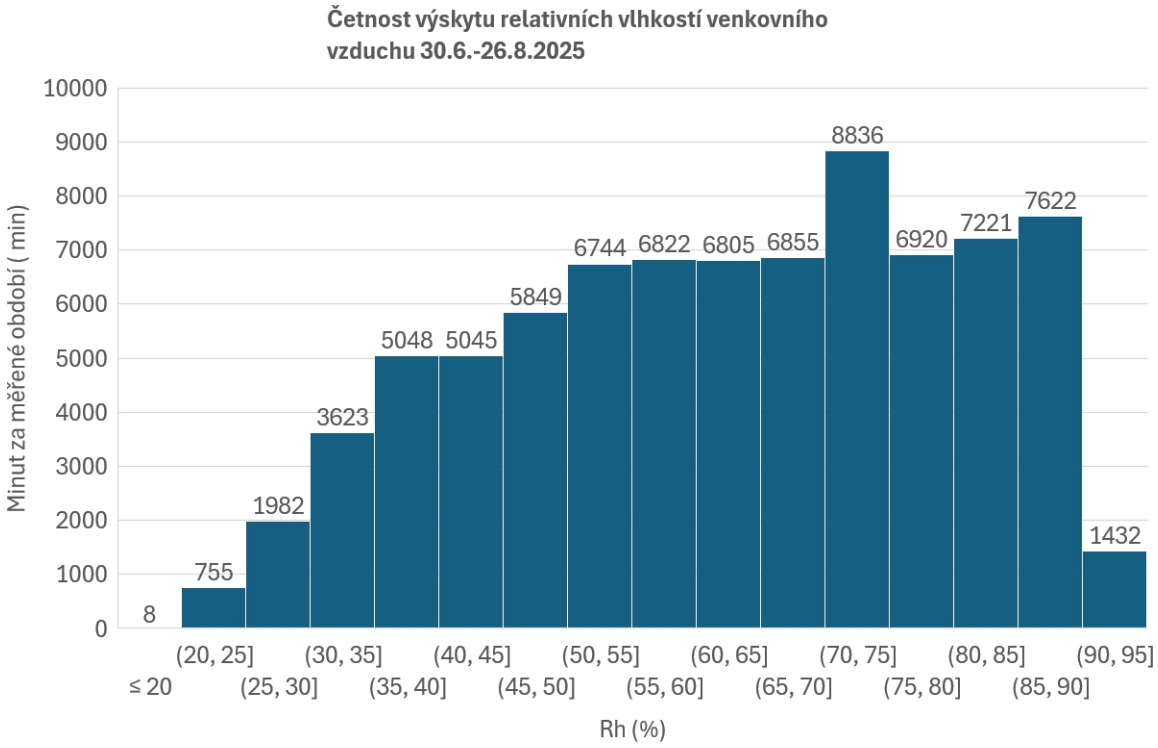


Fig. 13 Weather data – Humidity and dew point

7.2 Analysis of energy consumption for CH7 – scientific technologies

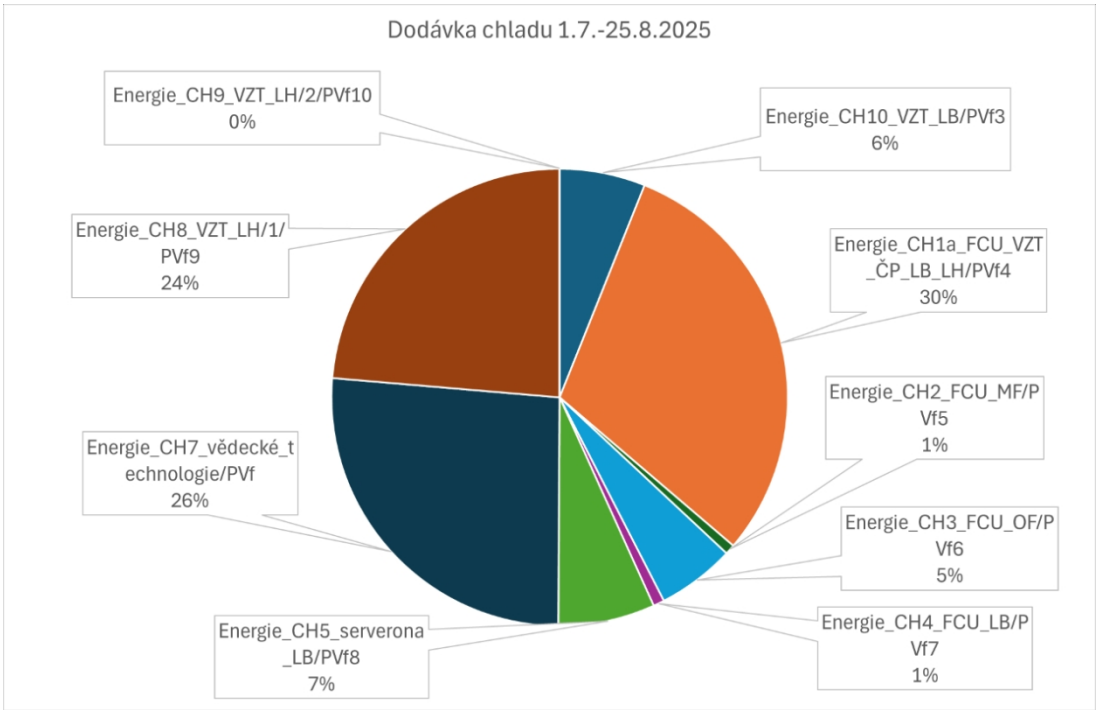


Fig. 14 Cooling supply for the period July 1, 2025–August 25, 2025

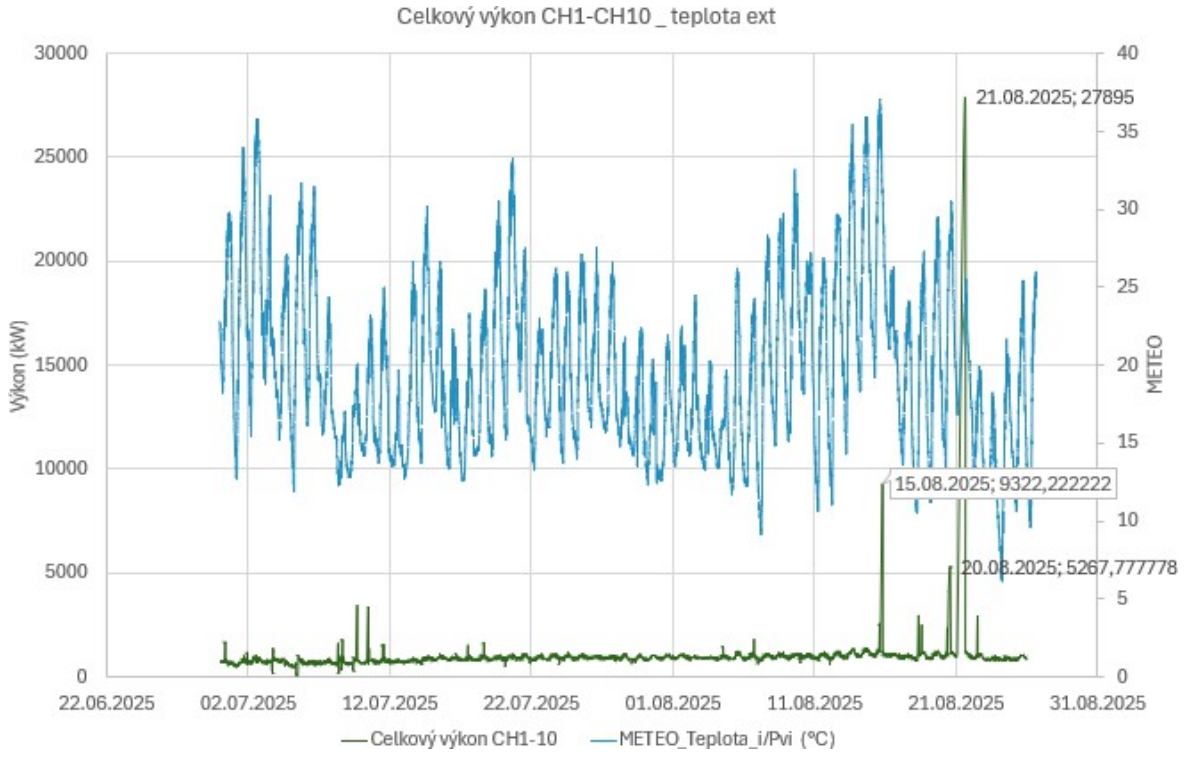


Fig. 15 Total combined output of CH1 to CH10 (half-hourly averages) and Meteodata – outdoor air temperature

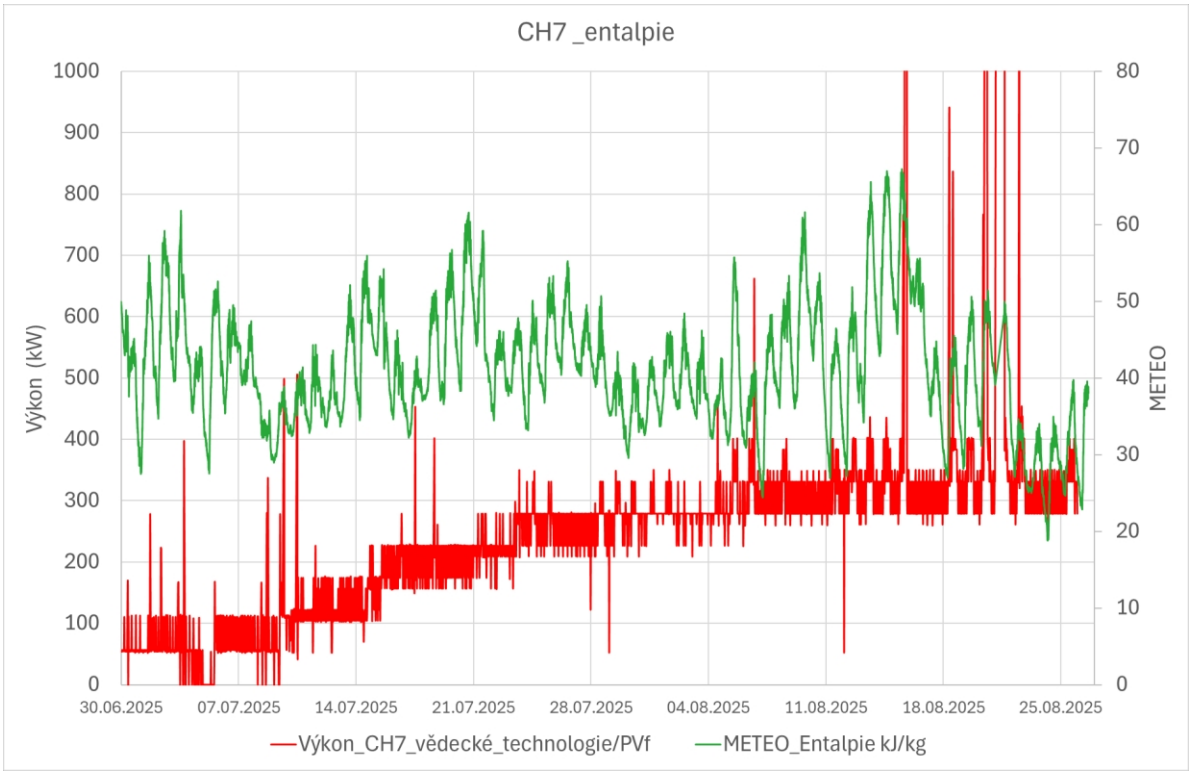


Fig. 16 Output of CH7 – scientific technologies (1/2-hour average) and Meteodata – outdoor air enthalpy

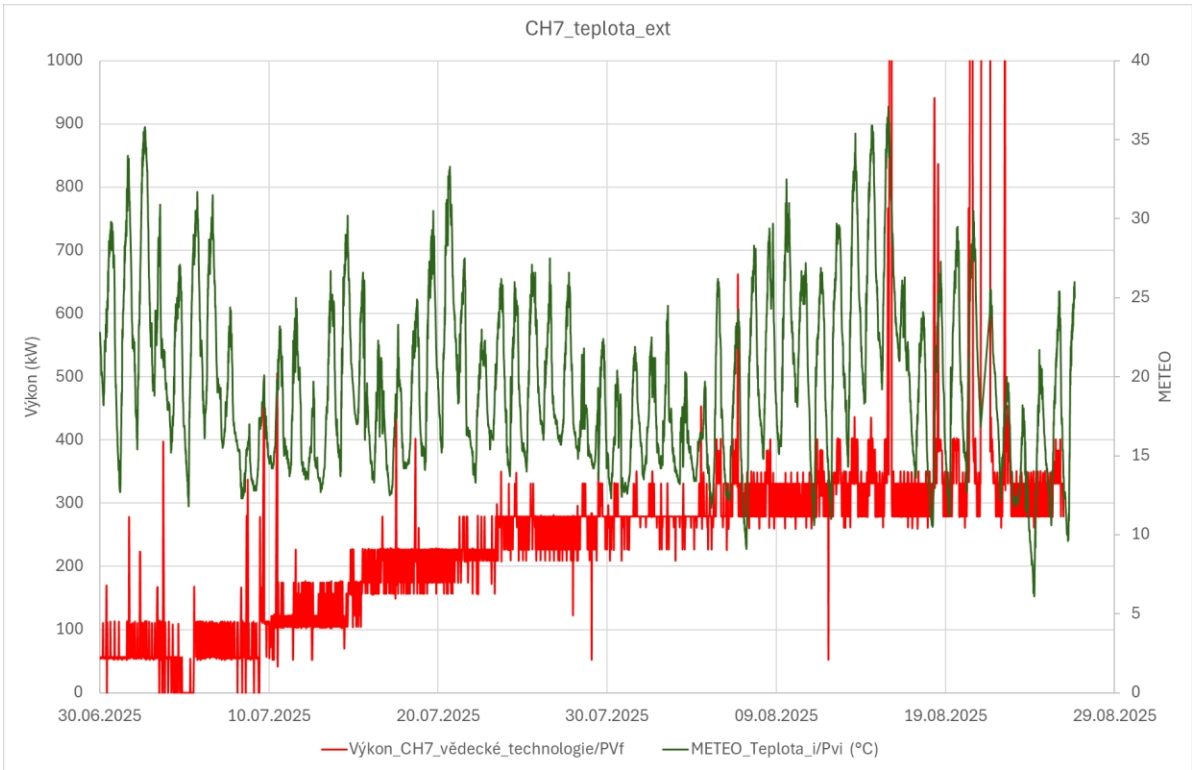


Fig. 17 Output of CH7 – scientific technologies (1/2 hour average) and Meteodata – outdoor air temperature

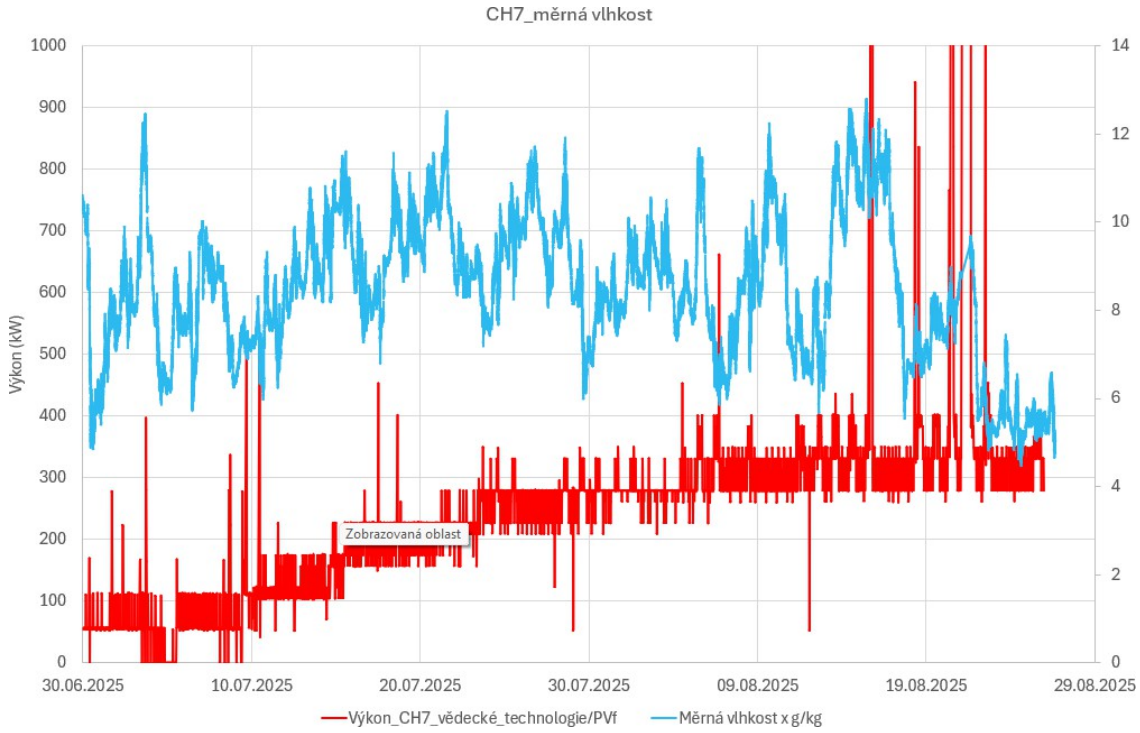


Fig. 18 CH7 performance – scientific technologies (1/2 hour average) and Meteodata – specific humidity of outdoor air

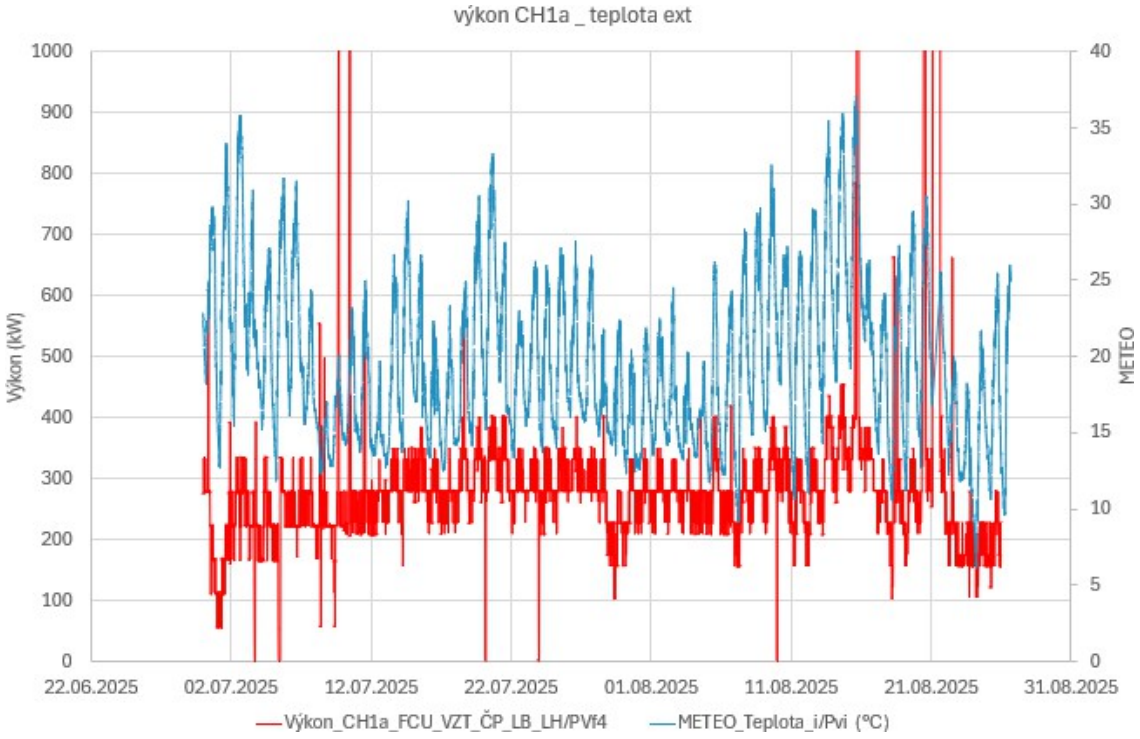


Fig. 19 CH1a output (1/2 hour average) and Meteodata – outdoor air temperature

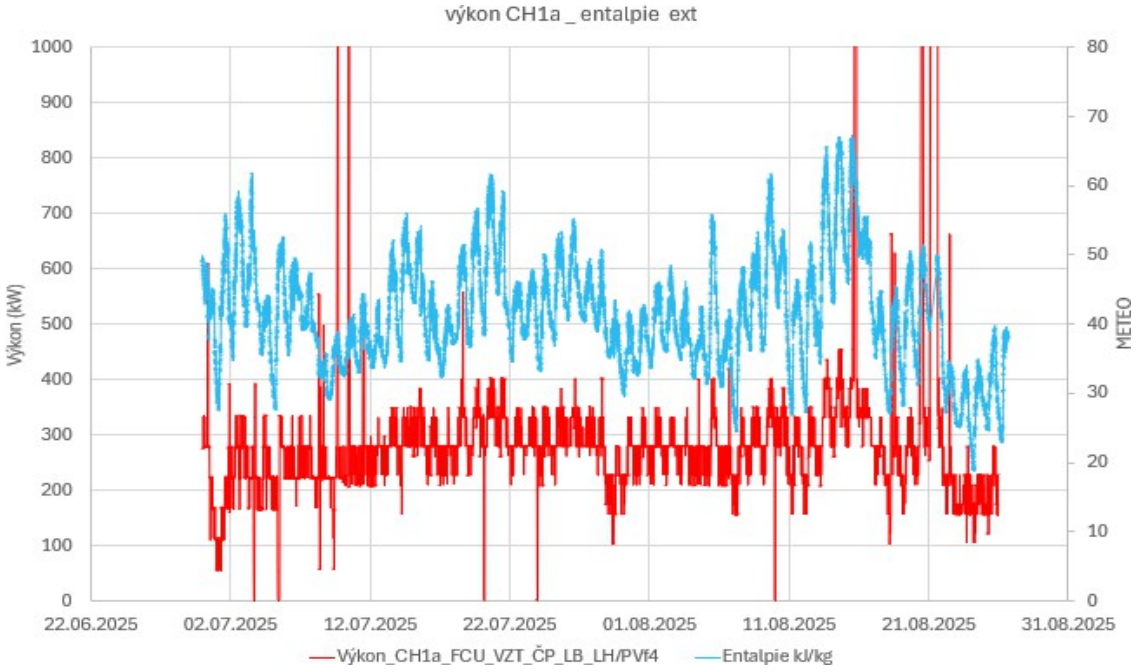


Fig. 20 CH1a output (1/2 hour average) and Meteodata – outdoor air enthalpy

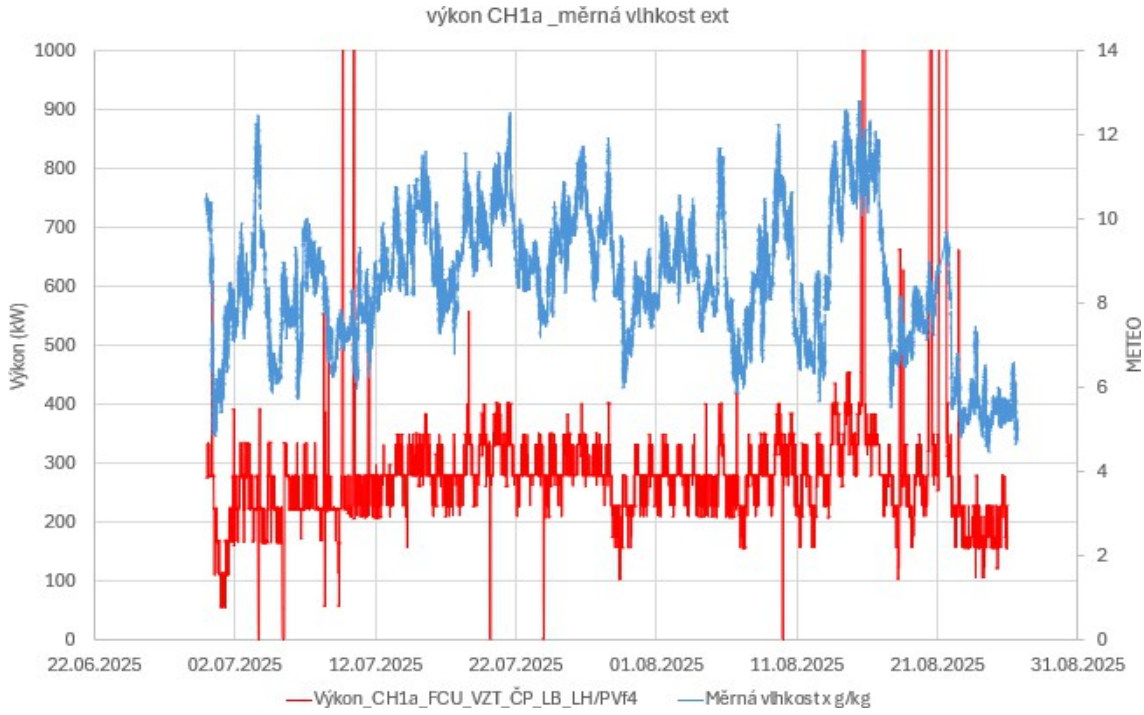


Fig. 21 CH1a output (1/2 hour average) and Meteodata – specific humidity of outdoor air

7.2.1 Partial conclusion

During the monitored period, the most significant consumption was in circuits CH1a and CH7. No direct correlation was observed between the cooling performance of circuit CH7 and outdoor climatic conditions. Short-term performance peaks are not linked to any extreme climatic data.

In circuit CH1a, a slight trend can be observed in the correlation between the nature of the performance curve and the enthalpy, temperature, and specific humidity of the outdoor air.

7.3 Analysis of operating data and reference measurements of temperatures and humidity in selected zones

The following operating data was provided for individual halls and AHU units at one-minute intervals:

- Exhaust temperature
- Supply air temperature
- Room temperature
- Exhaust humidity
- Supply humidity
- Room humidity
- Average temperature extracted from functional units
- Average humidity extracted from functional units

Reference measurements of air temperature and relative humidity were taken at five-minute intervals.
In halls L1, L2, L3, L4b, L4c, E1, E2, E3, E5 (see Table 1 for details), halls L1, L2, and E1 have been evaluated. For the other halls, a graphical evaluation of the data has been prepared at this stage of the research, with a detailed analysis to be carried out if necessary for the design of optimization measures.

Below is an evaluation of the operating data and reference values for halls L1, L2, E1 is provided in summary form for all parameters of each hall, then for each AHU unit located in the hall, for all inlets of all AHU units, for all outlets of all AHU units, and for all spatial values of all AHU units, always first for temperature values and then for humidity values.

7.3.1 Hall L1 - temperatures

7.3.1.1 Hall L1 Temperatures of all AHUs, TZB101 and required

Fig. 22 Hall L1 Temperatures of all AHUs, TZB101 and required

7.3.1.2 Hall L1 Temperatures of AHU 242C, TZB101 and required

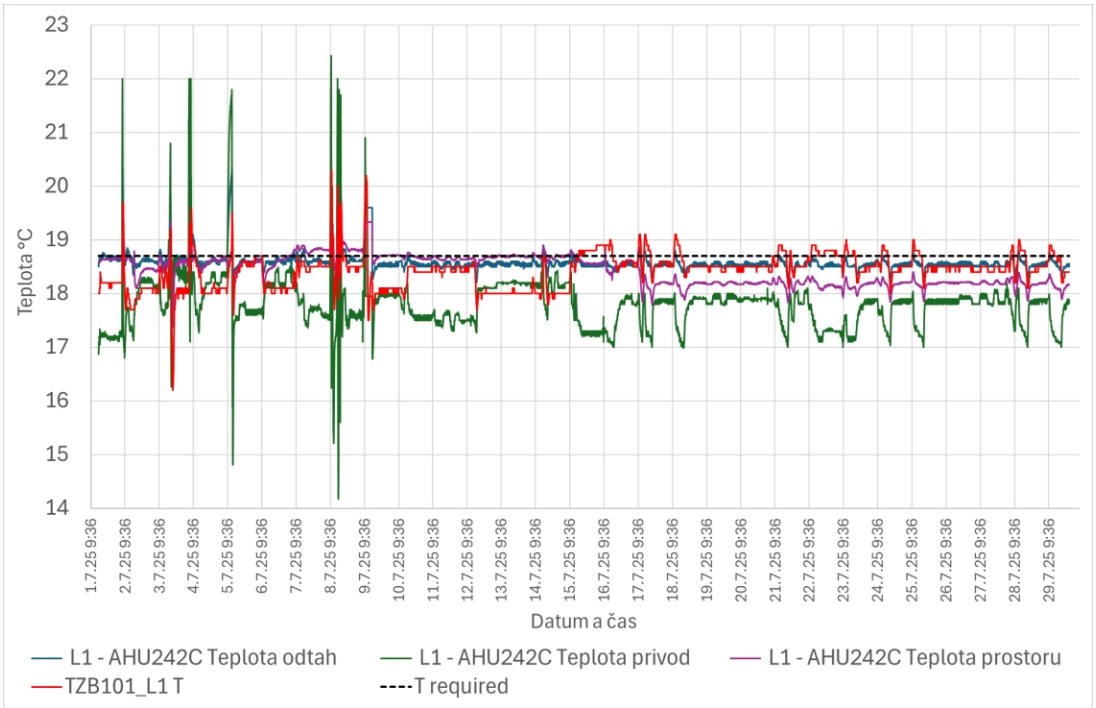


Fig. 23 Hall L1 Temperatures AHU 242C, TZB101 and required

7.3.1.3 Hall L1 Temperatures AHU 243C, TZB101 and required

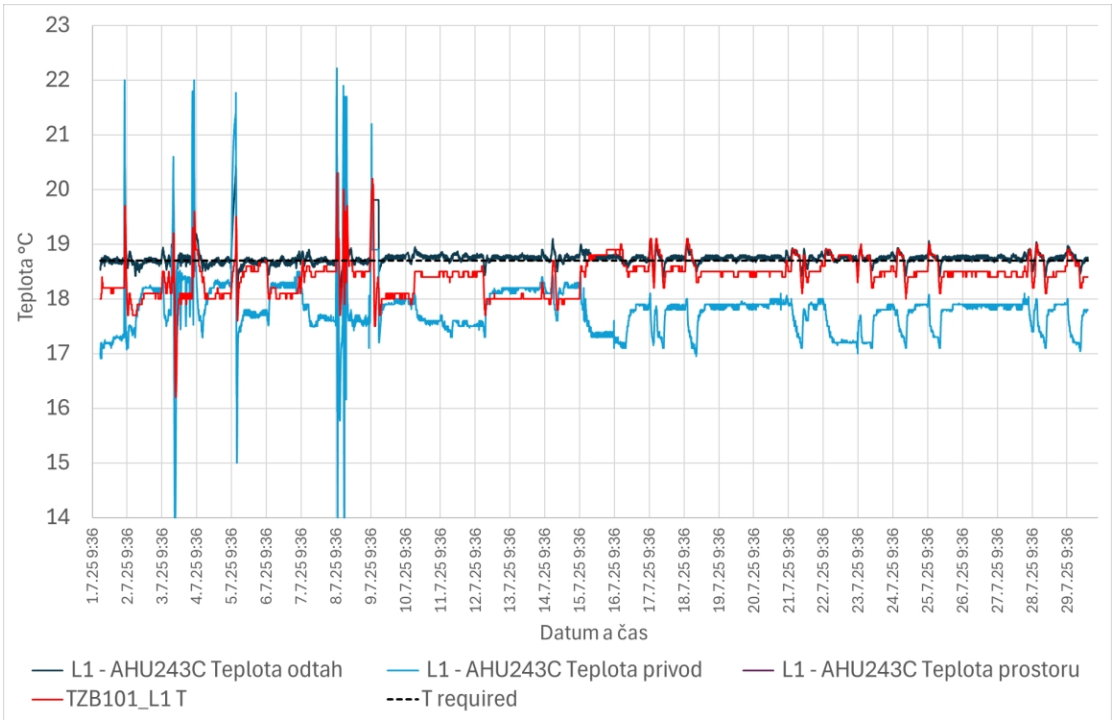


Fig. 24 Hall L1 Temperatures AHU 243C, TZB101 and required

7.3.1.4 Hall L1 Temperatures AHU 244C, TZB101 and required

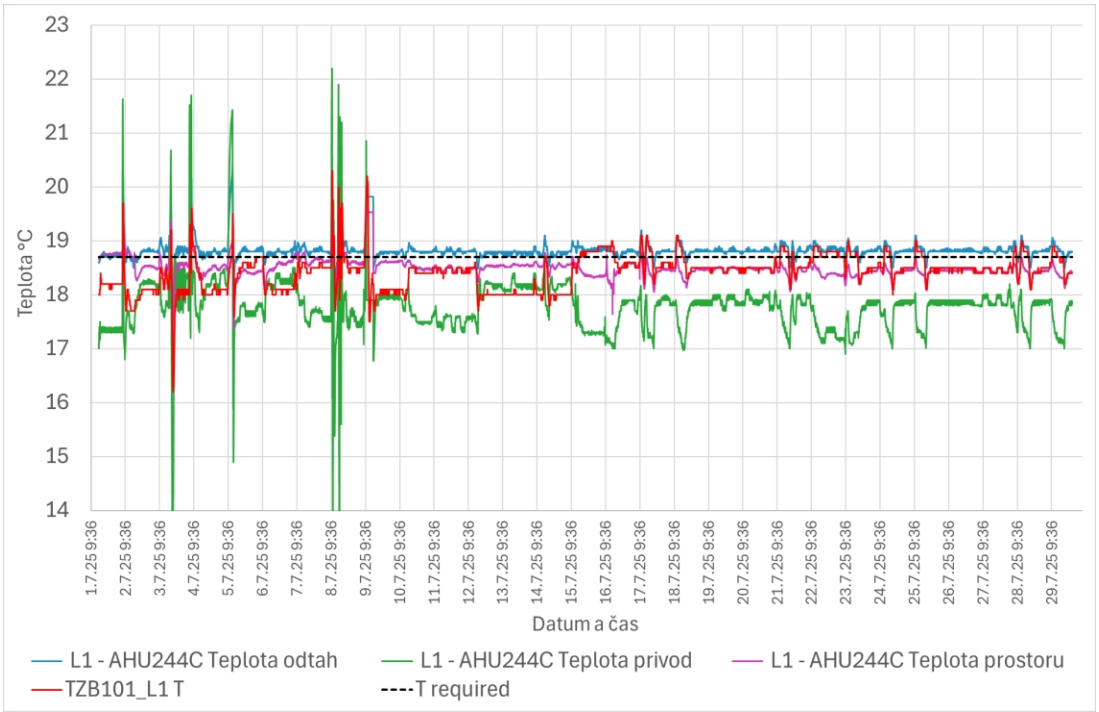


Fig. 25 Hall L1 Temperatures AHU 244C, TZB101 and required

7.3.1.5 *Hall L1 Temperatures all AHU exhaust, TZB101 and required*

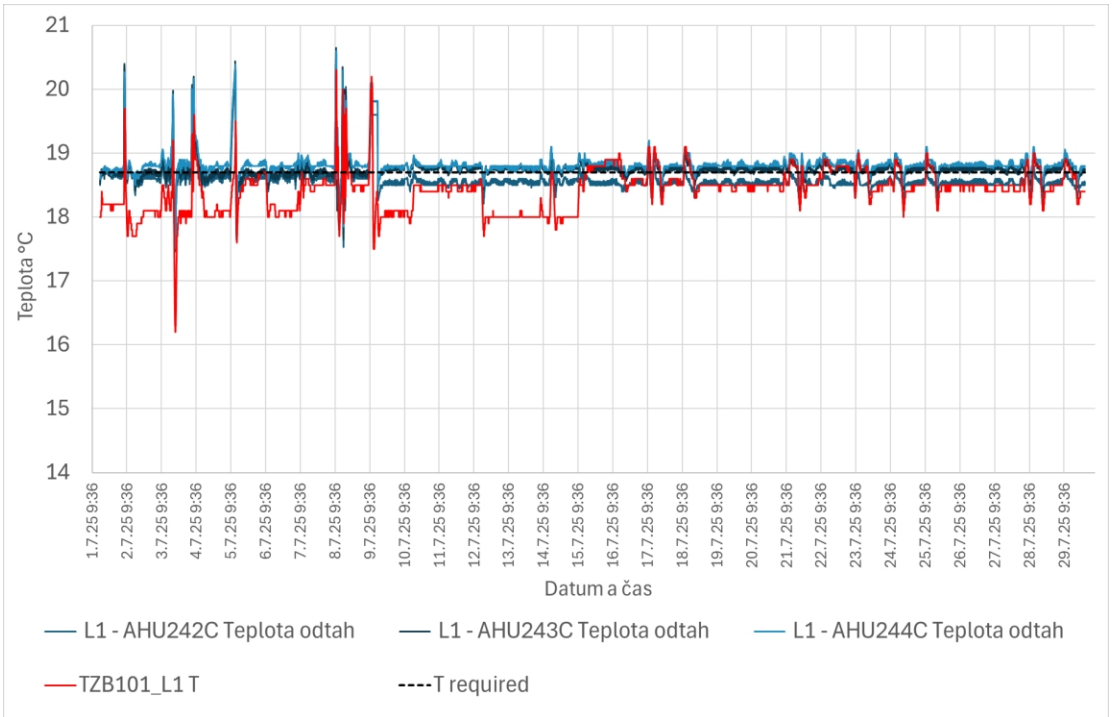


Fig. 26 Hall L1 Temperatures all AHU exhaust, TZB101 and required

7.3.1.6 *Hall L1 Temperatures all AHU supply, TZB101 and required*

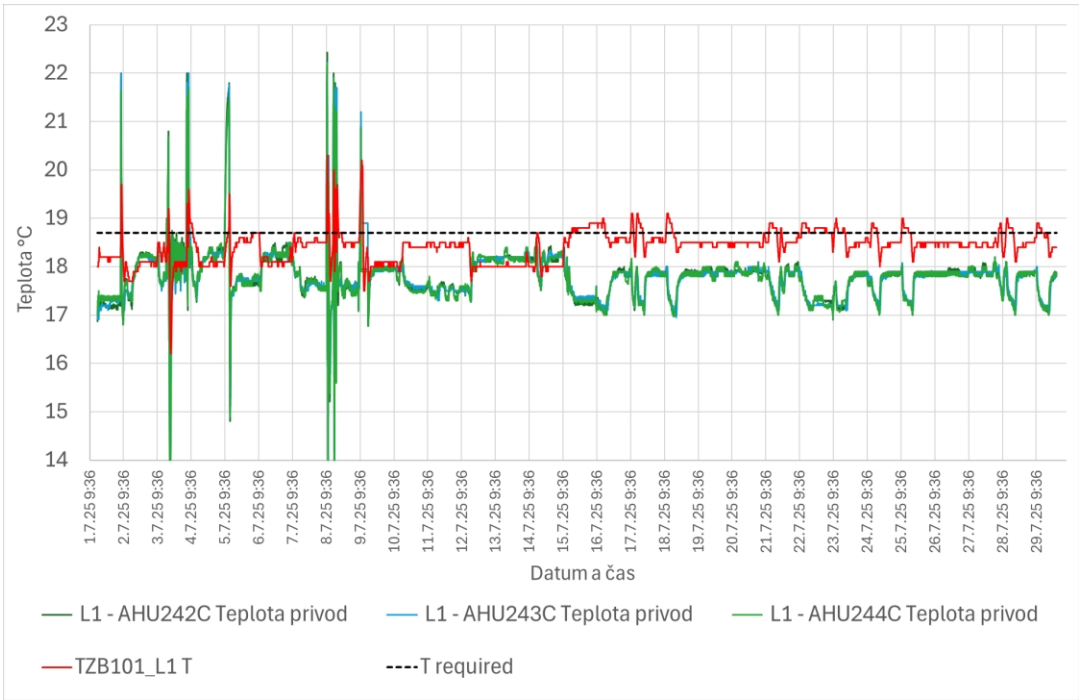


Fig. 27 Hall L1 Temperatures of all AHU supply, TZB101 and required

7.3.1.7 Hall L1 Temperatures of AHU 242C and 244C (243C strange data!!! Temperature 0.06°C) space, TZB101 and required

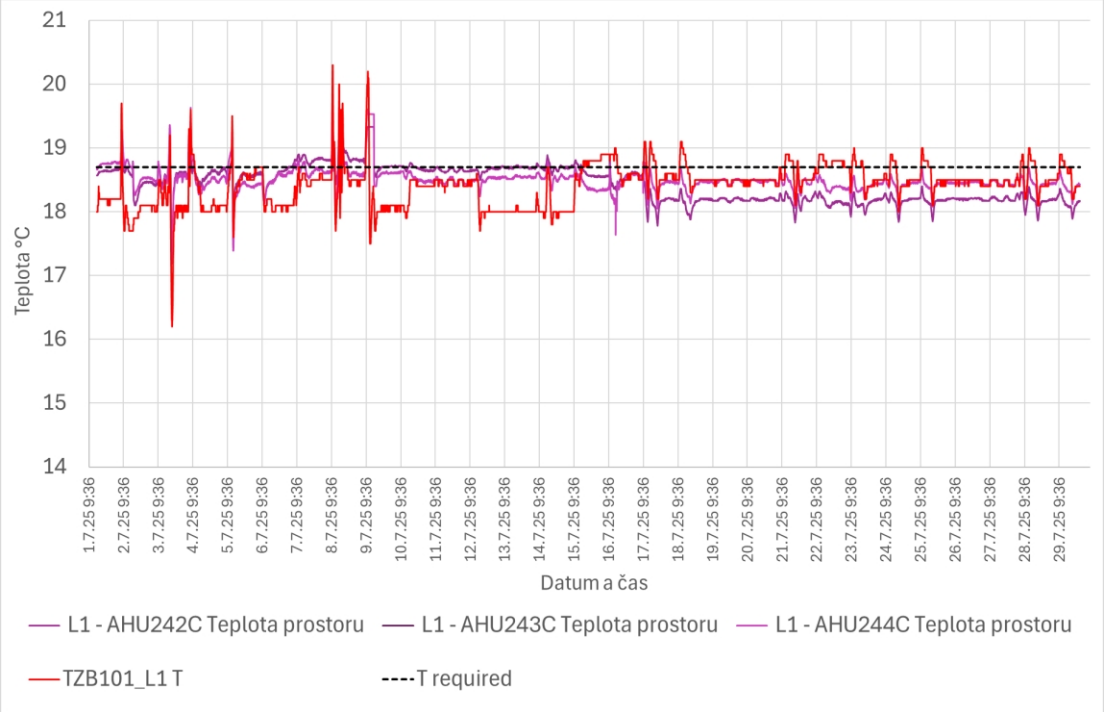


Fig. 28 Hall L1 Temperatures of AHU 242C and 244C (243C strange data!!! Temperature 0.06°C) space, TZB101 and required

7.3.1.8 Partial conclusion – L1 temperatures:

In the period from July 1 to July 15, 2025, the system shows large short-term fluctuations in the supply of all AHU units from approximately 14 °C to 22.5 °C, which are also reflected in the room and exhaust temperatures. Reference measurements by an independent device show a deviation from the desired temperature (+-1 °C).

In the period from July 15 to July 29, 2025, the system stabilized; fluctuations in the supply of AHU units from approximately 17
°C to 18.5 °C. AHU 242C is closest to the reference value, which is approximately 0.2 °C lower than the required value (T required 18.7 °C). The required value is maintained at the exhaust of units AHU 243C and 244C.

The exhaust values of all AHU units show the same pattern, differing only by approx. 0.1-0.3 °C, but all are close to the required value with occasional fluctuations with a maximum difference of approx. 0.5 °C.

Sensors labeled as room temperature only measure for AHU 242C and 244C. The AHU 243C sensor provides meaningless data. The values of the sensors marked as room temperature for AHU242C are approx. 0.5°C lower than the required value, for AHU 244C approx. 0.2°C lower, and these values also correspond approximately to the reference sensor.

7.3.2 Hall L1 - Humidity

7.3.2.1 Hall L1 RH all AHUs, TZB101

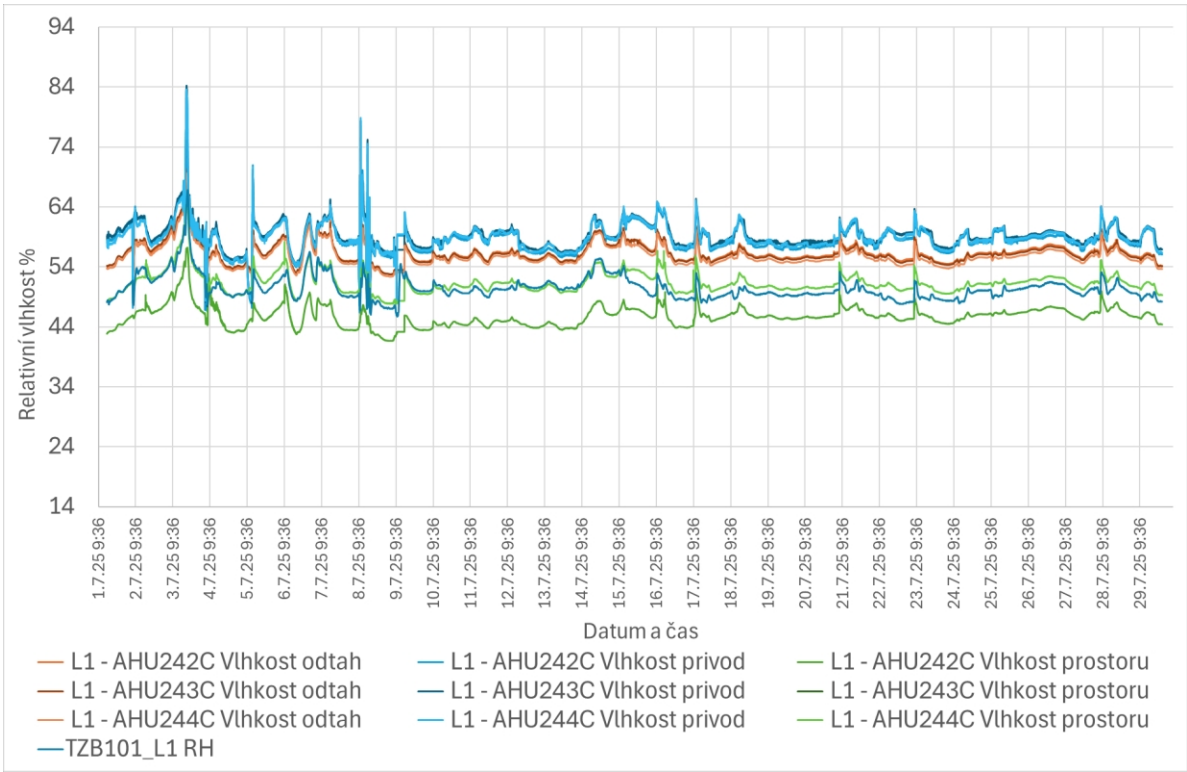


Fig. 29 Hall L1 Temperatures AHU 242C and 244C (243C strange data!!! Temperature 0.06°C) space, TZB101 and required

7.3.2.2 Hall L1 RH AHU 242C, TZB101

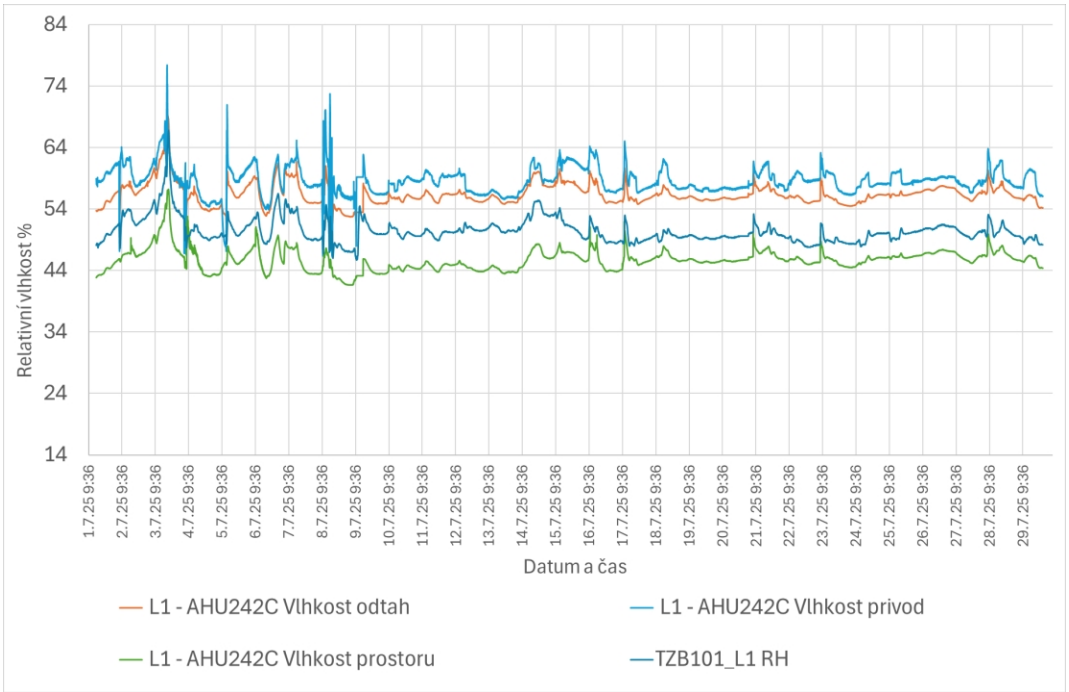


Fig. 30 Hall L1 RH AHU 242C, TZB101

7.3.2.3 Hall L1 RH AHU 243C, TZB101

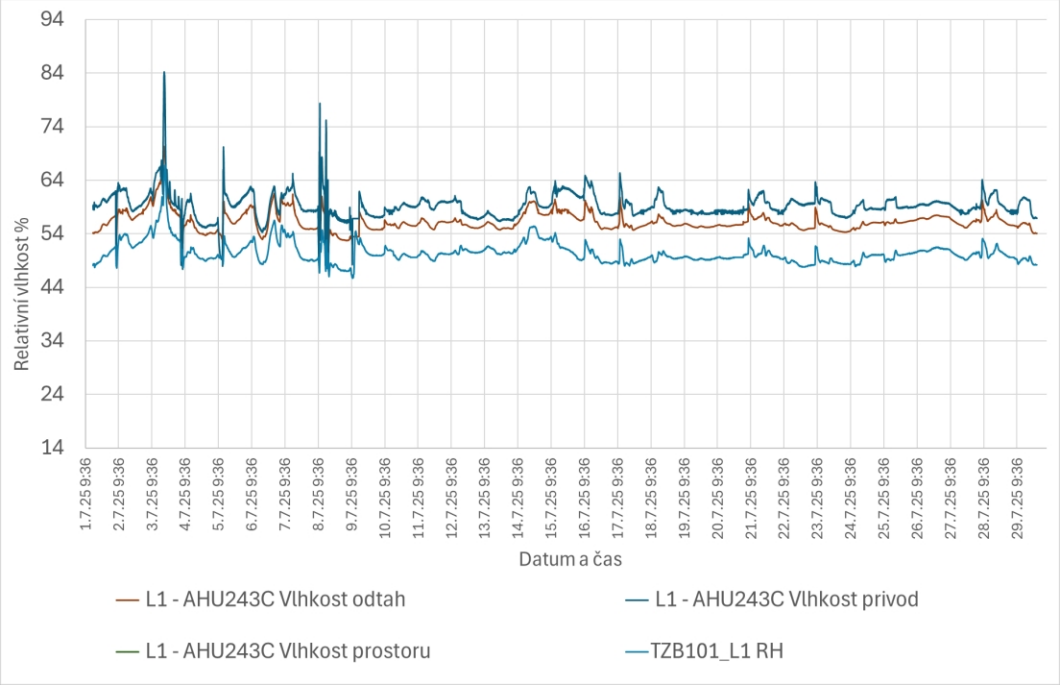


Fig. 31 Hall L1 RH AHU 243C, TZB101

7.3.2.4 Hall L1 RH AHU 244C, TZB101

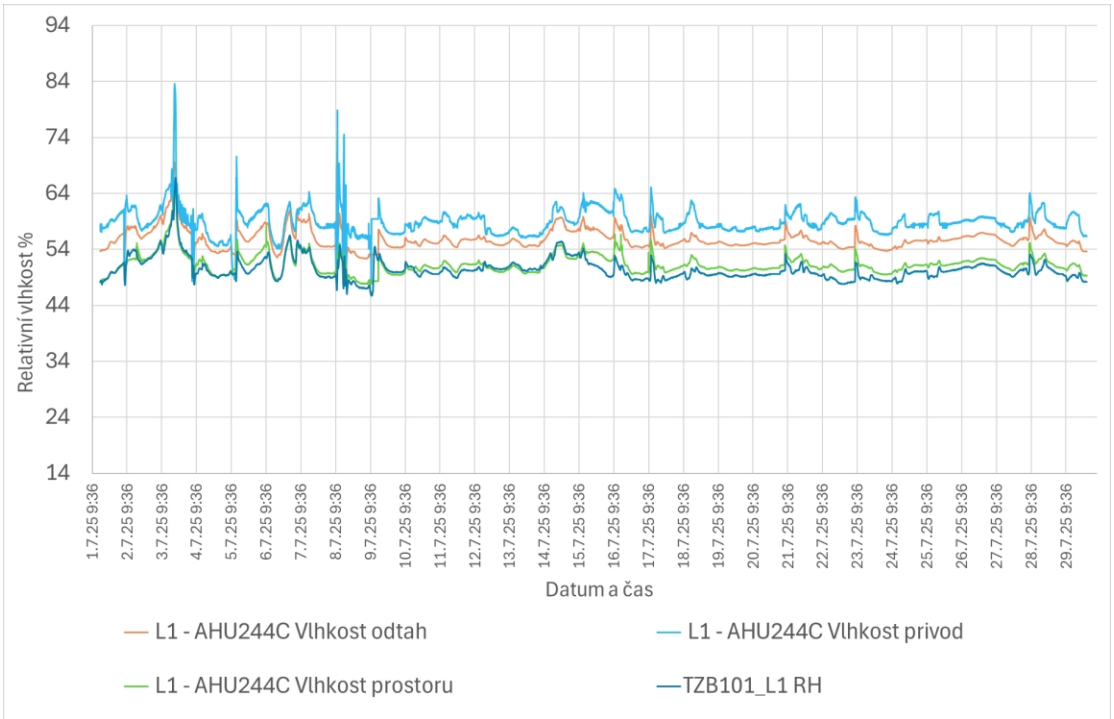


Fig. 32 Hall L1 RH AHU 244C, TZB101

7.3.2.5 Hall L1 RH all AHU exhaust, TZB101

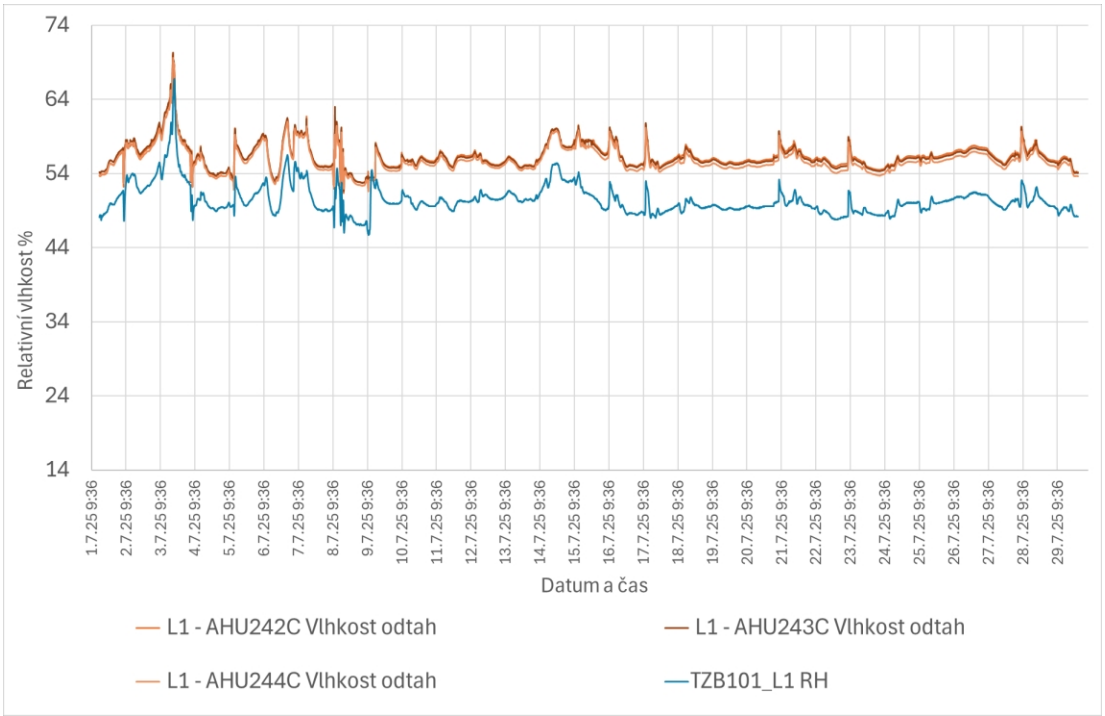


Fig. 337.3.1.12 Hall L1 RH all AHU exhaust, TZB101

7.3.2.6 Hall L1 RH all AHU supply, TZB101

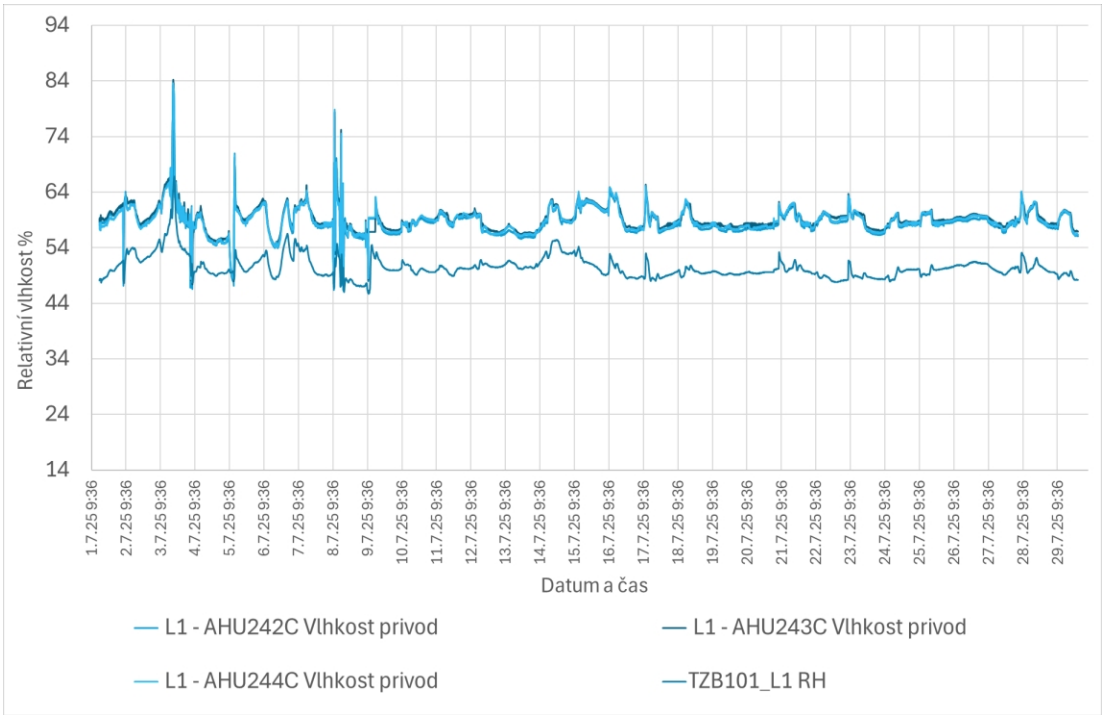


Fig. 34 Hall L1 RH all AHU supply, TZB101

7.3.2.7 Hall L1 RH AHU2 242C and 244C (243C strange data!!!RH 0.19%) space, TZB101

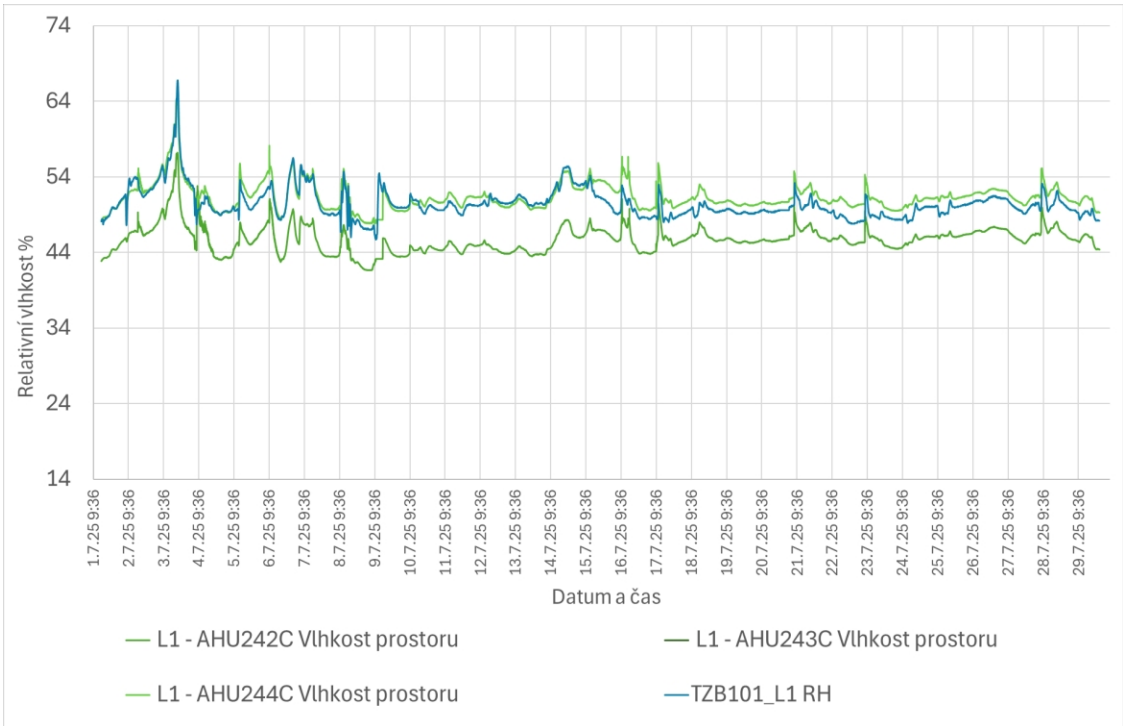


Fig. 35 Hall L1 RH AHU2 242C and 244C (243C strange data!!!RH 0.19%) space, TZB101

7.3.2.8 Partial conclusion – Hall L1 humidity

The supply and exhaust values of all AHUs are more or less identical and differ from the reference value by approximately
10%.

Sensors labeled as room humidity only measure for AHU 242C and 244C. The AHU 243C sensor provides meaningless data. The values of sensors labeled as room humidity for AHU242C are approximately 5% lower than the reference value, while for AHU 244C they correspond approximately to the reference sensor.

7.3.3 HALL L2 - temperatures

7.3.3.1 Hall L2 Temperatures of all AHUs, TZB104 and required

Fig. 36 Hall L2 Temperatures of all AHUs, TZB104 and required

7.3.3.2 Hall L2 Temperatures of AHU 247C, TZB104 and required

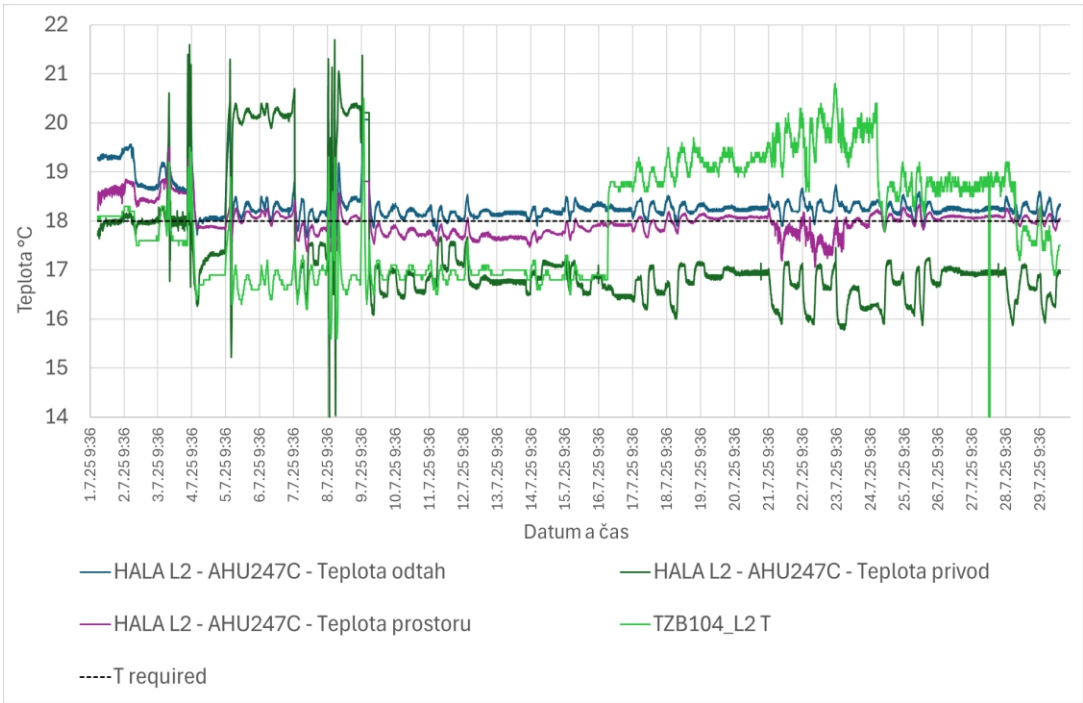


Fig. 37 Hall L2 Temperatures of AHU 247C, TZB104 and required

7.3.3.3 Hall L2 Temperatures of AHU 248C, TZB104 and required

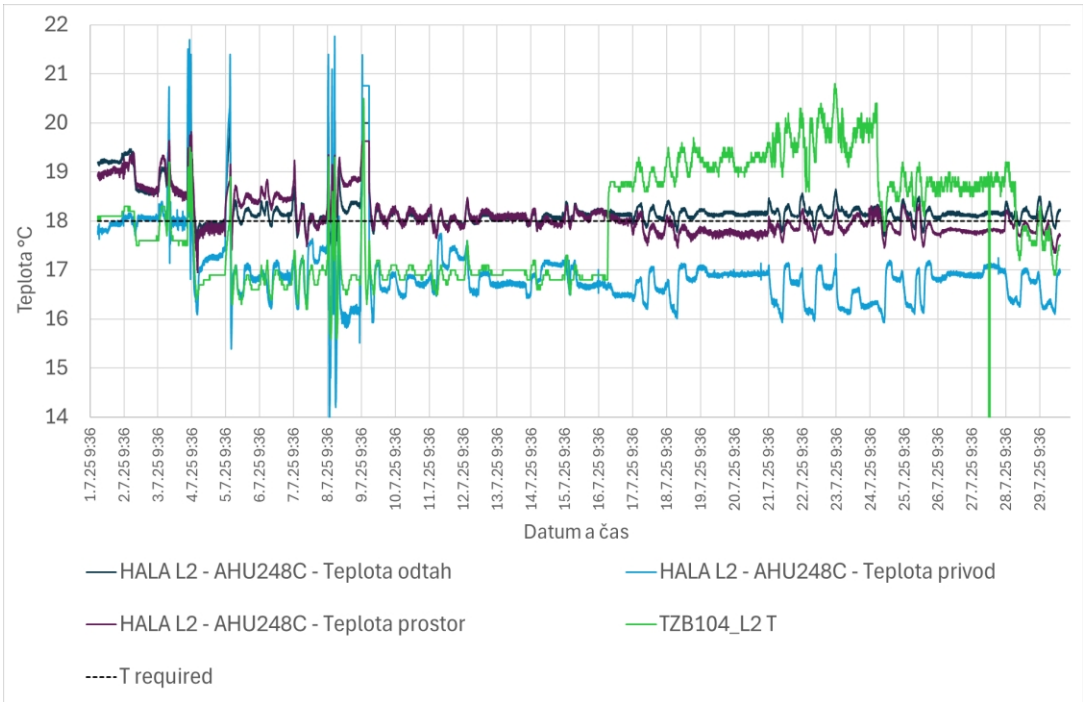


Fig. 38 Hall L2 Temperatures AHU 248C, TZB104 and required

7.3.3.4 *Hall L2 Temperatures AHU 249C, TZB104 and required*

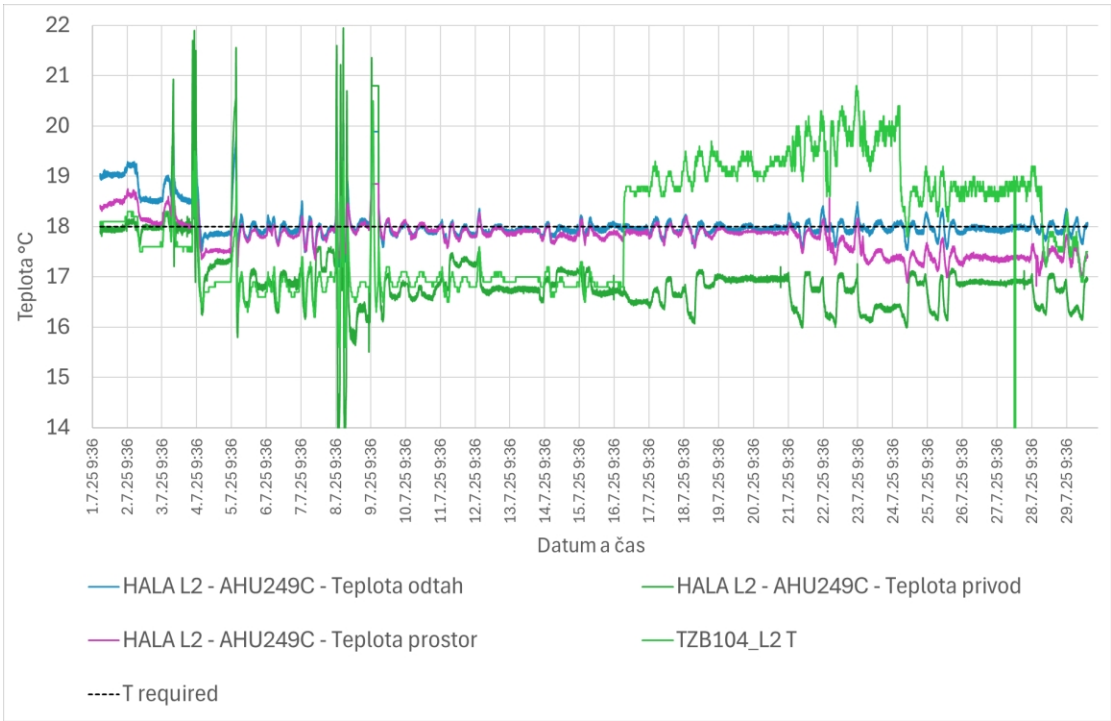


Fig. 39 Hall L2 Temperatures AHU 249C, TZB104 and required

7.3.3.5 *Hall L2 Temperatures AHU 250C, TZB104 and required*

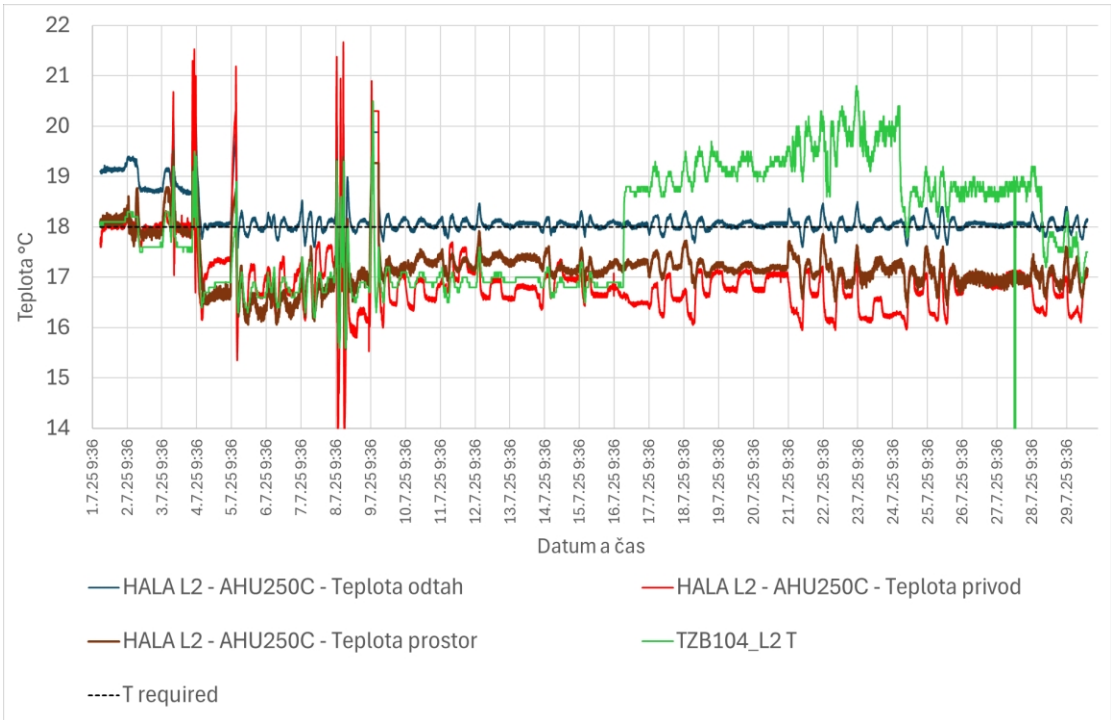


Fig. 40 Hall L2 AHU temperatures 250C, TZB104 and required

7.3.3.6 Hall L2 Temperatures AHU 251C, TZB104 and required

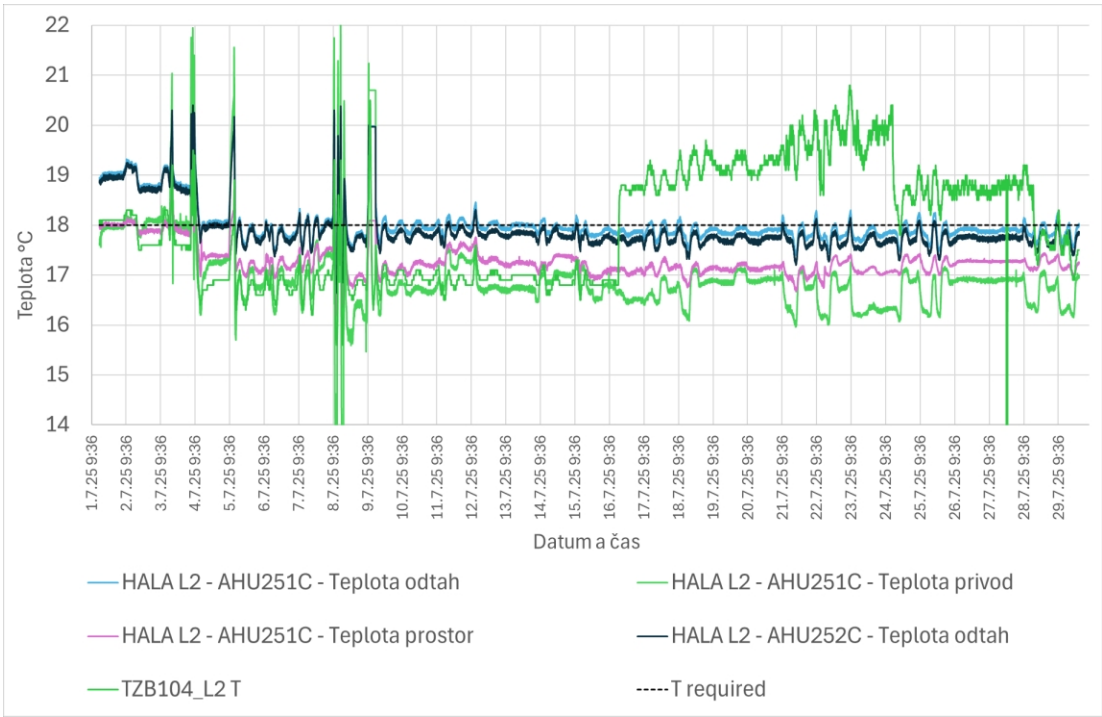


Fig. 41 Hall L2 AHU temperatures 251C, TZB104 and required

7.3.3.7 Hall L2 Temperatures AHU 252C, TZB104 and required

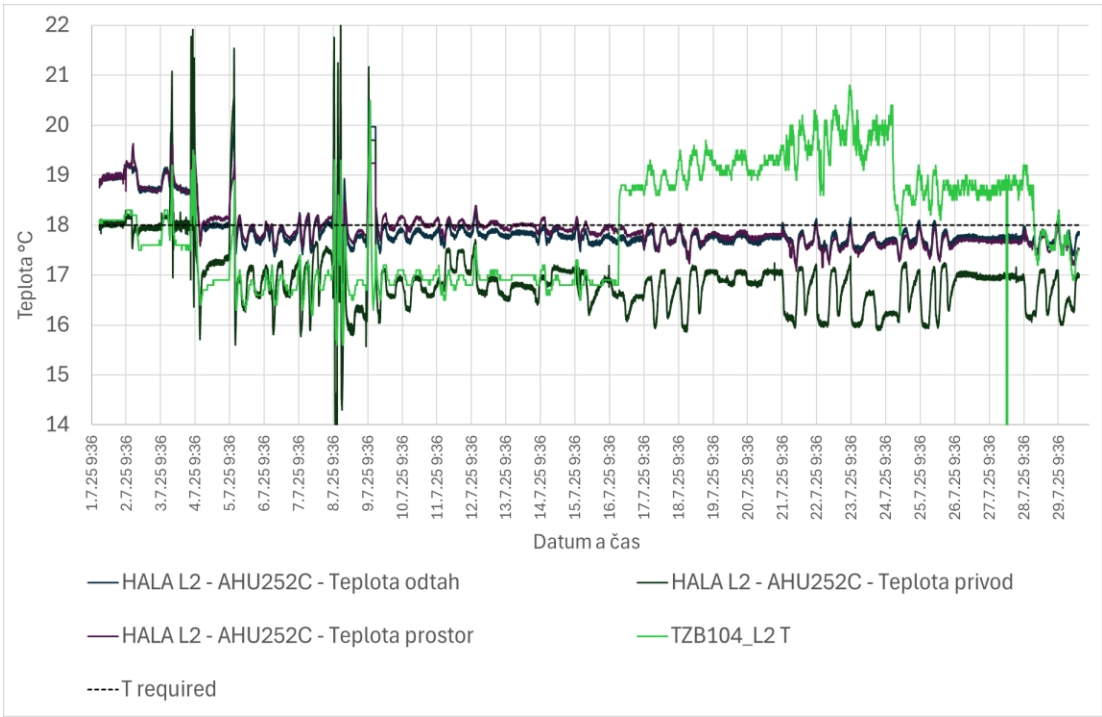


Fig. 42 Hall L2 Temperatures AHU 252C, TZB104 and required

7.3.3.8 Hall L2 Temperatures of all AHU exhaust, TZB104 and required

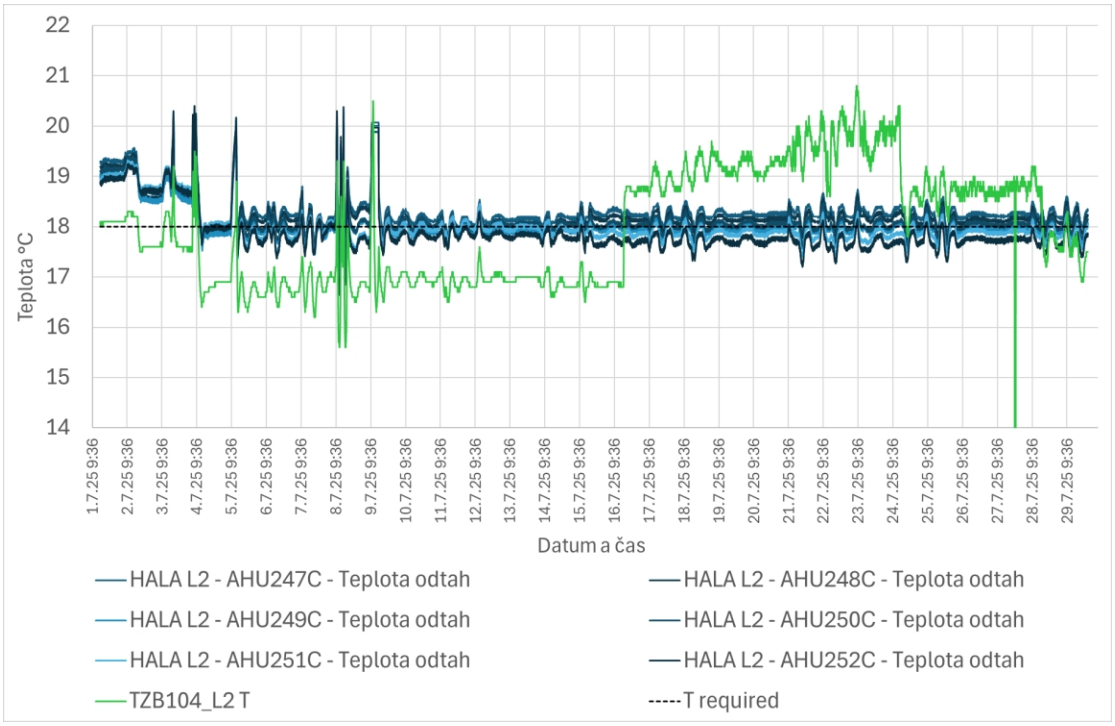


Fig. 43 Hall L2 Temperatures of all AHU exhaust, TZB104 and required

7.3.3.9 Hall L2 Temperatures of all AHU supply, TZB104 and required

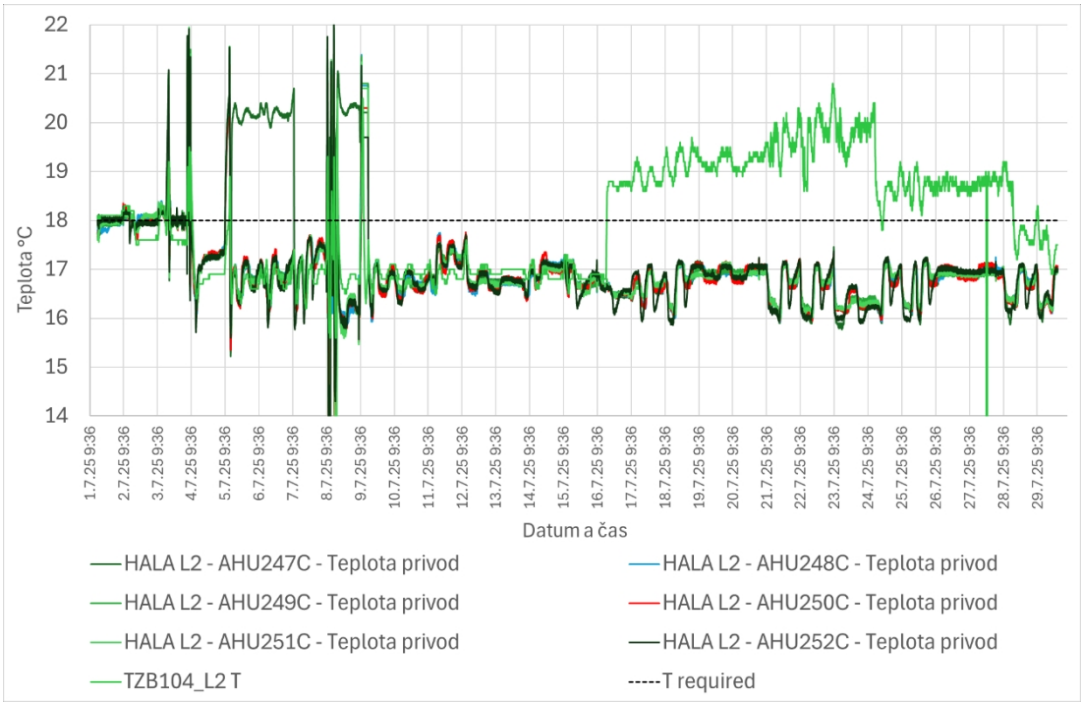


Fig. 44 Hall L2 Temperatures all AHU supply, TZB104 and required

7.3.3.10 Hall L2 Temperatures of all AHU spaces, TZB104 and required

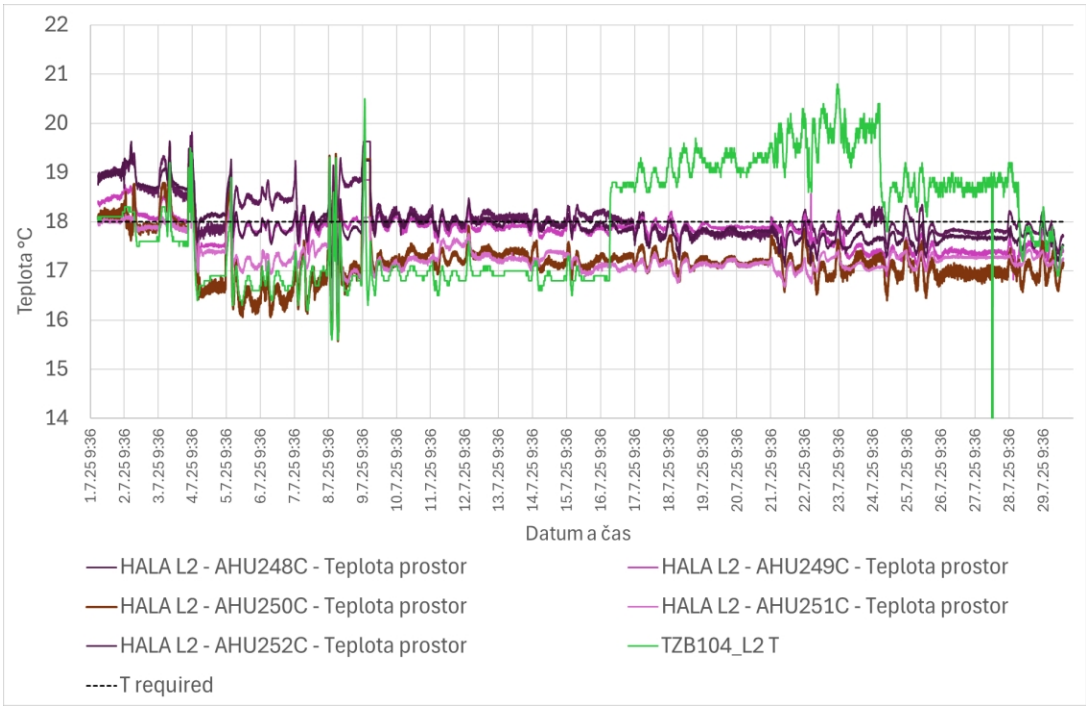


Fig. 45 Hall L2 Temperatures of all AHU spaces, TZB104 and required

7.3.3.11 Partial conclusion – Hall L2 temperatures

In the period from July 1 to July 9, 2025, the system shows greater short-term fluctuations in the supply of all AHU units from approximately 15.5 °C to 20.5 °C, which are also reflected in the room and exhaust temperatures. Reference measurements taken by an independent device show a deviation from the desired temperature (+-1 °C), but the reference sensor was probably moved on July 17, as its values are significantly different until July 28, when they return to the expected values.

In the period from July 12 to July 21, 2025, the system stabilized; fluctuations in the supply of AHU units ranged from approximately 15.9 °C to 17.2 °C, and their curves are almost identical for all AHU units.

The exhaust values of all AHU units show the same pattern, differing only by approximately 0.1-0.5 °C, but all are close to the required value with occasional fluctuations with a maximum difference of approximately 0.8 °C.

The values of the sensors marked as room temperature for AHU247C, 248C, and 252C are close to the required value, differing by approximately +- 0.1–0.3 °C. The values for AHU249C are close to the required value in the period from July 10 to July 21, lower by approx. 0.1 °C. From July 21 to July 29, they oscillate more and are lower by up to approx. 0.7 °C.
°C. The values for AHU250C and 251C are approximately 0.5–1.5 °C lower than the required value in the period from July 21 to July 29, and they fluctuate more. The values for AHU 252C

The values for AHU 250C and 251C from July 10 to July 16, 2025, approximately correspond to the reference sensor, being approximately 0.3°C higher. The reference sensor was probably moved on July 17, as its values are significantly different until July 28, when they return to the expected values.

7.3.4 HALL L2 - humidity

7.3.4.1 Hall L2 RH all AHUs, TZB104

Fig. 46 7.3.2.11 Hall L2 RH all AHUs, TZB104

7.3.4.2 Hall L2 RH AHU 247C, TZB104

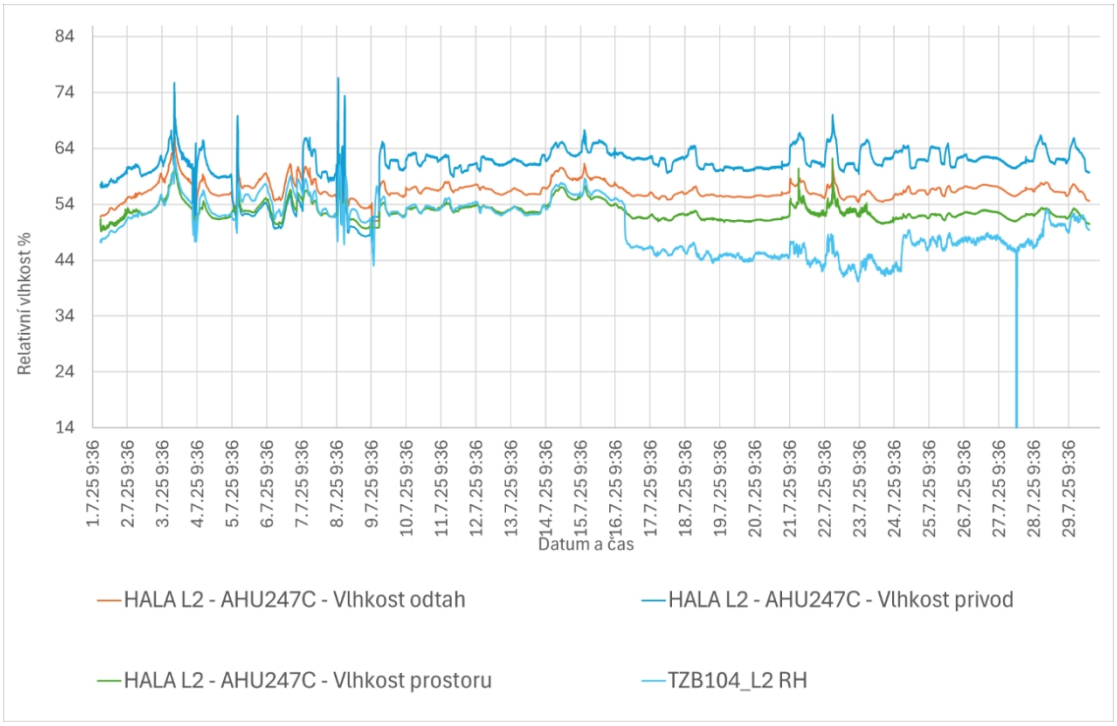


Fig. 47 7.3.2.12 Hall L2 RH AHU 247C, TZB104

7.3.4.3 Hall L2 RH AHU 248C, TZB104

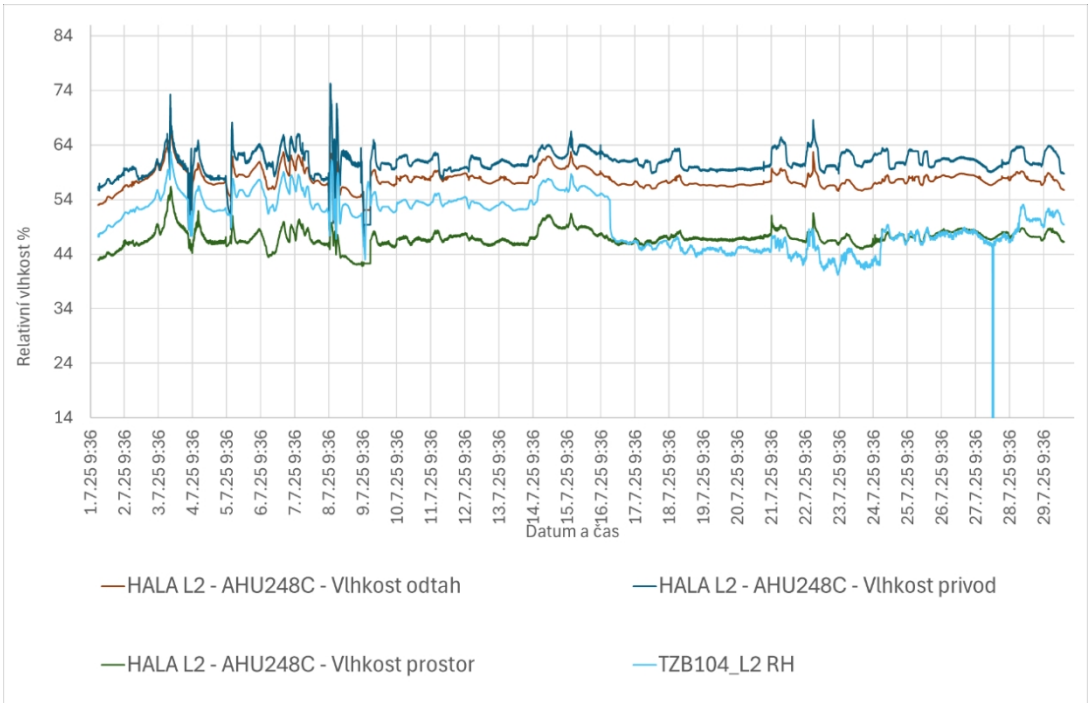


Fig. 48 Hall L2 RH AHU 248C, TZB104

7.3.4.4 Hall L2 RH AHU 249C, TZB104

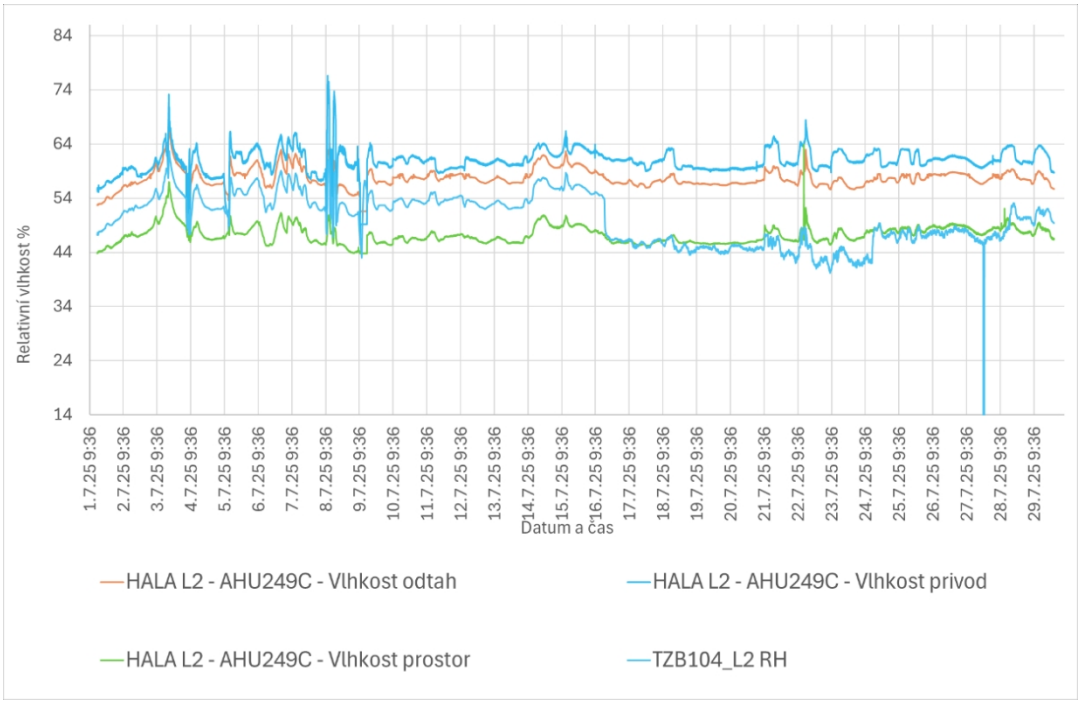


Fig. 49 Hall L2 RH AHU 249C, TZB104

7.3.4.5 Hall L2 RH AHU 250C, TZB104

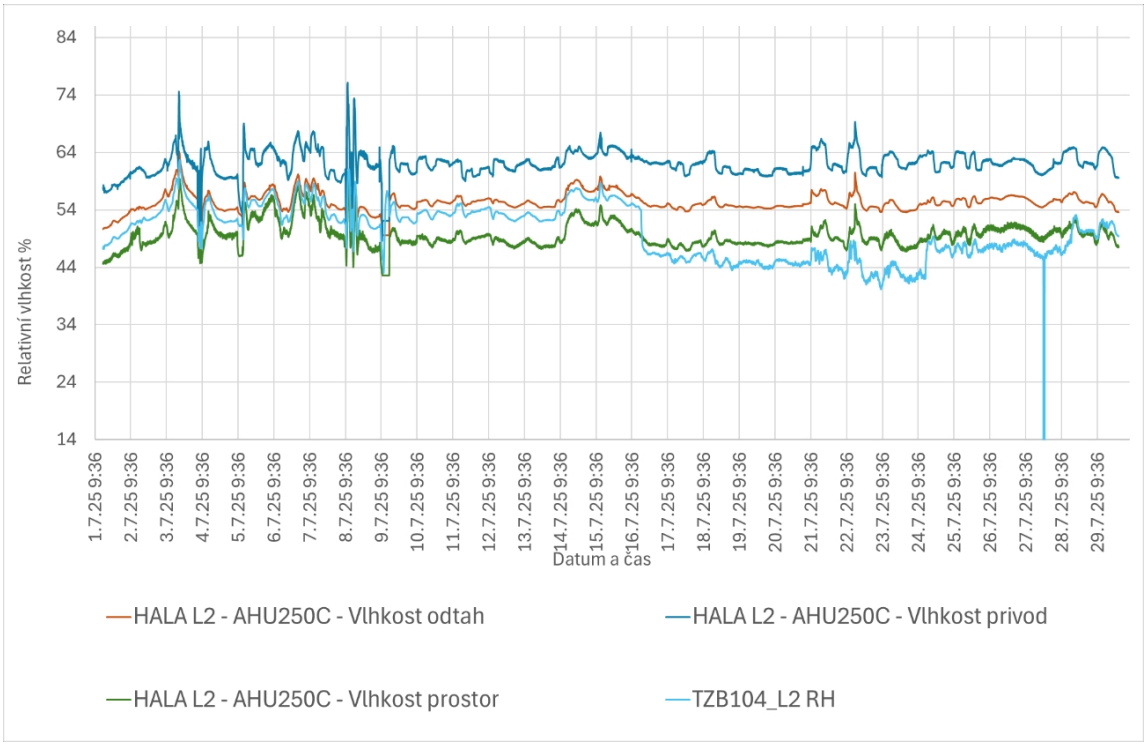


Fig. 50 Hall L2 RH AHU 250C, TZB104

7.3.4.6 Hall L2 RH AHU 251C, TZB104

Fig. 51 Hall L2 RH AHU 251C, TZB104

7.3.4.7 *Hall L2 RH AHU 252C, TZB104*

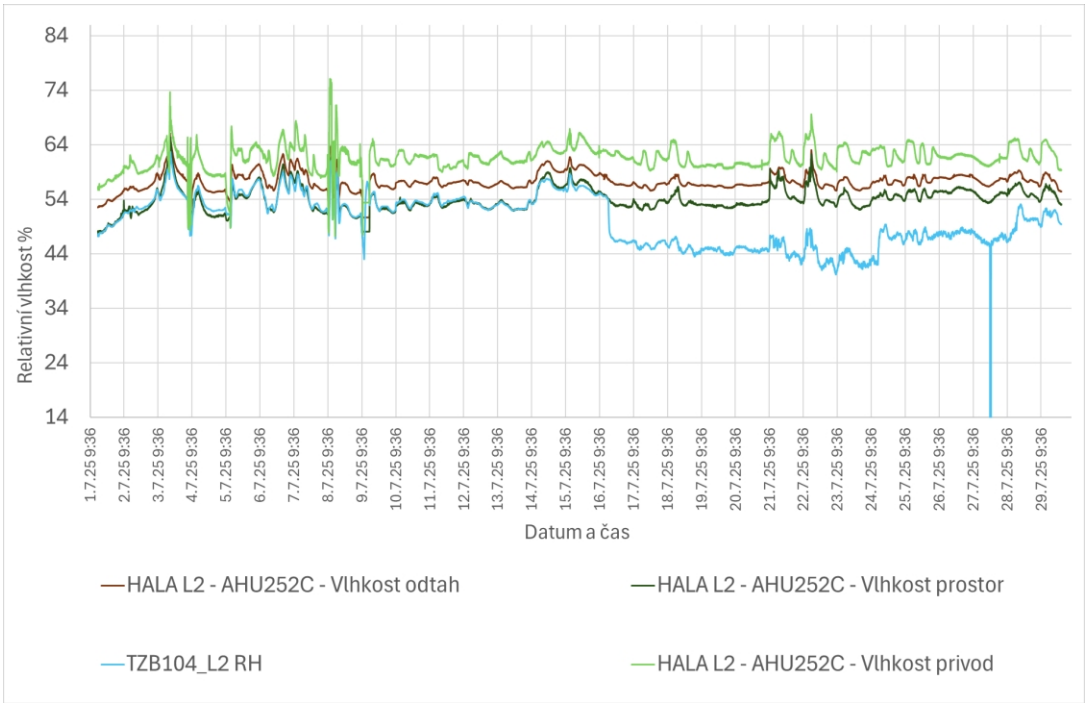


Fig. 52 Hall L2 RH AHU 252C, TZB104

7.3.4.8 *Hall L2 RH all AHU exhaust, TZB104*

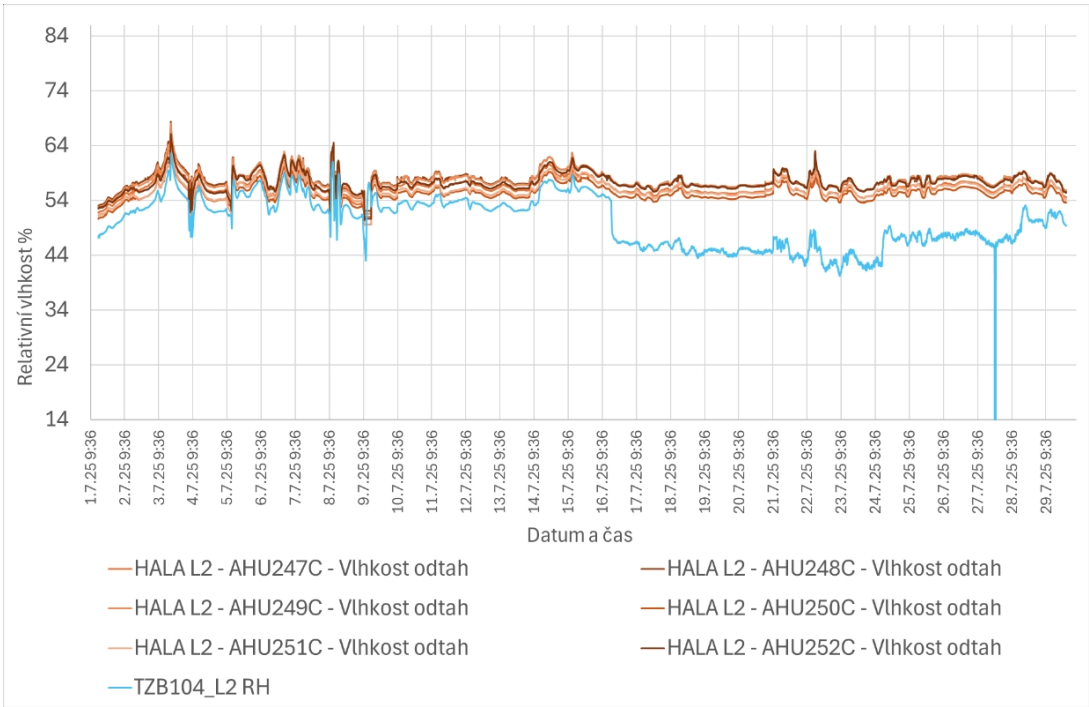


Fig. 53 Hall L2 RH all AHU exhaust, TZB104

7.3.4.9 *Hall L2 RH all AHU supply, TZB104*

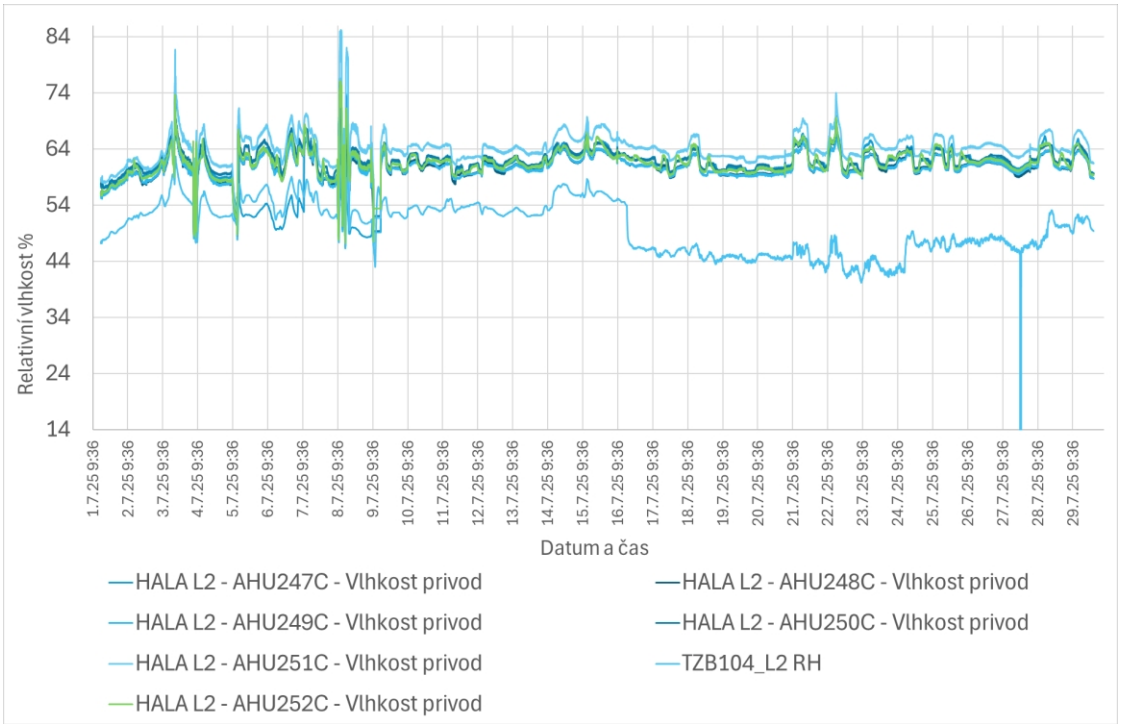


Fig. 54 Hall L2 RH all AHU supply, TZB104

7.3.4.10 *Hall L2 RH all AHU space, TZB104*

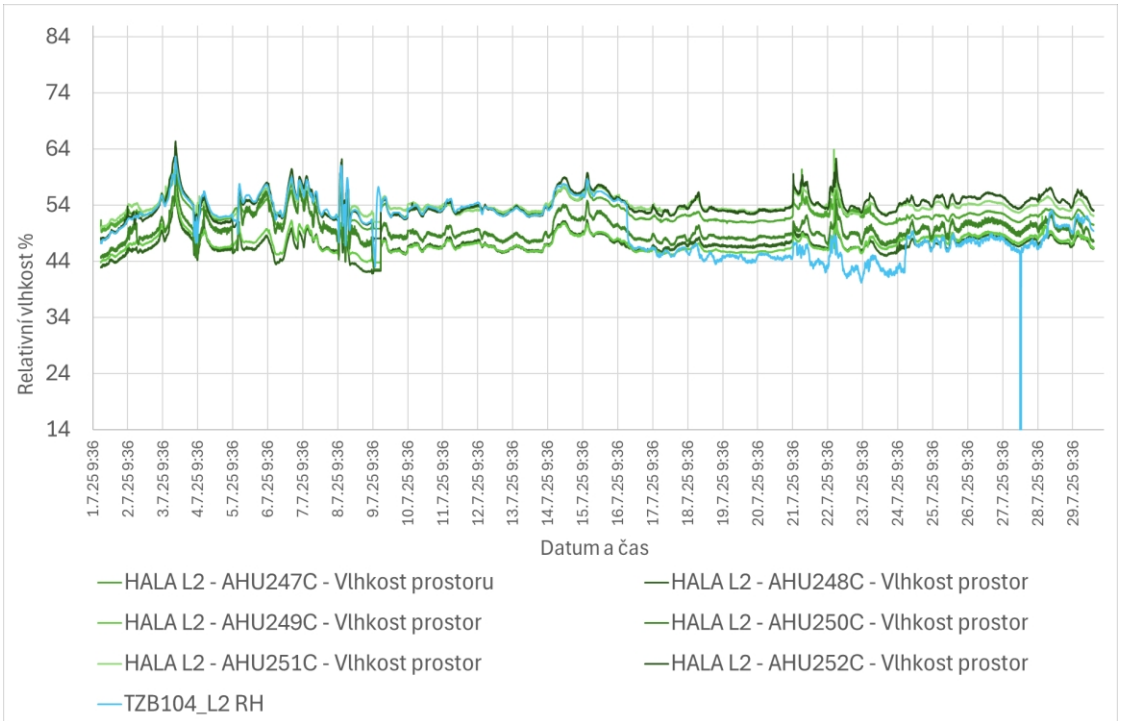


Fig. 55 Hall L2 RH all AHU space, TZB104

7.3.4.11 Partial conclusion – Hall L2 humidity

The values and curves for the supply and exhaust of all AHUs are more or less identical, with the supplies differing from the reference value by approx. 10% RH and the exhausts differing minimally (both except for the probable relocation of the reference sensor).

The values of the sensors marked as room humidity are almost identical to the reference values from July 10 to July 16, 2025 for AHU250C, 251C, 252C, and for AHU 247C, 248C, 249C, the values are slightly lower than for the reference sensor, by approximately 5-8% RH.

7.3.5 HALL E1 - temperatures

7.3.5.1 Hall E1 Temperatures of all AHUs, TZB103 and required

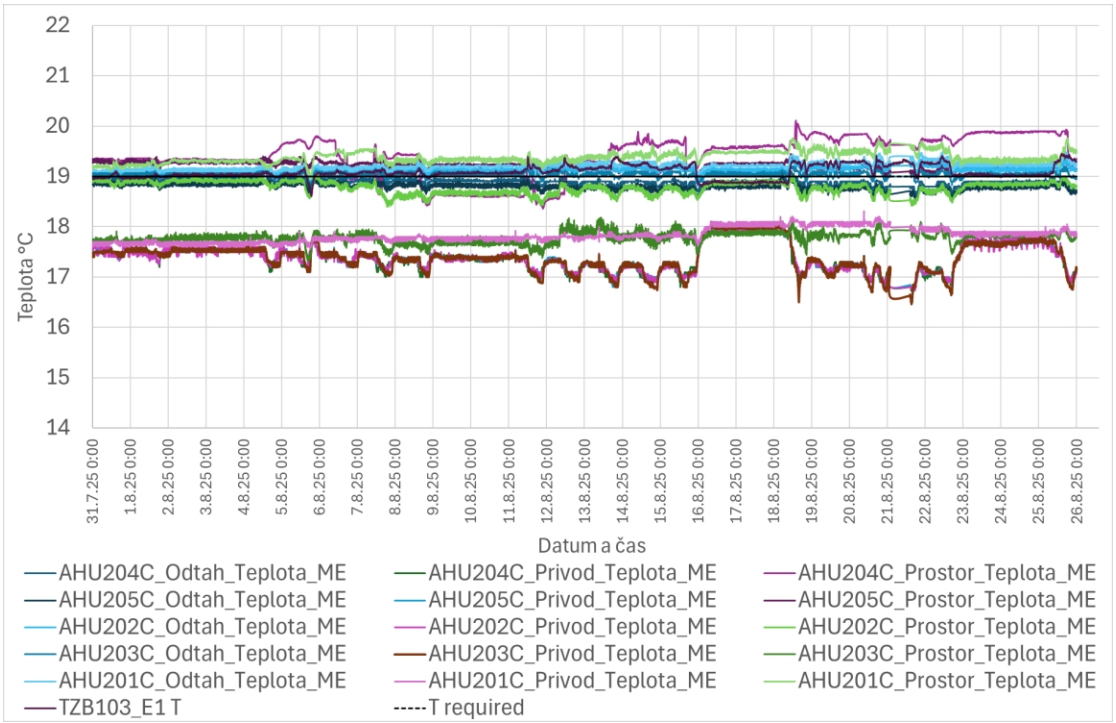


Fig. 56 Hall E1 Temperatures of all AHUs, TZB103 and required

7.3.5.2 *Hall E1 Temperatures of AHU 201C, TZB103 and required*

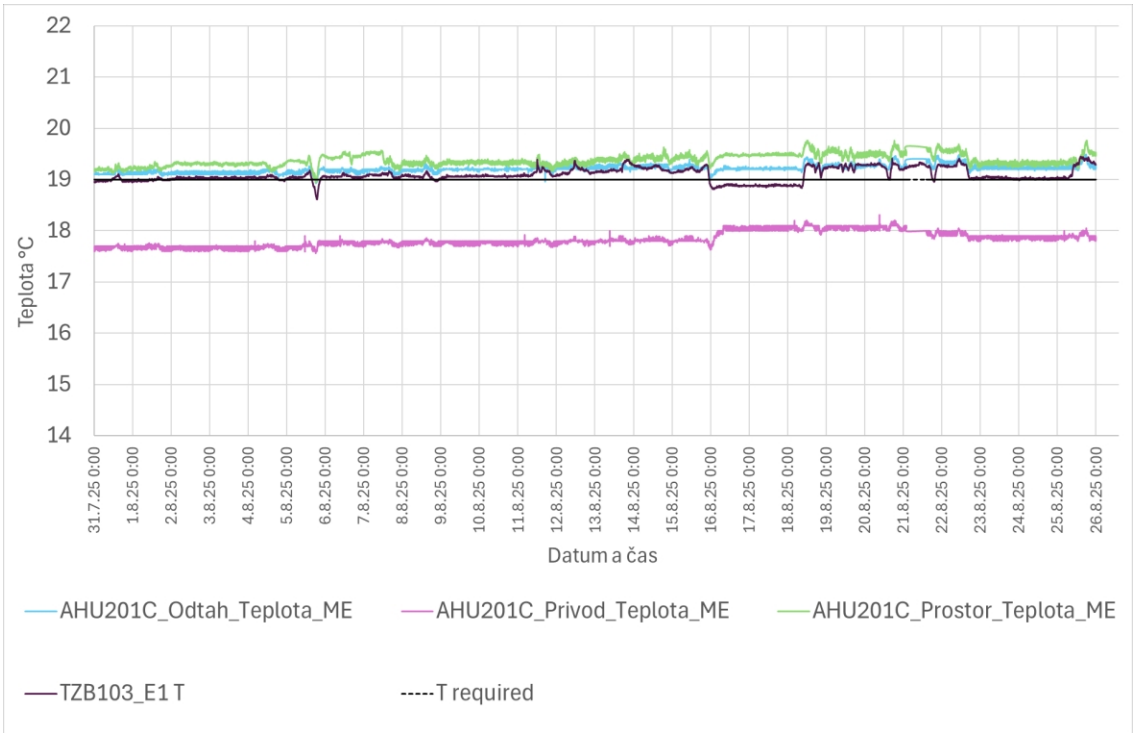


Fig. 57 Hall E1 Temperatures of AHU 201C, TZB103 and required

7.3.5.3 *Hall E1 Temperatures AHU 202C, TZB103 and required*

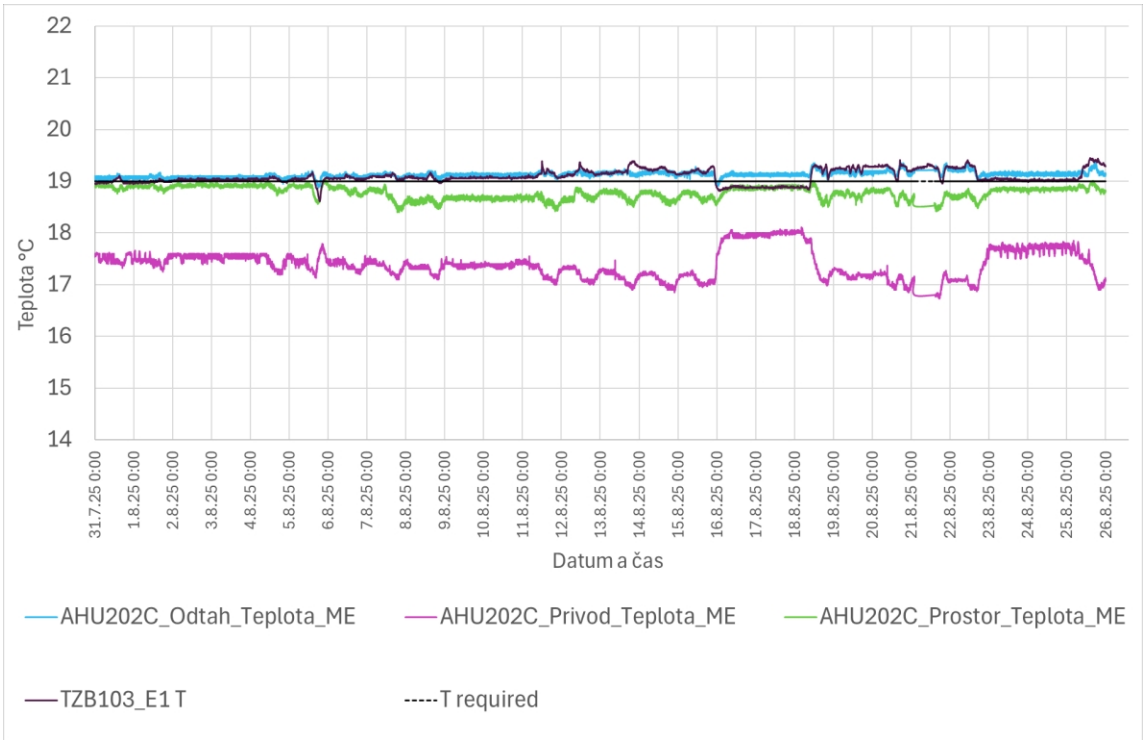


Fig. 58 Hall E1 Temperatures AHU 202C, TZB103 and required

7.3.5.4 Hall E1 Temperatures AHU 203C, TZB103 and required

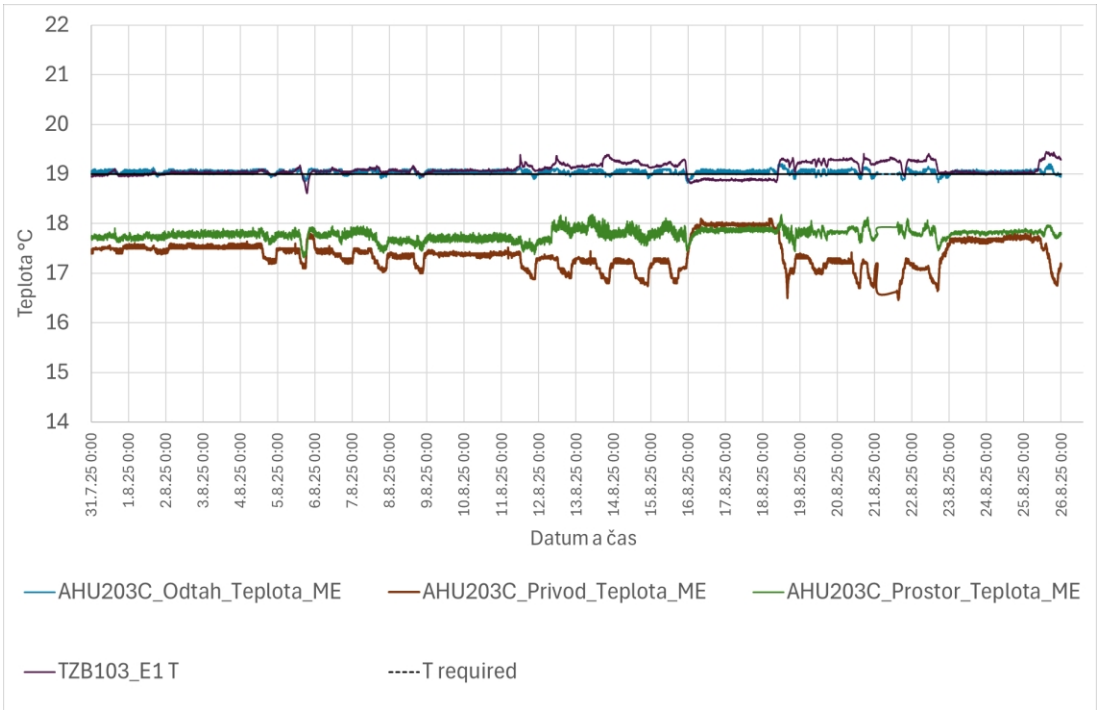


Fig. 59 Hall E1 Temperatures AHU 203C, TZB103 and required

7.3.5.5 Hall E1 AHU 204C, TZB103 and required temperatures

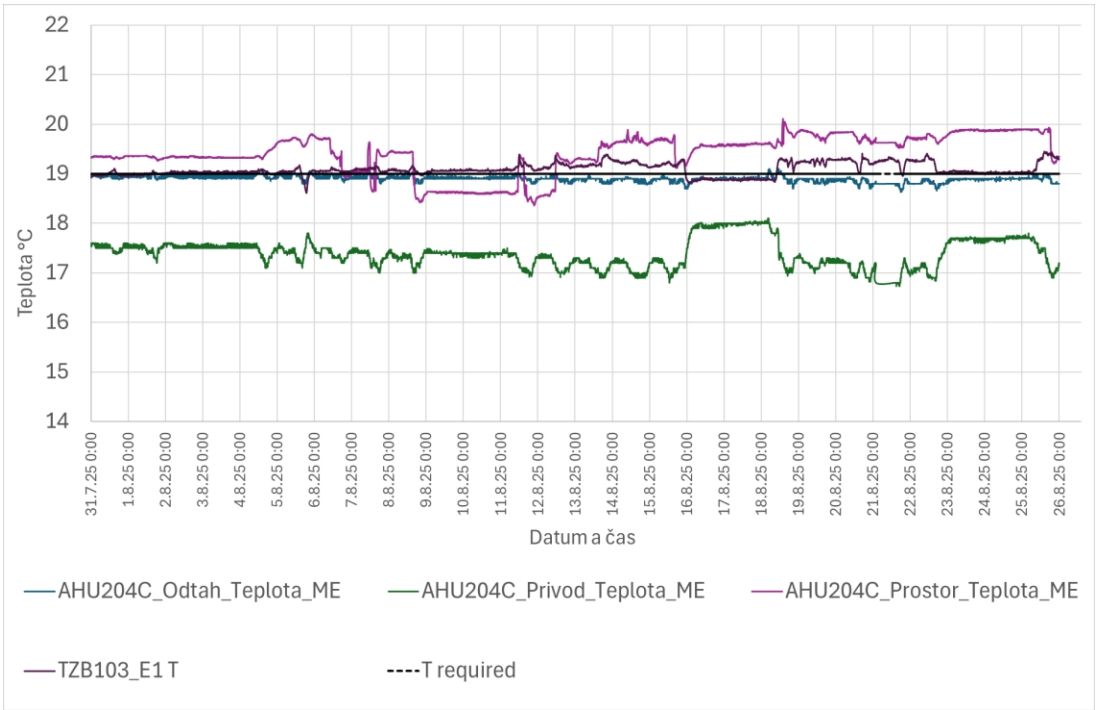


Fig. 60 Hall E1 Temperatures AHU 204C, TZB103 and required

7.3.5.6 Hall E1 Temperatures AHU 205C, TZB103 and required

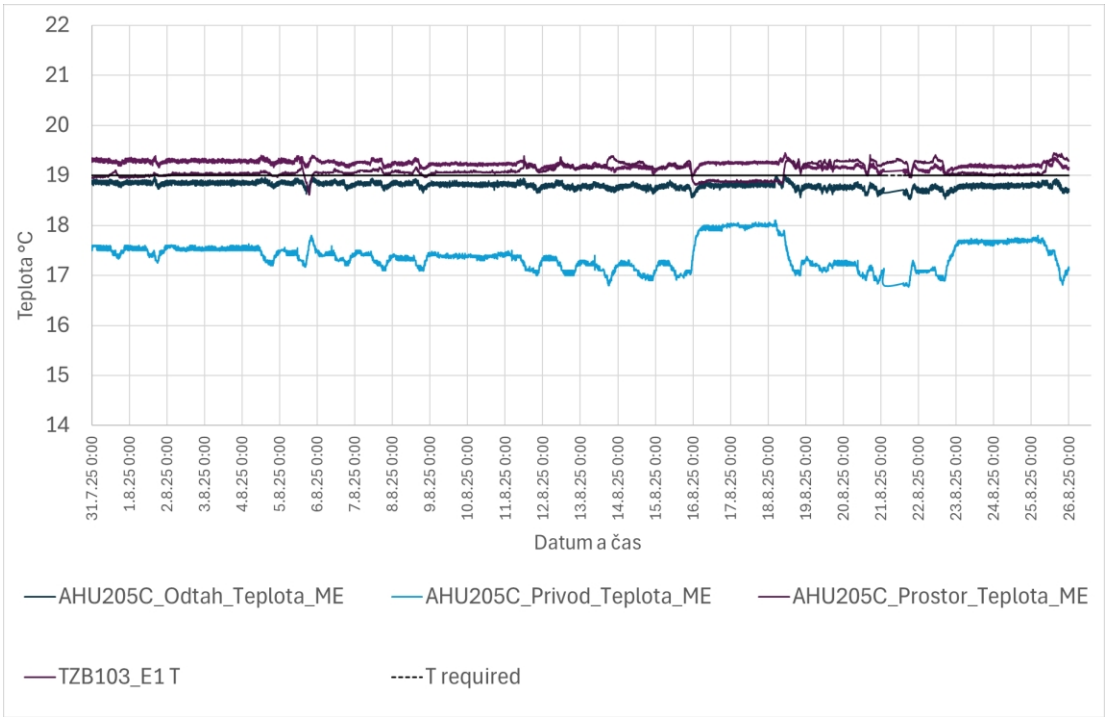


Fig. 61 Hall E1 AHU temperatures 205C, TZB103 and required

7.3.5.7 Hall E1 Exhaust temperatures for all AHU TZB103 and required

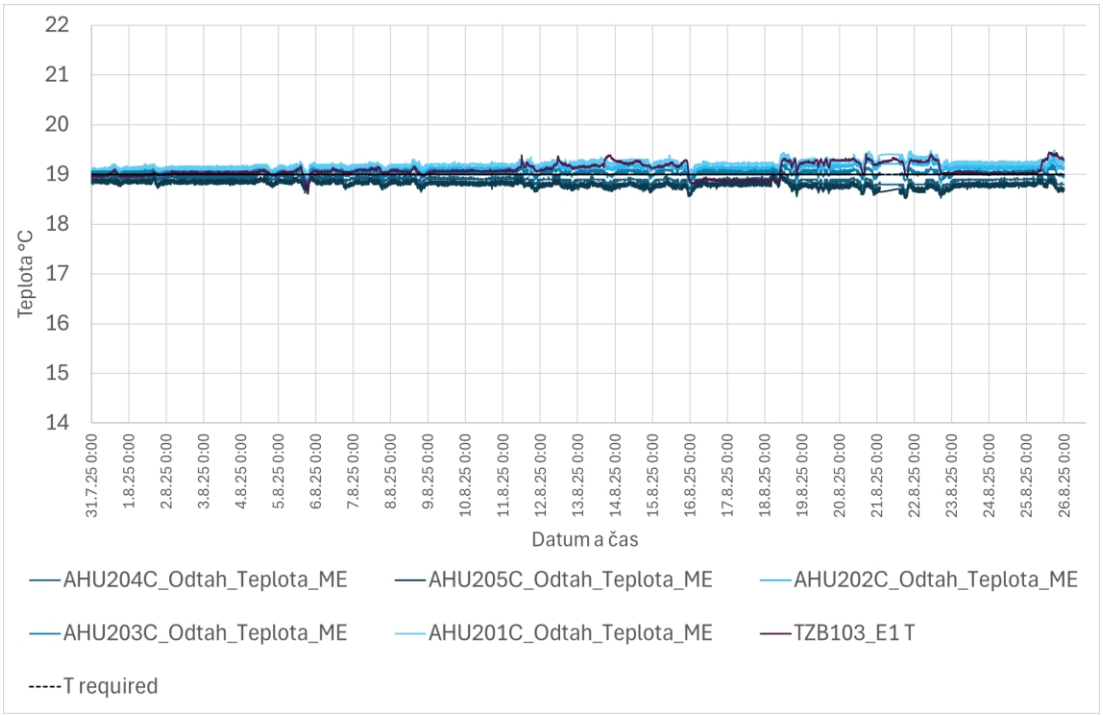


Fig. 62 Hall E1 Exhaust temperatures for all AHU TZB103 and required

7.3.5.8 *Hall E1 Supply air temperatures for all AHU TZB103 and required*

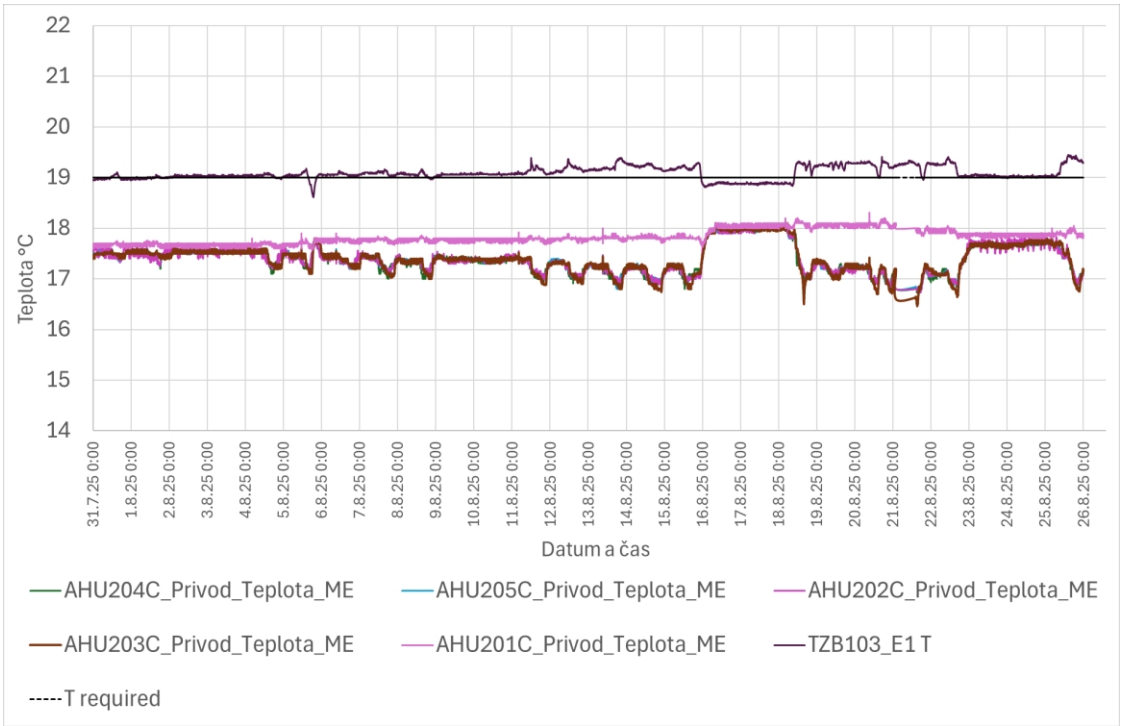


Fig. 63 Hall E1 Supply air temperatures for all AHU TZB103 and required

7.3.5.9 *Hall E1 Room temperatures of all AHU TZB103 and required*

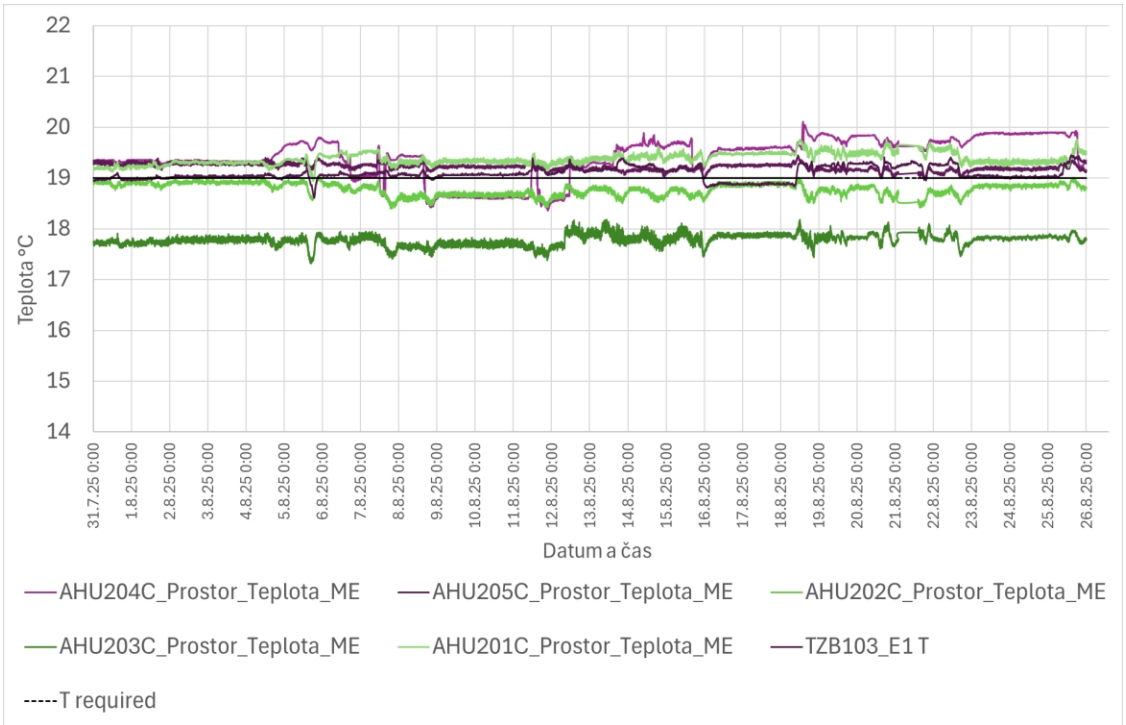


Fig. 64 Hall E1 Room temperatures of all AHU TZB103 and required

7.3.5.10 Partial conclusion – Hall E1 temperatures

During the measured period from July 31 to August 26, 2025, there are slight differences in the curves and fluctuations in the supply values of individual AHUs (in maximums from approx. 16.5 °C to 18 °C), especially from August 5 to August 9, August 11–16, and August 18–23, with the exception of AHU201C. Their curves are almost identical for all AHU units except AHU201C.

The supply values for all AHU units except AHU201C are almost identical.

Reference measurements taken by an independent device show a deviation from the desired temperature (+-0.3 °C).

The exhaust values of all AHU units show the same pattern, with minimal differences between them, and all are close to the desired value with occasional fluctuations with a maximum difference of approximately +-0.45 °C. The reference sensor pattern is also almost identical, including its values.

The values of the sensors marked as room temperature for AHU203C differ most from the remaining AHU units (201C, 202C, 204C, 205C) by up to approx. 2.2 °C at maximum, and they also differ from the required and reference values by up to approx. 1.6 °C at maximum.

7.3.6 Hall E1 - humidity

7.3.6.1 Hall E1 RH all AHUs, TZB103

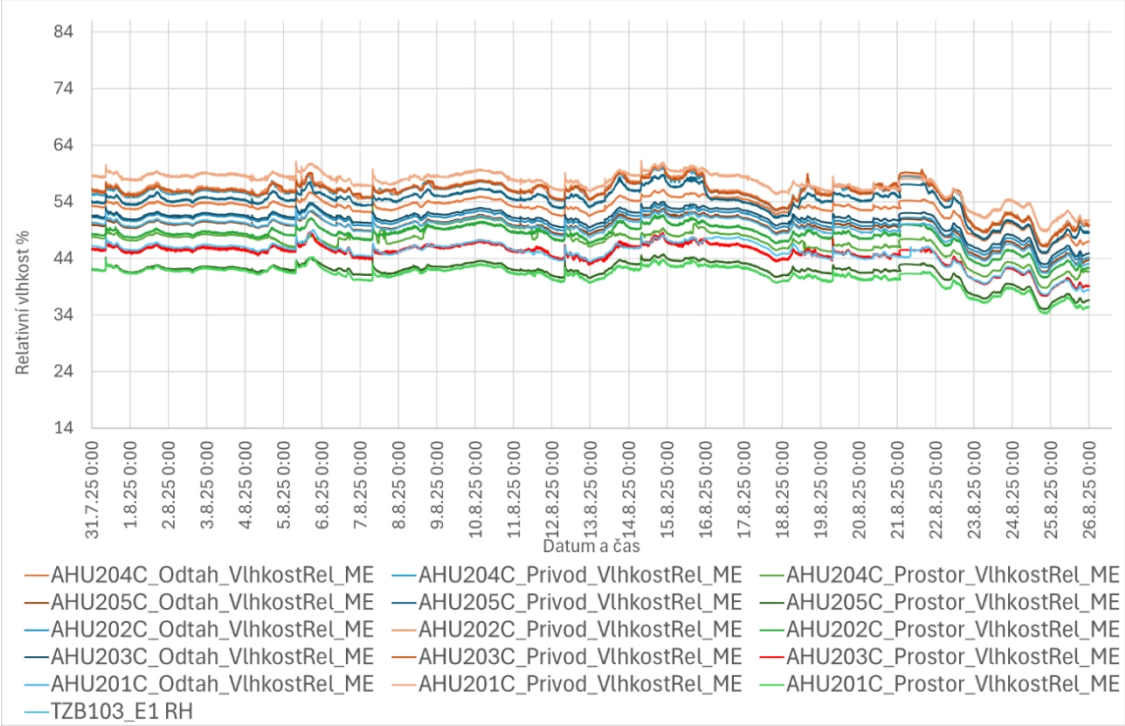


Fig. 65 Hall E1 RH all AHUs, TZB103

7.3.6.2 Hall E1 RH AHU201C, TZB103

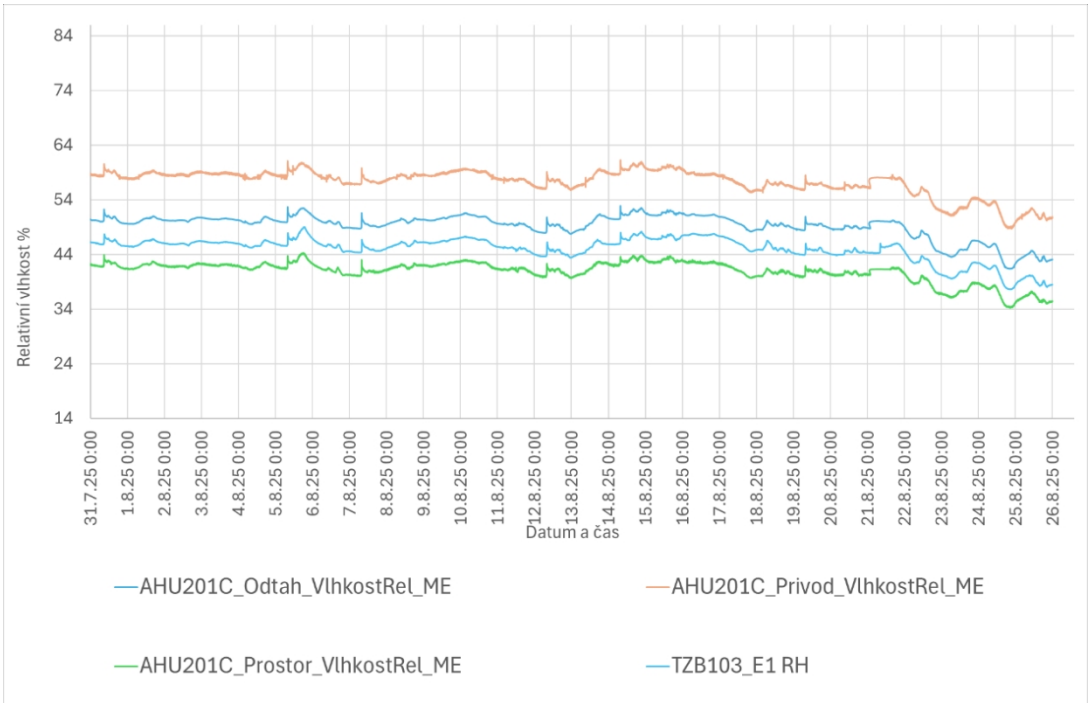


Fig. 66 Hall E1 RH AHU201C, TZB103

7.3.6.3 Hall E1 RH AHU202C, TZB103

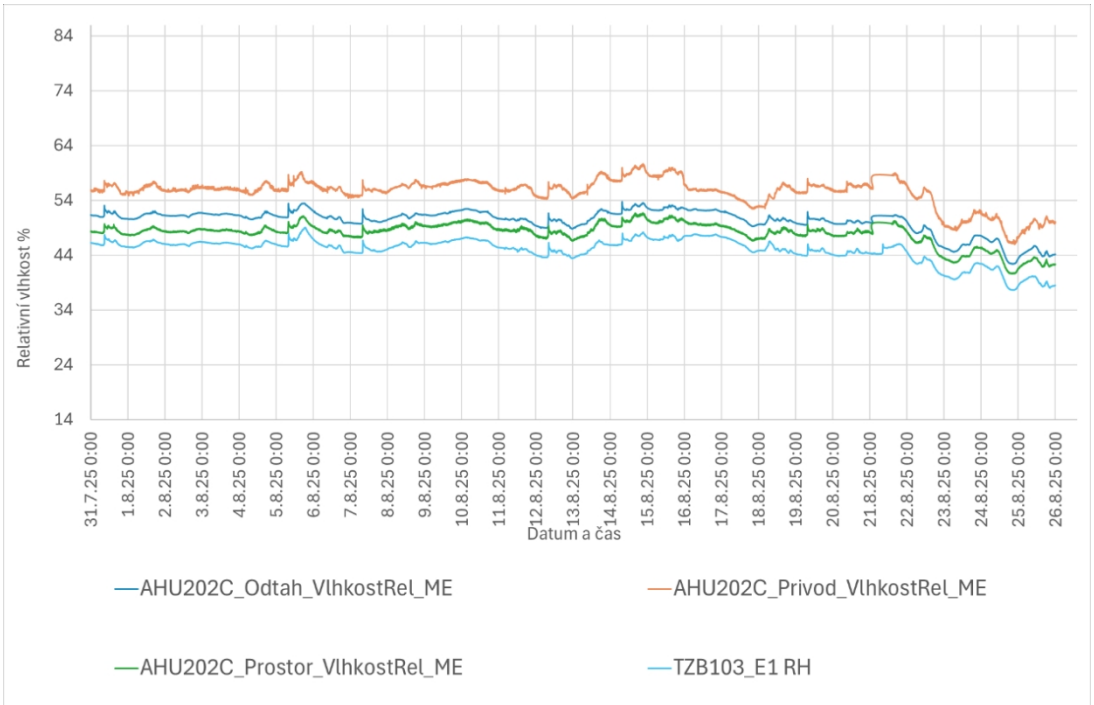


Fig. 67 Hall E1 RH AHU202C, TZB103

7.3.6.4 Hall E1 RH AHU203C, TZB103

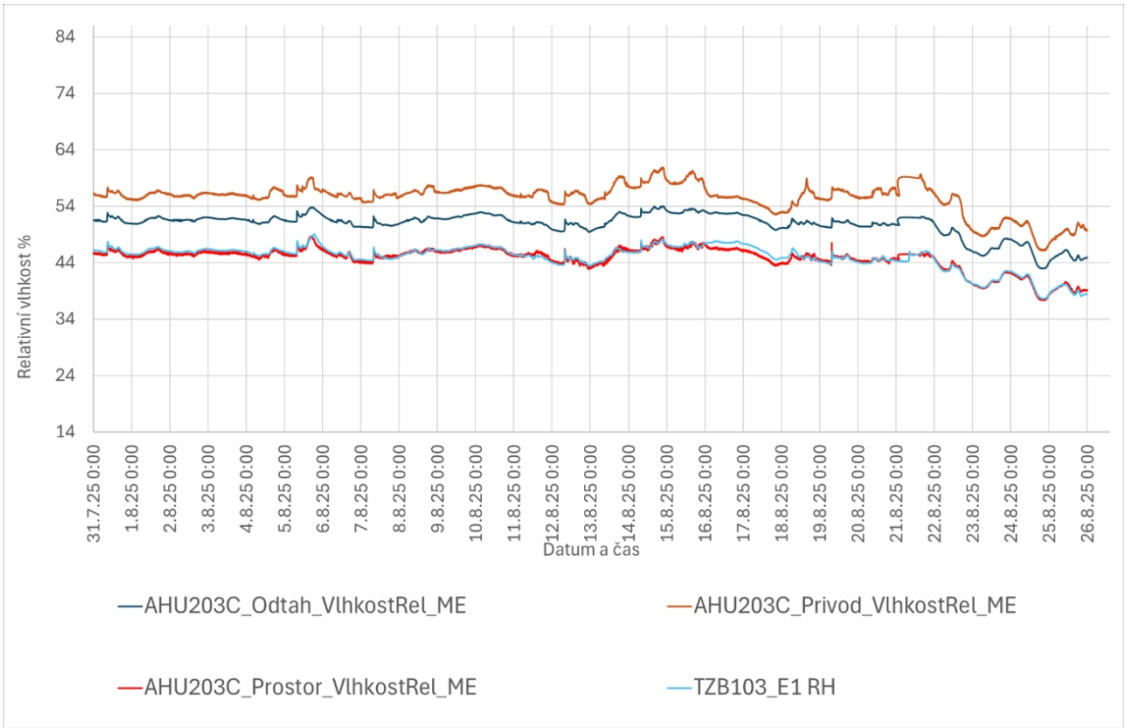


Fig. 68 Hall E1 RH AHU203C, TZB103

7.3.6.5 Hall E1 RH AHU204C, TZB103

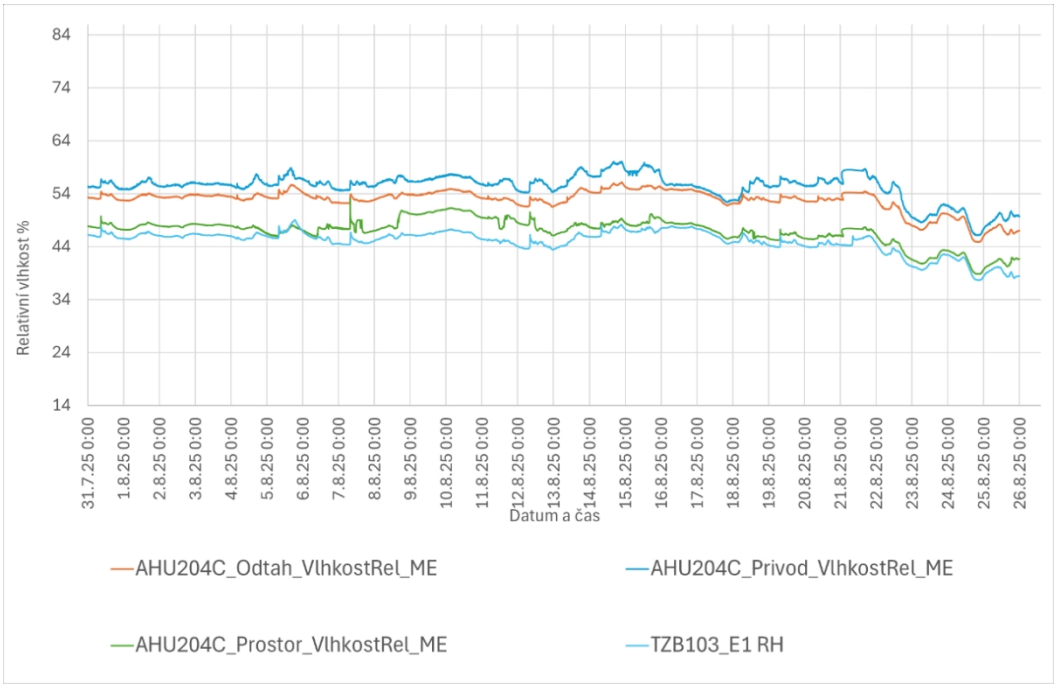


Fig. 69 Hall E1 RH AHU204C, TZB103

7.3.6.6 Hall E1 RH AHU205C, TZB103

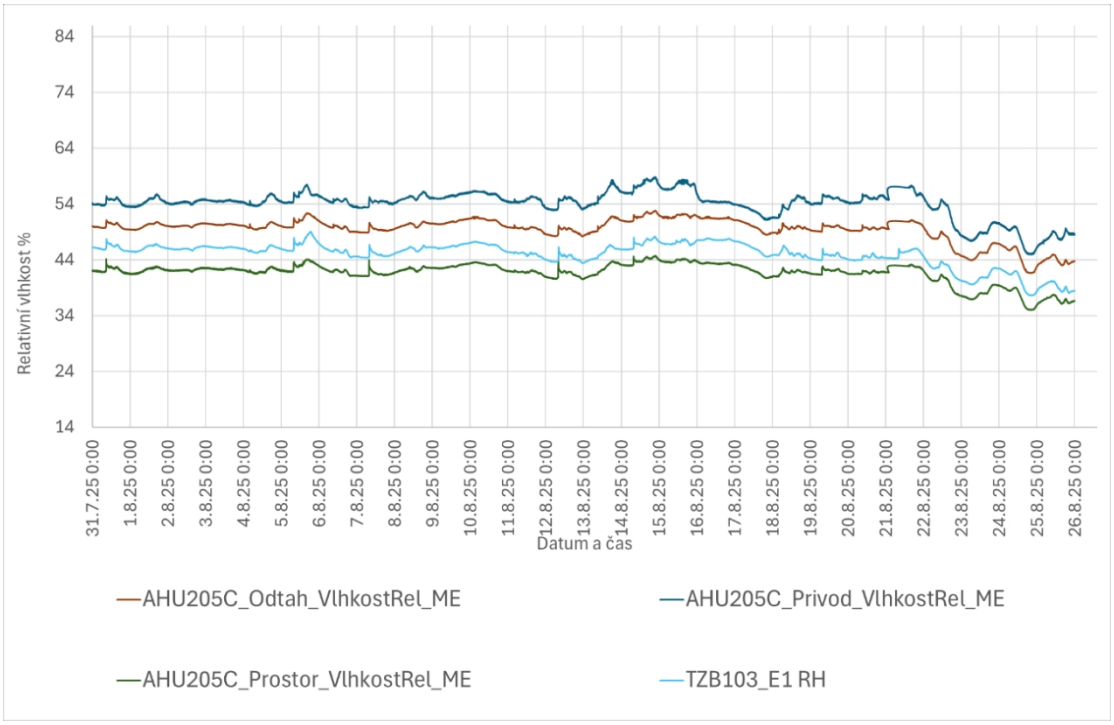


Fig. 70 7.3.3.15 Hall E1 RH AHU205C, TZB103

7.3.6.7 Partial conclusion – Hall E1 humidity

The values and curves for the supply and exhaust of all AHUs are more or less identical, with the supplies differing from the reference value by approx. 9-13% RH and the exhausts by approx. 4-7% RH.

The curves of the sensors marked as room humidity are almost identical. The values of the sensors marked as room humidity for AHU203C are almost identical to the reference values, for AHU 201C and 205C the values are almost identical, slightly lower than for the reference sensor, by approx. 4% RH, For AHU 202C and 204C, the values are almost identical, slightly higher than for the reference sensor, by approximately 3–4% RH.

7.3.7 HALL E2 - temperatures

7.3.7.1 Hall E2 Temperatures of all AHUs, TZB102, and required

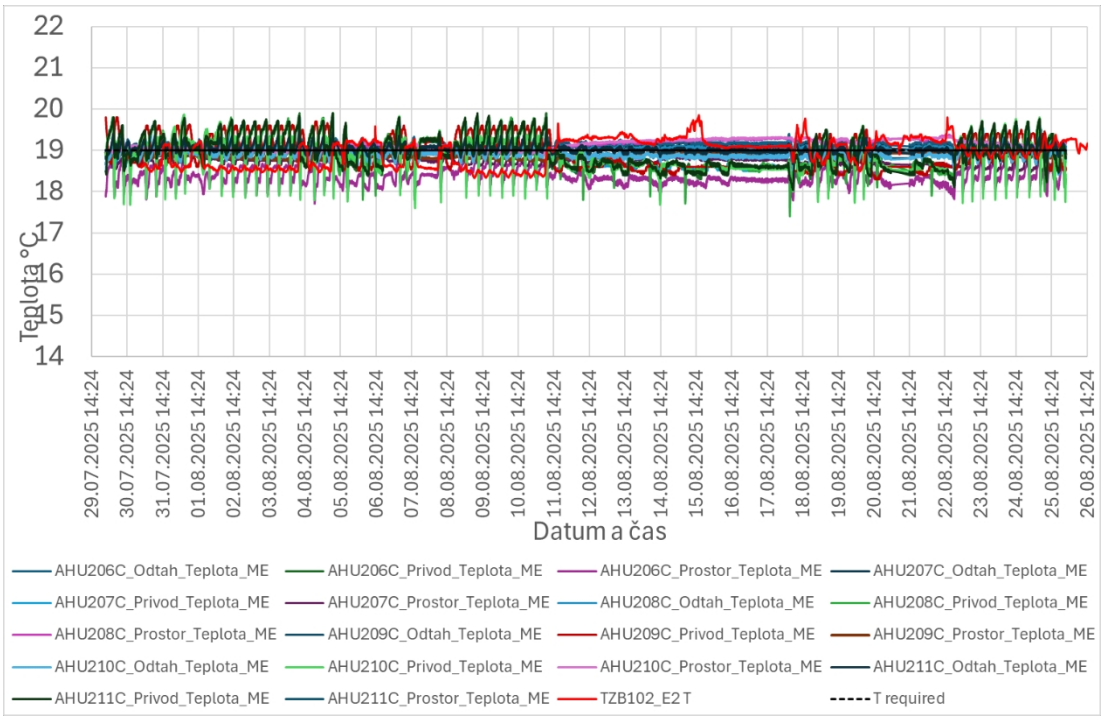


Fig. 71 Hall E2 Temperatures of all AHUs, TZB102 and required

7.3.8 Hall E2 - humidity

7.3.8.1 Hall E2 RH all AHUs, TZB102

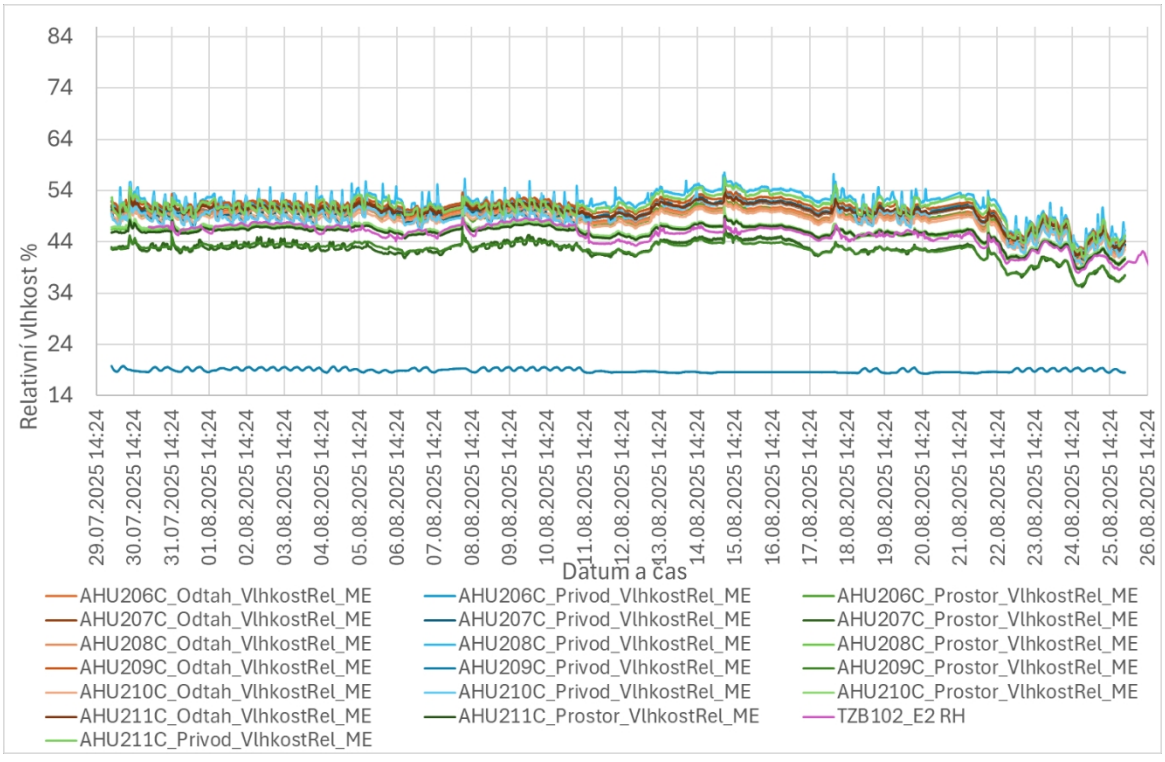


Fig. 72 Hall E2 RH all AHUs, TZB102

7.3.9 HALL E3 – temperatures

7.3.9.1 Hall E3 Temperatures of all AHUs, TZB104 and required

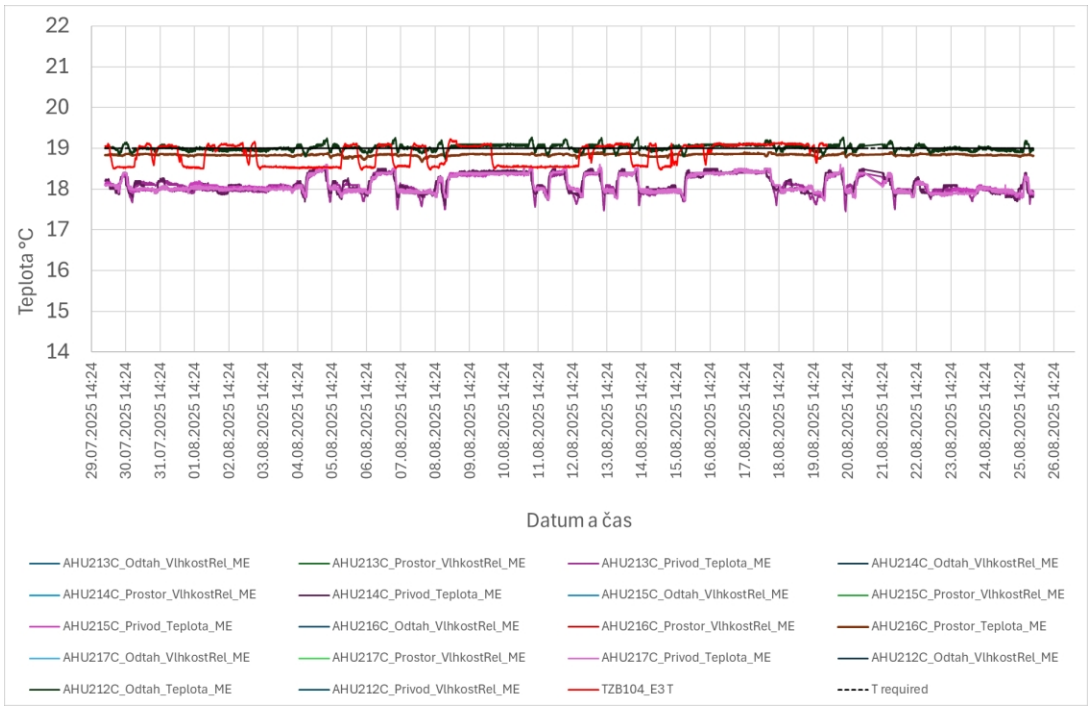


Fig. 73 Hall E3 Temperatures of all AHUs, TZB104 and required

7.3.10 Hall E3 – humidity

7.3.10.1 Hall E3 RH all AHUs, TZB104

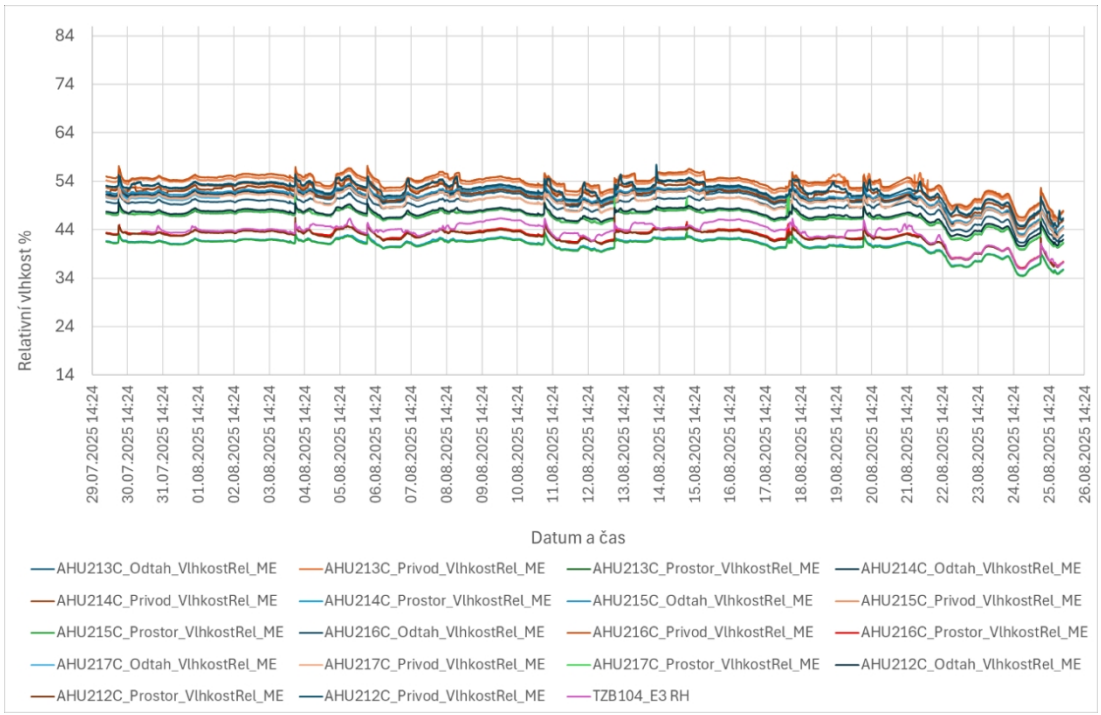


Fig. 74 Hall E3 RH all AHUs, TZB104

7.3.11 HALL E5 - temperatures

7.3.11.1 Hall E5 Temperatures of all AHUs, TZB106 and required

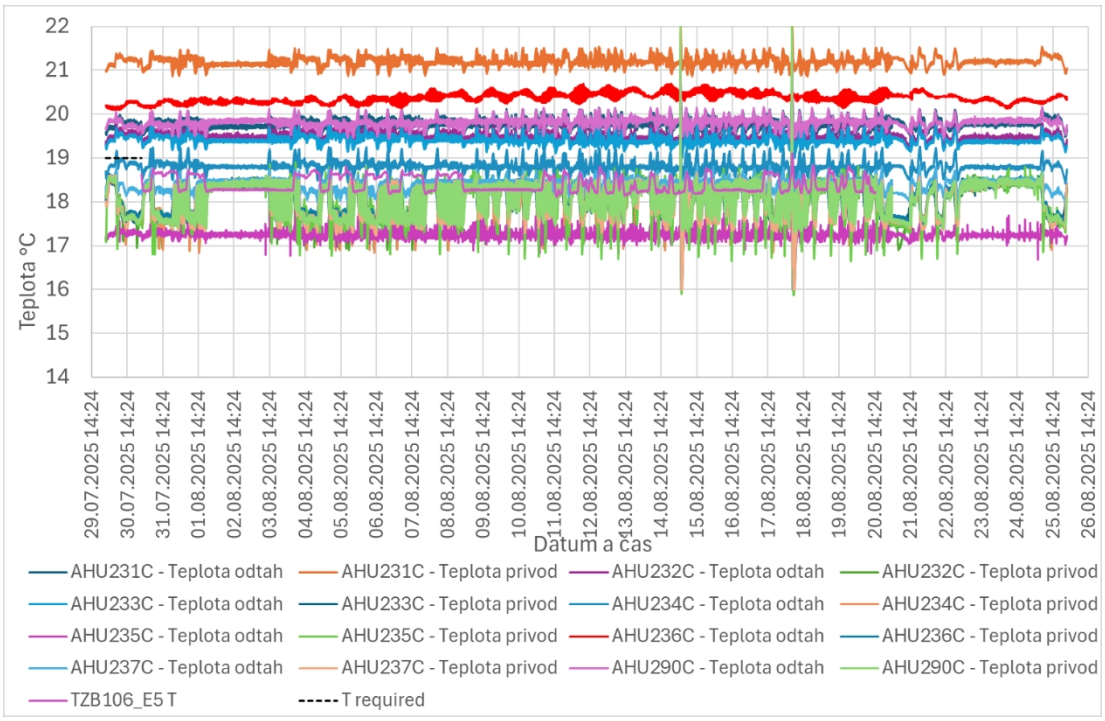


Fig. 75 Hall E5 Temperatures of all AHUs, TZB106 and required

7.3.12 Hall E5 - humidity

7.3.12.1 Hall E5 RH all AHUs, TZB106

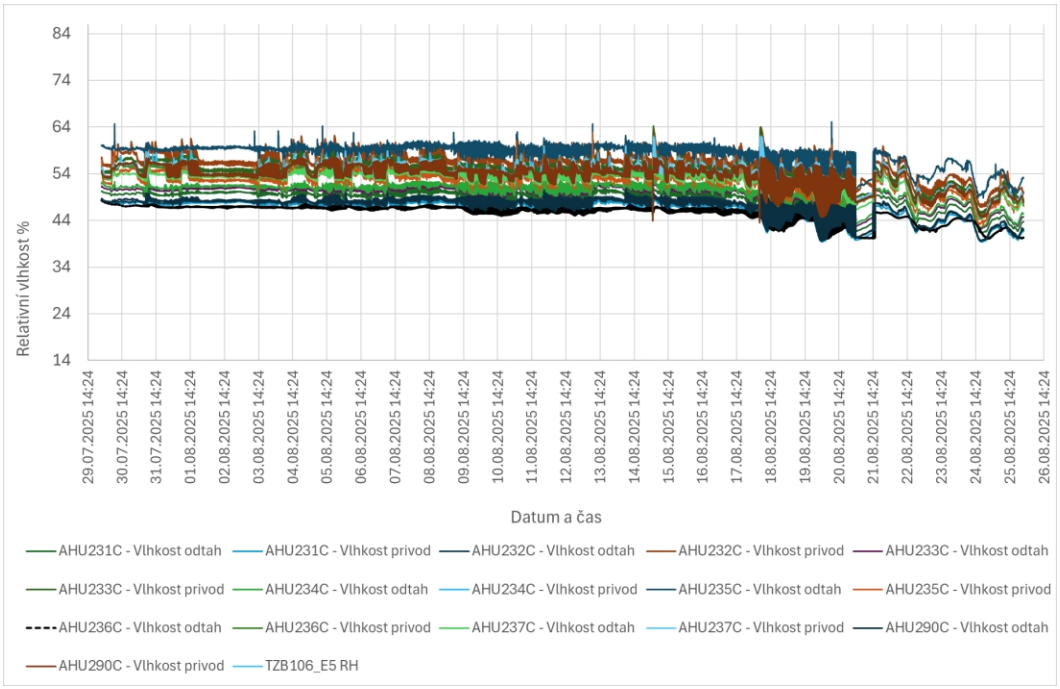


Fig. 76 Hall E5 RH all AHUs, TZB106

7.3.13 HALL L4c - temperatures

7.3.13.1 Hall L4 Temperatures of all AHUs, TZB105 and required

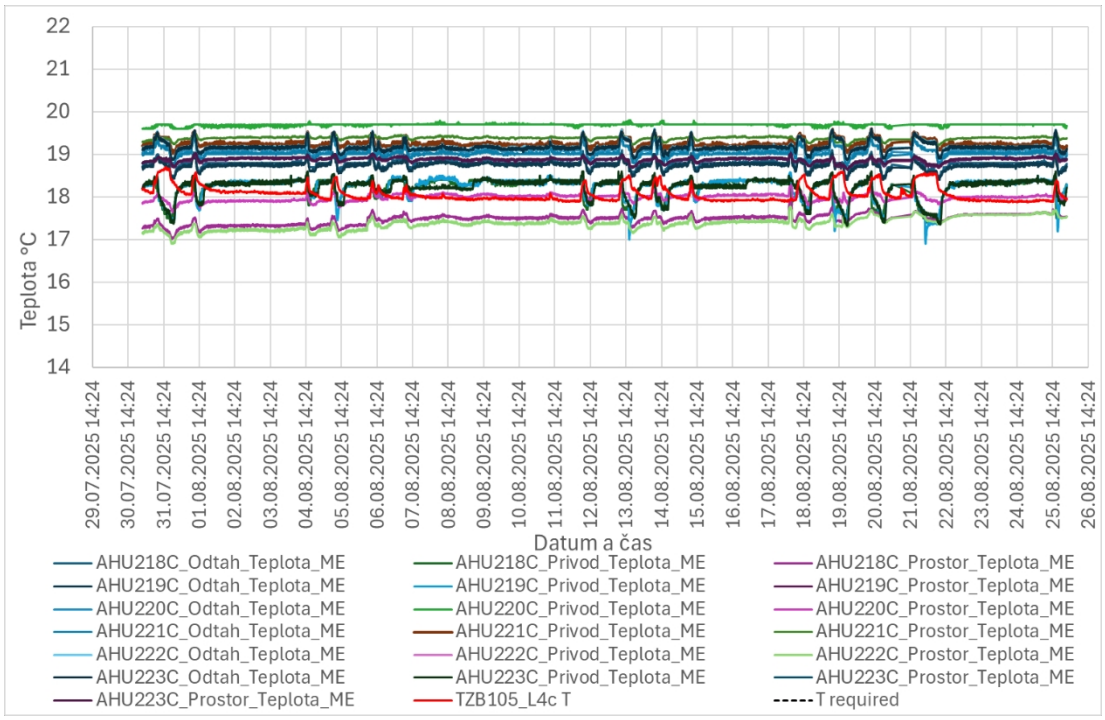


Fig. 77 Hall L4c Temperatures of all AHUs, TZB105 and required

7.3.14 Hall L4c - humidity

7.3.14.1 Hall L4c RH all AHUs, TZB105

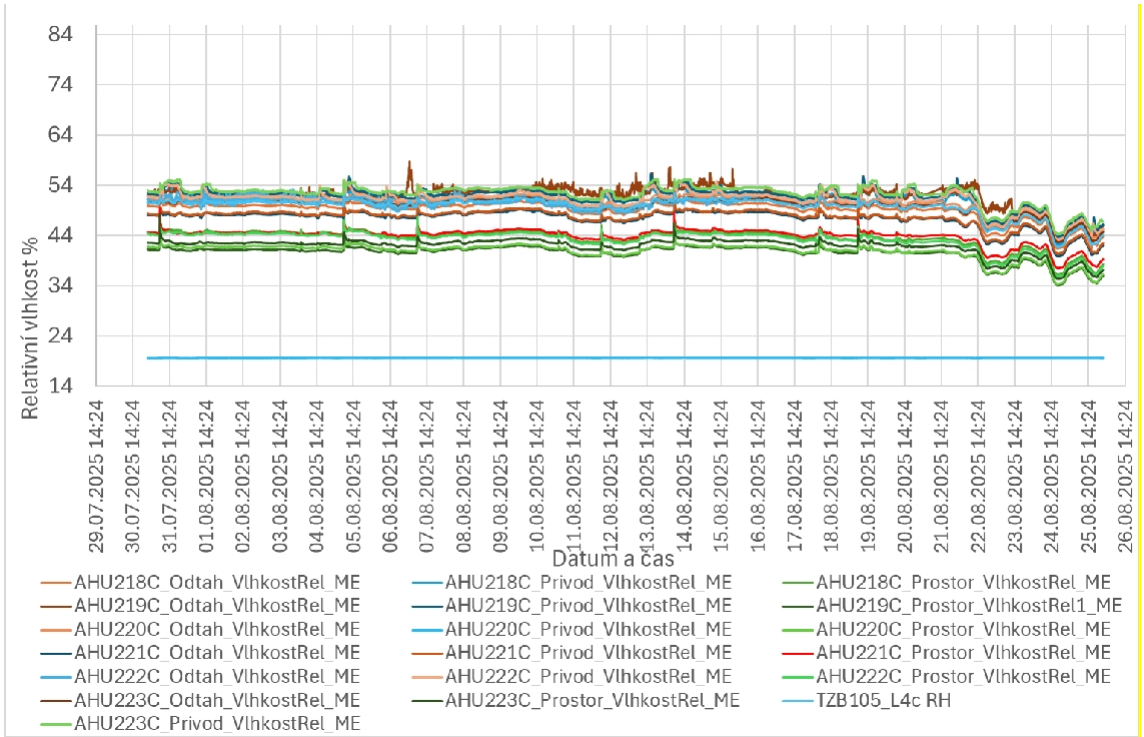


Fig. 78 Hall L4c RH all AHUs, TZB105

7.3.15 HALL L3 - temperatures

7.3.15.1 Hall L3 Temperatures of all AHUs, TZB106 and required

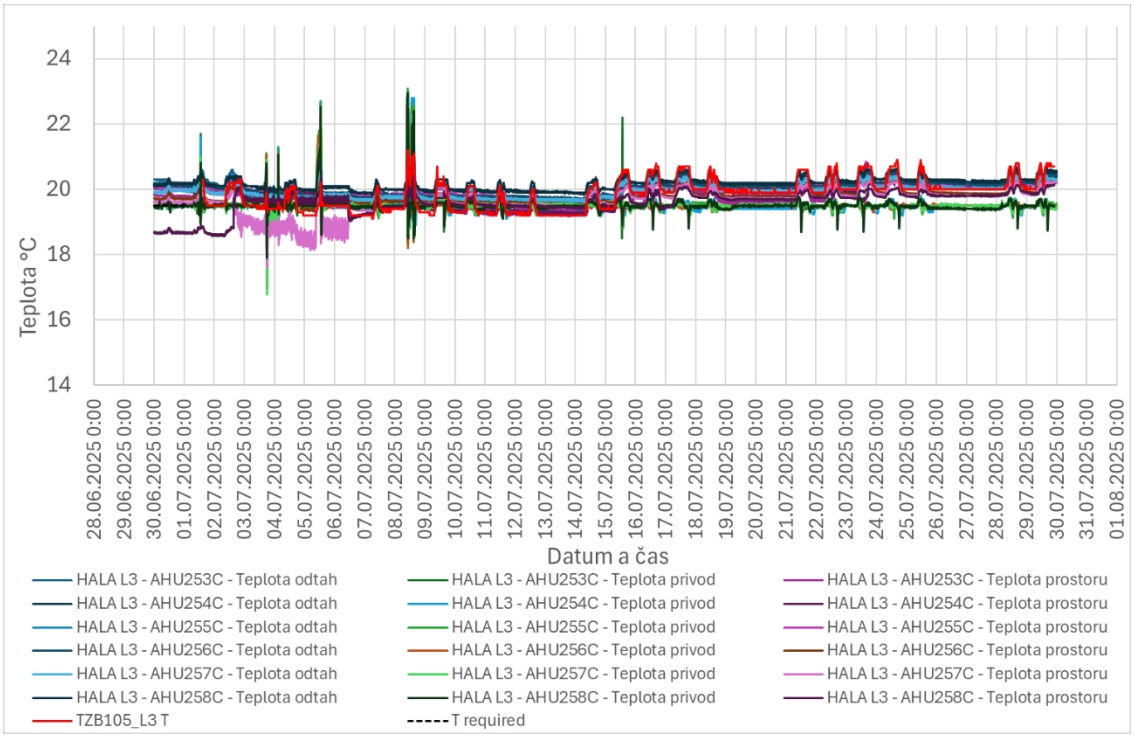


Fig. 79 Hall L3 Temperatures of all AHUs, TZB106 and required

7.3.16 Hall L3 - humidity

7.3.16.1 Hall L3 RH all AHUs, TZB106

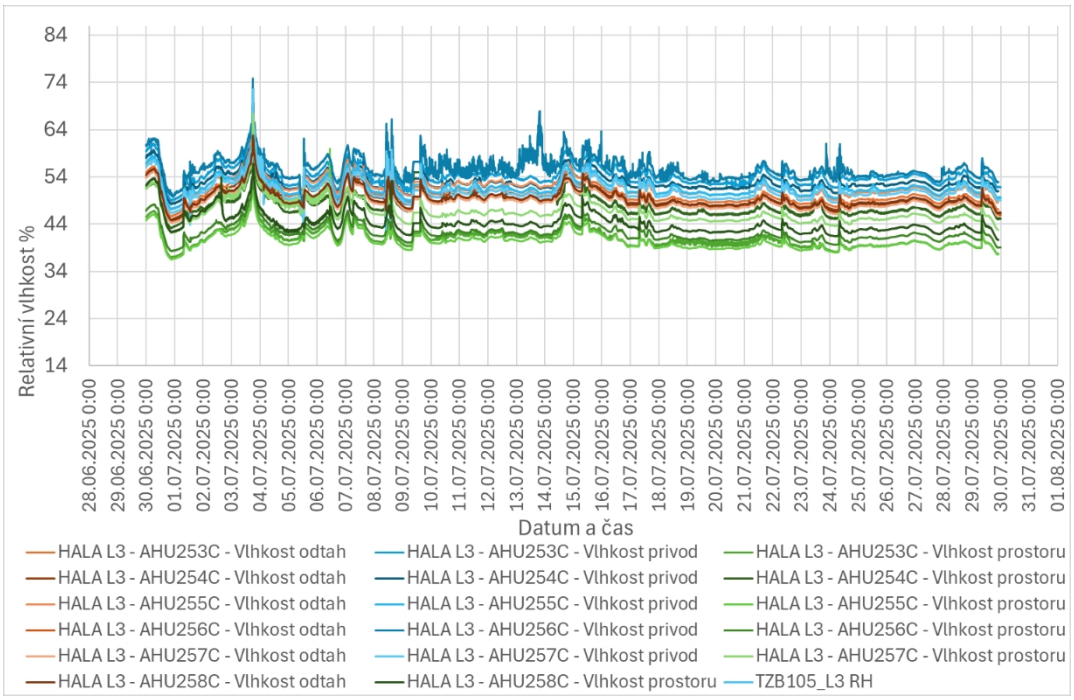


Fig. 80 Hall L3 RH all AHUs, TZB106

7.3.17 HALL L4b - temperatures

7.3.17.1 Hall L4b Temperatures of all AHUs, TZB105 and required

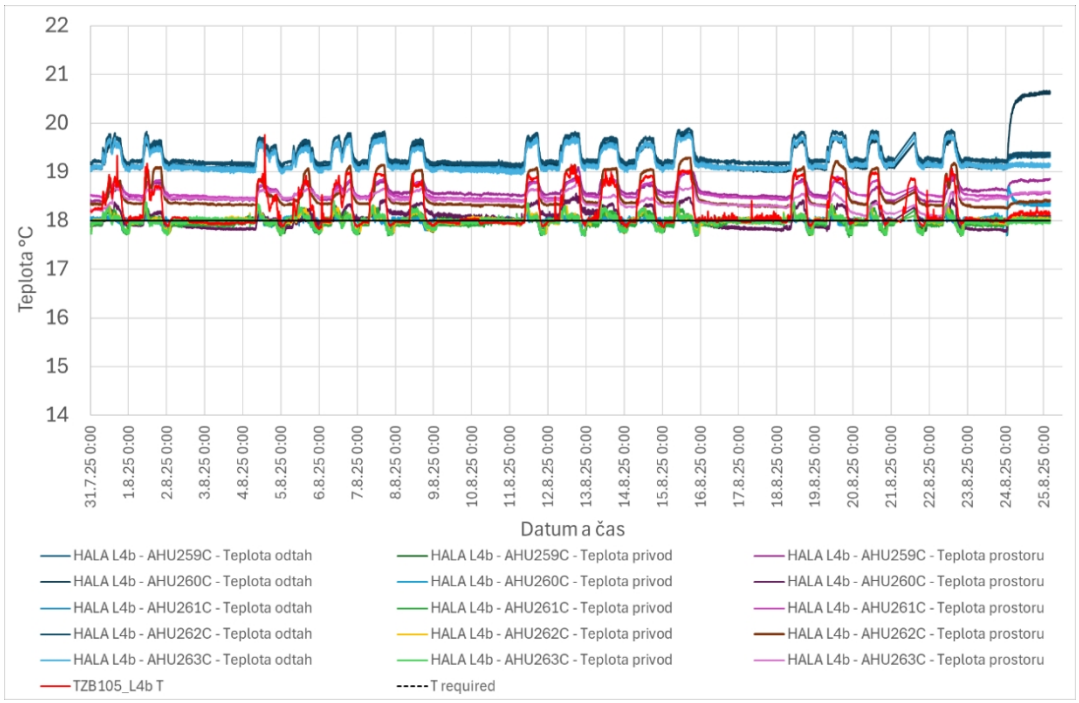


Fig. 81 Hall L4b Temperatures of all AHUs, TZB105 and required

7.3.18 Hall L4b - humidity

7.3.18.1 Hall L4b RH all AHUs, TZB105

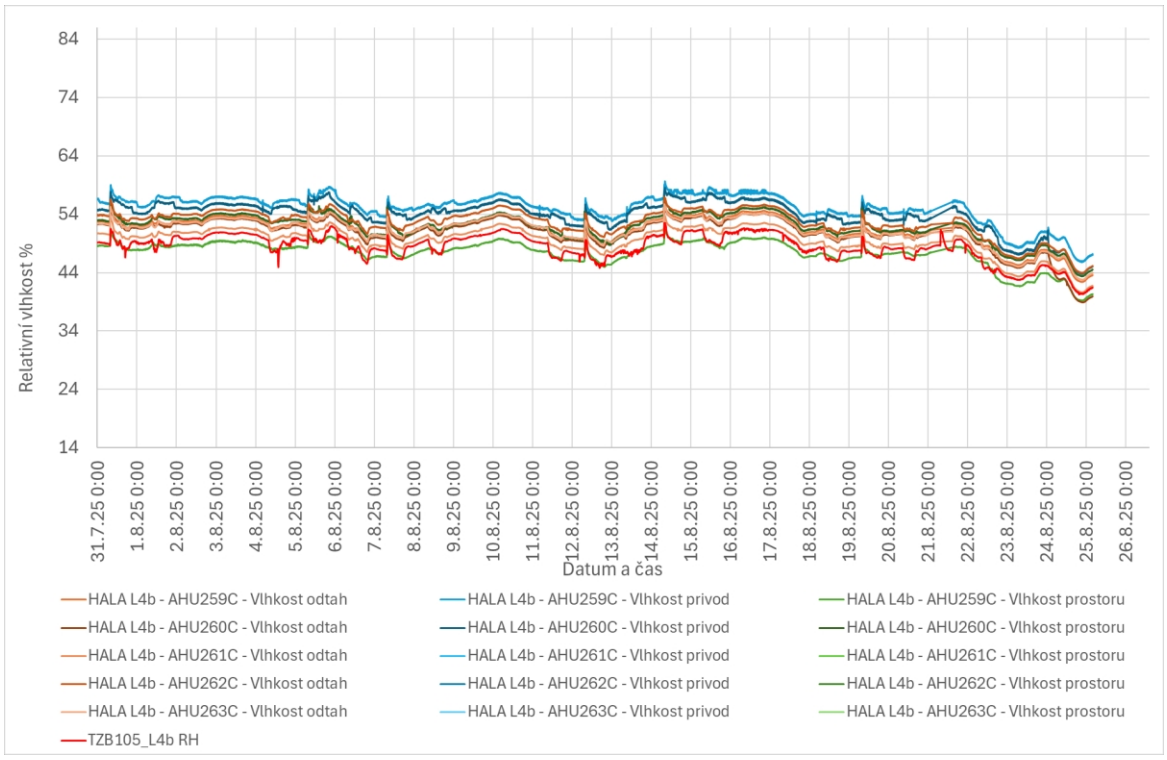


Fig. 82 Hall L4b RH all AHUs, TZB105

8 Conclusion

8.1 Analysis of energy supplied to CH1 to CH10

During the monitored period, the most significant consumption was in circuits CH1a and CH7. No direct correlation was observed between the cooling capacity of circuit CH7 and outdoor climatic conditions. Short-term power peaks are not linked to any extreme climatic data.

In circuit CH1a, a slight trend can be observed in the correlation between the performance curve and the enthalpy, temperature, and specific humidity of the outdoor air.

8.2 Summary of temperature and humidity data measured by the MaR system with a reference meter for halls L1, L2, and E1

Reference measurements of air temperature and relative humidity were taken at five-minute intervals.
In halls L1, L2, L3, L4b, L4c, E1, E2, E3, E5 (see Table 1 for details), halls L1, L2, and E1 have been evaluated. For the other halls, a graphical evaluation of the data has been prepared at this stage of the research, with a detailed analysis to be carried out if necessary for the design of optimization measures.

L1:

In the period from July 1 to July 15, 2025, the system shows large short-term fluctuations in the supply of all AHU units from approximately 14 °C to 22.5 °C, which are also reflected in the room and exhaust temperatures. Reference measurements taken by an independent device show a deviation from the desired temperature (+-1 °C).

In the period from July 15 to July 29, 2025, the system stabilized; fluctuations in the supply of AHU units from approximately 17
°C to 18.5 °C. AHU 242C is closest to the reference value, which is approximately 0.2 °C lower than the required value (T required 18.7 °C). The required value is maintained at the exhaust of AHU 243C and 244C units.

The exhaust values of all AHU units show the same pattern, differing only by approx. 0.1-0.3 °C, but all are close to the required value with occasional fluctuations with a maximum difference of approx. 0.5 °C.

Sensors labeled as room temperature only measure for AHU 242C and 244C. The AHU 243C sensor provides meaningless data. The values of the sensors marked as room temperature for AHU242C are approximately 0.5°C lower than the required value, for AHU 244C approximately 0.2°C lower, and these values also correspond approximately to the reference sensor.

The supply and exhaust values of all AHUs are more or less the same and differ from the reference value by approx. 10%.

Sensors labeled as room humidity only measure for AHU 242C and 244C. The AHU 243C sensor gives nonsense data. The values of sensors labeled as room humidity for AHU242C are about 5% lower than the reference value, for AHU 244C they approximately correspond to the reference sensor.

L2:

In the period from July 1 to July 9, 2025, the system shows greater short-term fluctuations in the supply of all AHU units, ranging from approximately 15.5 °C to 20.5 °C, which are also reflected in the room and exhaust temperatures. Reference

measurements taken by an independent device show a deviation from the desired temperature (+-1 °C), but the reference sensor was probably moved on July 17, as its values are significantly different until July 28, when they return to the expected values.

In the period from July 12 to July 21, 2025, the system stabilized; fluctuations in the supply of AHU units from approximately 15.9 °C to 17.2 °C and their curves are almost identical for all AHU units.

The exhaust values of all AHU units show the same pattern, differing only by approximately 0.1-0.5 °C, but all are close to the required value with occasional fluctuations with a maximum difference of approximately 0.8 °C.

The values of the sensors marked as room temperature for AHU247C, 248C, and 252C are close to the required value, differing by approximately +- 0.1–0.3 °C. The values for AHU249C are close to the required value in the period from July 10 to July 21, lower by approx. 0.1 °C. From July 21 to July 29, they oscillate more and are lower by up to approx. 0.7 °C.
°C. The values for AHU250C and 251C are approximately 0.5–1.5 °C lower than the required value in the period from July 21 to July 29 and fluctuate more. The values for AHU 252C

The values for AHU 250C and 251C from July 10 to July 16, 2025, approximately correspond to the reference sensor, being approximately 0.3°C higher. The reference sensor was probably moved on July 17, as its values are significantly different until July 28, when they return to the expected values.

The values and curves for the supply and exhaust of all AHUs are more or less identical, with the supplies differing from the reference value by approximately 10% RH and the exhausts differing minimally (both except for the probable relocation of the reference sensor).

E1:

During the measured period from July 31 to August 26, 2025, there are slight differences in the curves and fluctuations in the supply values of individual AHUs (at maximum values of approximately 16.5 °C to 18 °C), especially from August 5 to August 9, August 11–16, and August 18–23, with the exception of AHU201C. Their curves are almost identical for all AHU units except AHU201C.

The supply values for all AHU units except AHU201C are almost identical.

Reference measurements by an independent device show a deviation from the desired temperature (+-0.3 °C).

The exhaust values of all AHU units show the same pattern, with minimal differences between them, and all are close to the desired value with occasional fluctuations with a maximum difference of approximately +-0.45 °C. The reference sensor curve is also almost identical, including its values.

The values of sensors marked as room temperature for AHU203C differ most from the remaining AHU units (201C, 202C, 204C, 205C) by up to approx. 2.2 °C at maximum, and they also differ from the required and reference values by up to approx. 1.6 °C at maximum.

The values and curves for the supply and exhaust of all AHUs are more or less the same, with the supplies differing from the reference value by approx. 9-13% RH and the exhausts by approx. 4-7% RH.

The curves of the sensors marked as room humidity are almost identical. The values of the sensors marked as room humidity for AHU203C are almost identical to the reference values, for AHU 201C and 205C the values are almost identical, slightly lower than for the reference sensor, by approx. 4% RH, For AHU 202C and 204C, the values are almost identical, slightly higher than for the reference sensor, by approximately 3-4% RH.

8.3 Summary and recommendations for further action

The analysis provided information on the basis of which it is possible to continue with contractual research focused on optimizing the existing solution of technical systems for ensuring the indoor environment. Based on the processing of values obtained from our own reference measurements of selected indoor environment parameters and from the building's measurement and control system, it can be stated that most of the installed sensors provide relevant data that can be used to indicate the impact of further proposed opportunities and measures to increase the stability of system operation and their evaluation. Although deviations in absolute values were measured for some sensors, their curves corresponded in most cases to the curves measured by the processor's reference measuring instruments.

Based on the analysis of the current state of selected research infrastructure premises, we recommend the following steps in the next phase of contractual research:

- Identification of significant energy consumers for environmental control and processing the energy balance of these appliances (e.g., cooling, heating, air humidity control) and their projection onto individual facilities;
- Preparation of a sensitivity analysis of the correlation of internal and external environment parameters to determine the impact of climatic conditions on changes in the internal environment;
- Processing of operating data from the following period or additional own measurements, as necessary;
- Identifying opportunities to increase the stability of indoor environment parameters by modifying existing technical systems (including measurement and control elements);
- Identifying opportunities to reduce the energy intensity of the indoor environment by modifying existing technical systems (including measurement and control elements);
- Determining the expected benefits of implementing opportunities in terms of increasing the stability of indoor environment parameters;
- Determining the expected benefits of implementing opportunities in terms of changing energy intensity;
- Using the HAIEQ methodology to evaluate opportunities, determine the potential for increasing the stability of the indoor environment and changing energy intensity;
- Prepare a list of opportunities recommended for further development into a draft measure.

In Prague, September

2025 Karel Kabele

Zuzana Veverková