# APPLICATION OF THE GaSENS IOT DEVICES TO IMPROVE THE USE OF ENERGY SOURCES AT FEI STU

Štefan Čerba[1], Branislav Vrban[1], Jakub Luley[1], Miroslav Behul[2]

*[1]Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology, Centre for Nuclear Technology and Applications, Ilkovičova 3, 812 19 Bratislava, Slovak Republic, E-mail: stefan.cerba@stuba.sk*
*[1]Slovak University of Technology in Bratislava, Faculty of Electrical Engineering and Information Technology, Institute of Photonics and electronics, Ilkovičova 3, 812 19 Bratislava, Slovak Republic, E-mail: stefan.cerba@stuba.sk*

**Abstract**
The progress in the IoT devices, regarding their functions, precision and price open new possibilities for their application. Subsequent AI based analyses of data gathered from IoT devices can help identifying patterns in data based on which the effectivity of the heating and cooling systems can be assessed. In this paper we present the results of the use of GaSens smart devices installed at FEI STU in the frame of the REBECCA - Renewable Energy for the Creation of a Balanced Ecological Carbon Agenda, project. The aim of the project is to gain new knowledge and procedures for the future decarbonization of the energy economy of selected university buildings and workplaces and to create a replicable model for the conditions of the Slovak Republic.

**The GaSens IoT devices**
Fluctuations in laboratory temperature, humidity, and air quality compromise experimental reliability and equipment safety. While commercial monitoring systems are often expensive and rigid, the GaSens device designed at STU is a low-cost, open-source, and distributed Internet of Things (IoT) monitoring node tailored for small-scale and educational research labs. Its hardware architecture is built around the high-performance ESP32 microcontroller and the compact GaSens node integrates:

- A Bosch BME680 sensor for continuous temperature and humidity tracking.
- EEPROM memory for persistent storage of network credentials, MQTT settings, and sensor calibration metrics.
- Status LEDs & MicroUSB Power (5V): A red LED confirms power/operation, while a blue LED indicates an active local web interface/hotspot (which powers down during energy-saving autonomous modes).
- Hybrid Communication: To maximize interoperability, data is simultaneously transmitted via HTTP REST requests and MQTT telemetry, facilitating smooth integration into both dedicated cloud services and localized web-based visualization dashboards.

The prototype and system architecture of GaSens are shown in Fig. 1. More information can be found in [1]. The current version of the device, V14, measures temperature, humidity, pressure, volatile gas concentration, CO2 equivalent, and air quality index. The data are gathered through the STU information system (IS) [2], which also features visualization and data export.

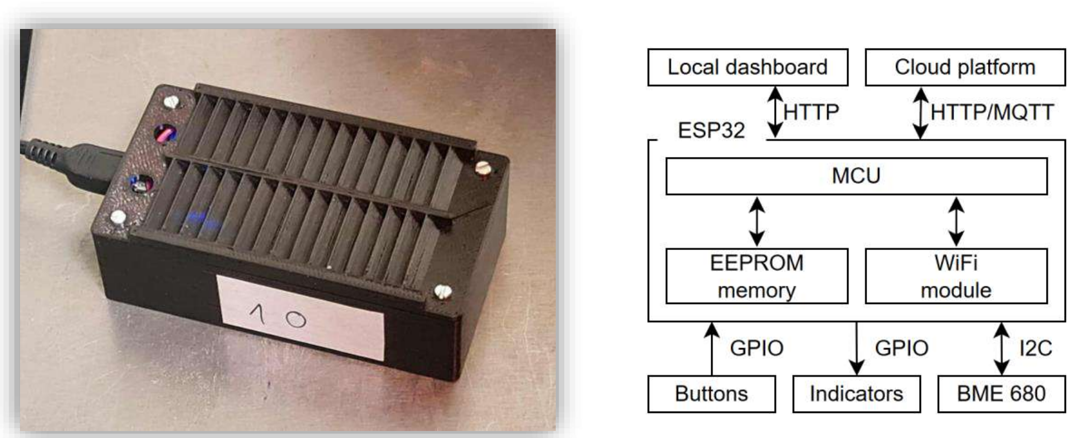


**Fig. 1** Prototype and architecture of the GaSens monitroring device [1]

**Installation of devices at STU**

The devices were installed during the summer of 2025. For monitoring, 10 locations of the Faculty of Electrical Engineering and Information Technology (FEI) of STU were selected: in each room, a unique GaSens device was installed. The characteristics of the monitored rooms are shown in Tab.1, and the positions of the devices are shown in the illustrative map of FEI STU in Fig.2. As the use of air conditioning and heating is an important input in the monitoring of environmental parameters and subsequently assessing the effectiveness of their use, the monitoring was divided into two periods:

1. Summer period: From July 10th to September 30th 2025.
2. Winter period: From November 18th 2025 to April 30th 2026.

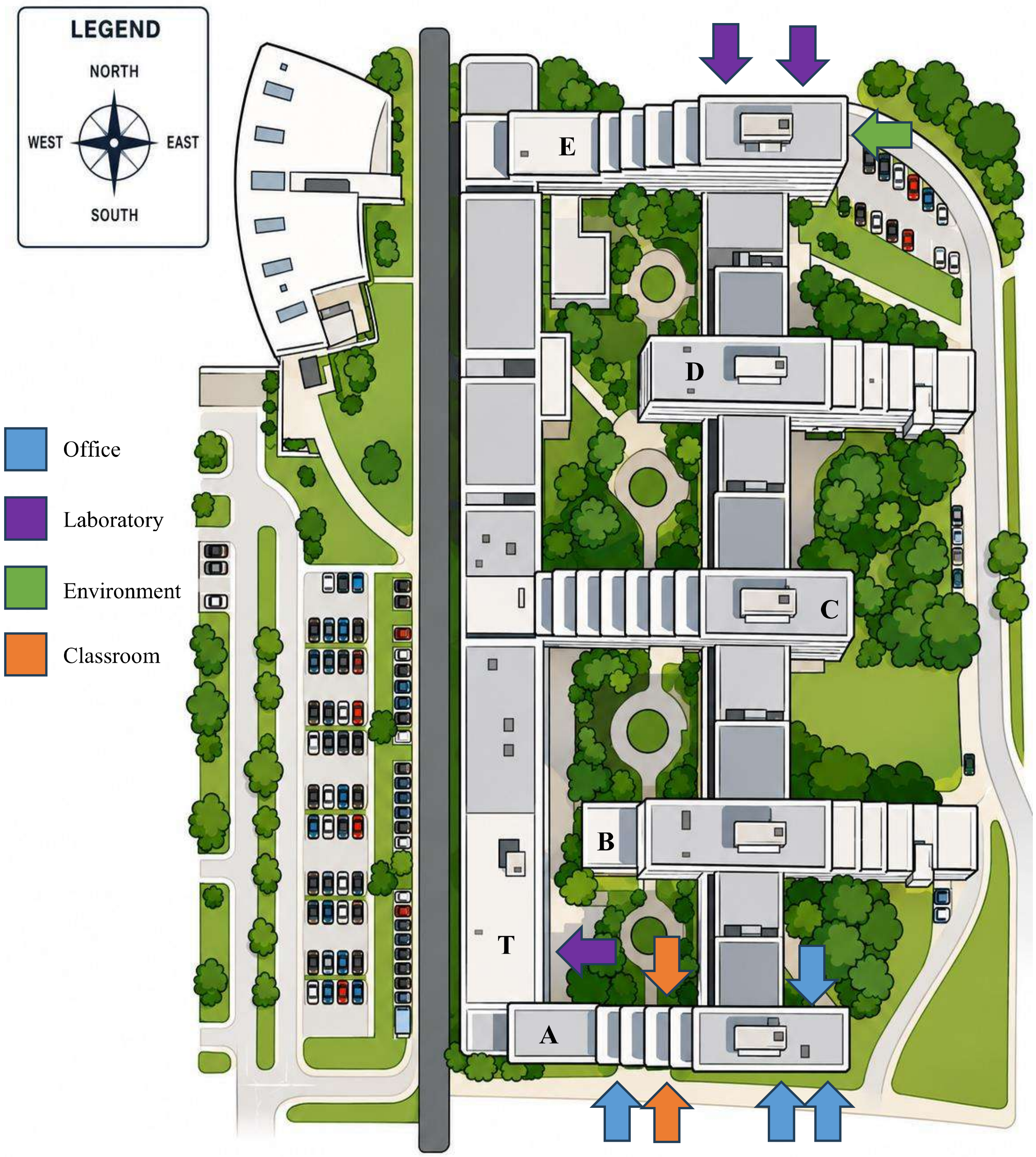


**Fig. 2** Illustrative map of installed devices at FEI STU

| GaSens ID | Room type | Room size [$m^2$] | Building | Floor | Orientation | Air conditioning |
|---|---|---|---|---|---|---|
| 1 | Office | 32.5 | A | 7 | South | Yes |
| 2 | Office | 22.5 | A | 7 | South | No |
| 3 | Classroom | 32.5 | A | 7 | South | No |
| 4 | Environment | 90 | E | 4 | East | No |
| 5 | Classroom | 32.3 | A | 7 | North | No |
| 6 | Office | 19.5 | A | 8 | South | No |
| 7 | Office | 19.5 | A | 3 | South | Yes |
| 8 | Laboratory | 96 | A | -1 | East | No |
| 9 | Laboratory | 32.5 | E | 4 | North | No |
| 10 | Laboratory | 19.5 | E | 4 | North | No |

**Tab. 1** Characterization of the monitored areas

**Examples of gathered data**

In this section, we present examples of data collected during both the summer and winter monitoring periods. These examples are shown in Fig. 3 and Fig. 4. In both cases, a profile of monitored parameters is compared with an environmental profile representing the parameters outside the monitored building. According to SHMU, the hottest day during the summer monitoring period was August 15 [3]. This day was selected for the exercise. For the winter monitoring period, January 11 was selected as one of the coldest days. It is important to note that during the summer monitoring period, the BME environmental sensors were calibrated before installation using laboratory equipment; in the winter period, the devices were calibrated at the monitoring site. As the reference temperature, the one from the intelligent heating system of FEI STU was used. It should also be noted that during the summer period, we used the V13 version of GaSens, while during the winter period, we used the newer V14 version. This difference does not reflect any change in the hardware but rather a newer firmware version, especially the list of monitored parameters.

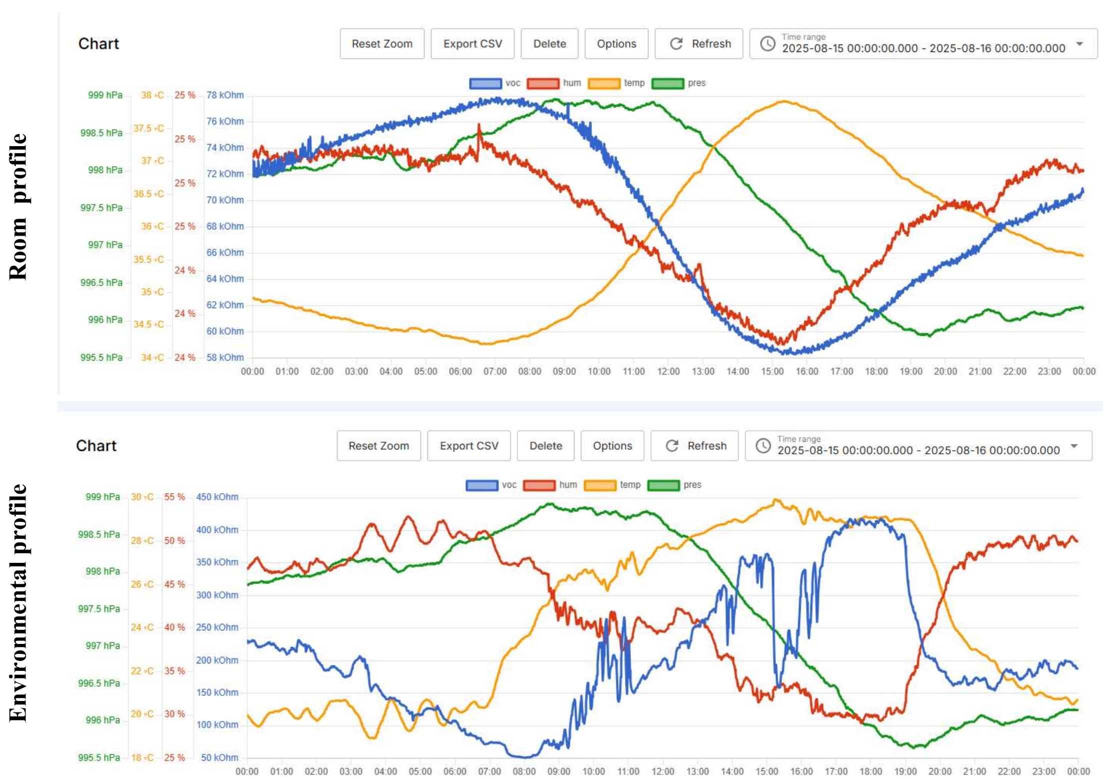


**Fig. 3** Comparison of the monitoring profiles during the hottest day of the summer monitoring period

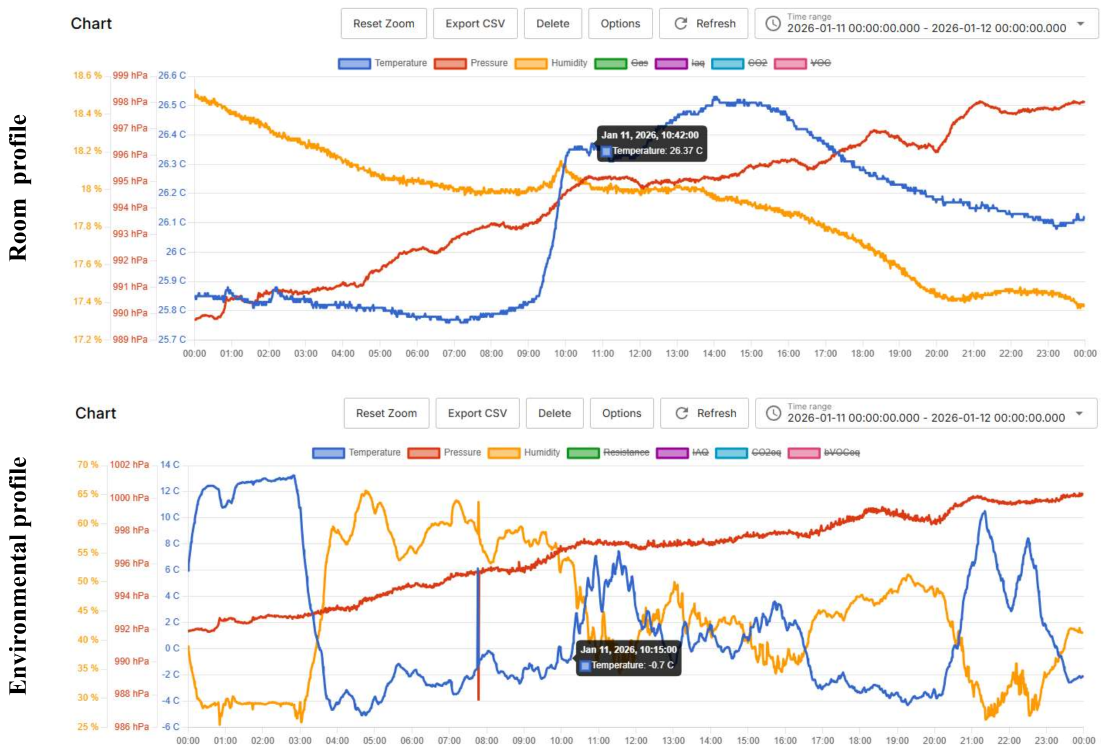


**Fig. 4** Comparison of the monitoring profiles during the coldest day of the winter monitoring period

**Analys based on the average temperature in the monitored areas**

In this part of the paper we are presenting the average temperatures in the monitored areas over the summer and winter monitoring stages. The results can be found in Tabs. 2 and 3. In addition to the average temperatures and their corresponding uncertainties, the tables present the number of hours when the temperature was outside the desired range of 20 to 26 °C [4]. In the summer, if the temperature is too low and the room is equipped with an air conditioner, it indicates that energy is wasted on air conditioning. Otherwise, if the temperature is too high, the room is not ideal for work, and corrective measures must be taken. During the winter, the temperature is too high, and the heating system is too powerful, leading to energy losses. If the temperature is too low, either the room's insulation or the heating level is insufficient.

| GaSens | $T_{avg}$ [°C] | T < 20 °C [h] | T < 20 °C [%] | T > 26 °C [h] | T > 26 °C [%] |
|---|---|---|---|---|---|
| 1 – Office | 27.06 ± 2.52 | 0.00 | 0.00 | 1277.11 | 65.57 |
| 2 – Office | 26.25 ± 2.36 | 0.00 | 0.00 | 2160.15 | 70.73 |
| 3 – Classroom | 30.00 ± 2.37 | 0.00 | 0.00 | 2573.15 | 84.27 |
| 4 – Outside | 20.09 ± 3.25 | - | - | - | - |
| 5 – Classroom | 25.19 ± 2.61 | 217.68 | 7.07 | 1668.45 | 54.17 |
| 6 – Office | 27.64 ± 2.89 | 8.60 | 0.28 | 2354.20 | 76.03 |
| 7 – Office | 34.17 ± 3.29 | 0.00 | 0.00 | 3848.60 | 99.99 |
| 8 – Laboratory | 24.31 ± 2.90 | 1233.58 | 19.26 | 726.33 | 32.69 |
| 9 – Laboratory | 28.91 ± 4.40 | 7.50 | 0.22 | 2257.97 | 67.59 |
| 10 – Laboratory | 29.74 ± 1.79 | 0.00 | 0.00 | 4017.98 | 99.23 |

**Tab. 2** Analysis of room temperatures in the summer monitoring period

| GaSens | $T_{avg}$ [°C] | T < 20 °C [h] | T < 20 °C [%] | T > 26 °C [h] | T > 26 °C [%] |
|---|---|---|---|---|---|
| 1 – Office | 21.60 ± 2.09 | 350.05 | 14.66 | 132.33 | 5.54 |
| 2 – Office | 21.83 ± 1.13 | 310.98 | 13.30 | 0.00 | 0.00 |
| 3 – Classroom | 19.54 ± 2.62 | 1788.23 | 75.06 | 67.00 | 2.81 |
| 4 – Outside | 12.67 ± 5.57 | | - | | - |
| 5 – Classroom | 23.61 ± 1.98 | 5.87 | 0.25 | 317.98 | 13.34 |
| 6 – Office | 25.96 ± 2.27 | 8.33 | 0.35 | 1090.77 | 45.79 |
| 7 – Office | 22.29 ± 1.83 | 17.95 | 0.80 | 169.02 | 7.49 |
| 8 – Laboratory | 26.46 ± 0.35 | 0.00 | 0.00 | 145.21* | 92.42 |
| 9 – Laboratory | 24.63 ± 1.37 | 1.95 | 0.73 | 44.42 | 16.57 |
| 10 – Laboratory | 25.81 ± 3.16 | 32.48 | 1.36 | 1247.85 | 52.29 |

* due to reconstruction, the monitoring was carried out only for 268h

**Tab. 3** Analysis of room temperatures in the winter monitoring period

The results of the summer monitoring period show that, in almost all areas, temperatures were too high. This could be because, during the monitoring period, no window blinds were installed; therefore, the air conditioning units were unable to cool the rooms in the southern part of the building. The vertical window blinds were installed during the autumn of 2025; their influence will be evident in the next summer period. Rooms where the temperatures were below the recommended range for a reasonable time were the classroom with GaSens 5 and the Laboratory with GaSens 8. This is because these rooms are located on the north and east sides of the building, so there is no significant impact from direct sunlight. In general, none of the monitored rooms shows ineffective use of air conditioning. Indeed, the Office with GaSens 7 and the Laboratory with GaSens 10 seem to be uncooled and require improvement and shading assessment. The stark contrast between Lab 8 (well-cooled) and the rest of the building suggests a severe imbalance that will need further analysis.

Regarding the winter period, interesting phenomena can be seen. Office 1 and Office 2 maintain comfortable seasonal averages, Office 6 experiences severe overheating with a mean temperature of 25.96 °C and spends nearly half the entire monitoring period above the 26 °C threshold. This clearly indicates that the heating system was not used effectively. Classroom 3 is distinctly under-heated, spending 75.06% of its time below 20 °C. Conversely, Classroom 5 skews hot, spending 13.34% of its time above 26 °C. This could also been seen as a result of sunlight, as Classroom 3 is located on the south and Classroom 5 in the north, as well as not effective regulation of the heating system. The effect of the orientation and the insufficient temperature regulation can be seen also in case of the laboratories. The laboratory with GaSens 8 is overheated, as the average temperature exceeds 26 °C more than 92% of the time. Laboratory with Gasens 10 experienced the worst overheating in the dataset, spending 1,247.85 hours above 26 °C, coupled with a high standard deviation of 3.16 °C, indicating poor climate stability. For the winter period it can be concluded that Office 6 and Lab 10 are suffering from severe cooling/ventilation deficits. The laboratory with GaSens 8 indicate the recalibration of the thermostat. The room is stable but set significantly too high for typical laboratory standards. Classroom 3 seems to be chronically cold environment compared to all other indoor spaces, which may negatively impact student comfort and alertness.

**Application of AI tools for identifying typical patterns of air conditioning and heating**

In this section we are presenting the results of the first AI based analysis which was performed on the environmental data to identify signs typical to ineffective use of air conditioning, such as opening the window with the air conditioning on etc. For this first analysis, the free versions of the ChatGPT 5.5 instant and Gemini 3.5 Flash large language modes (LLM) were used. The dataset consisted of 24h time series data from the GaSens 1 device collected for 31st July 2025. The temperature, humidity and pressure profile is shown in Fig. 5. It has to be noted that no annotations and learning dataset were used therefore a zero-shoot [5] learning principle was used. We asked the LLM to look for signs of the following events and highlight them on a graph:

- Turning the air conditioning on/off.
- Turning the air conditioning on/off.
- Opening the windows.
- Closing the windows.
- Time of sunset.
- Time of sunrise.

The resulting graphs are shown in Fig.6 and Fig. 7 and the metrics of the analysis are shown in Tab.4

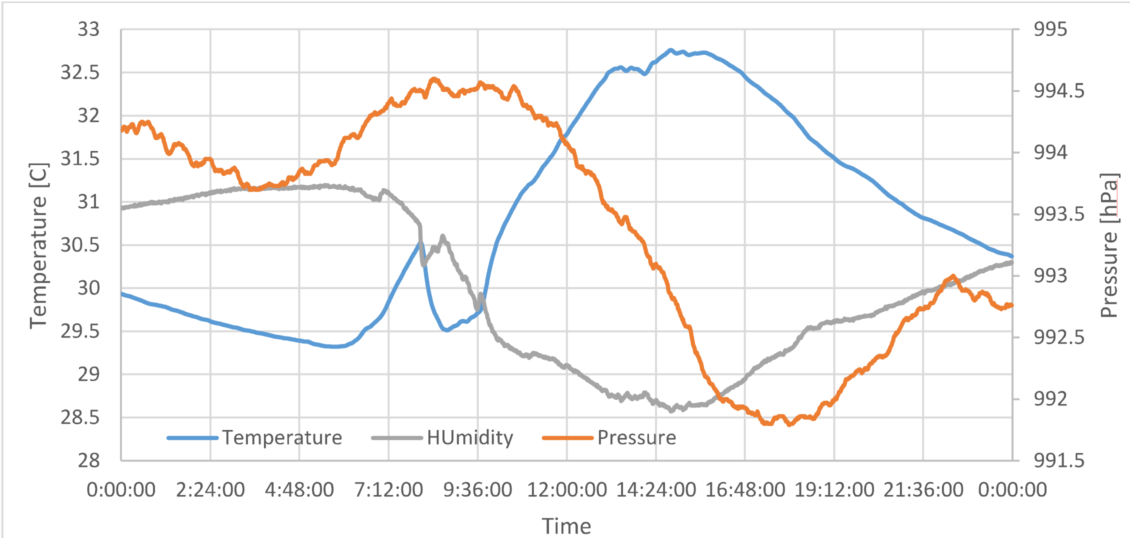


**Fig. 5** Time series profile of environmental parameters used for the AI analysis

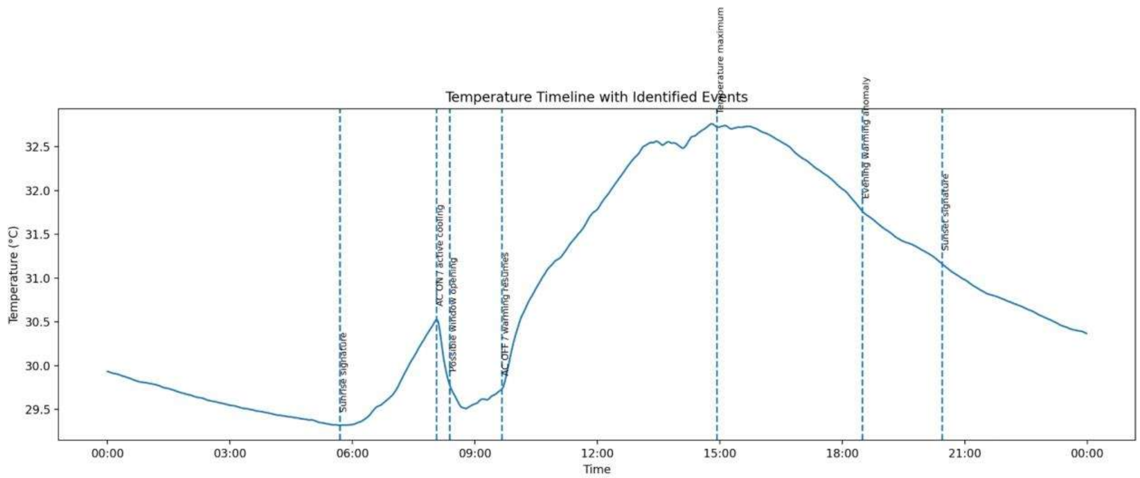


**Fig. 6** Identified event by ChatGPT

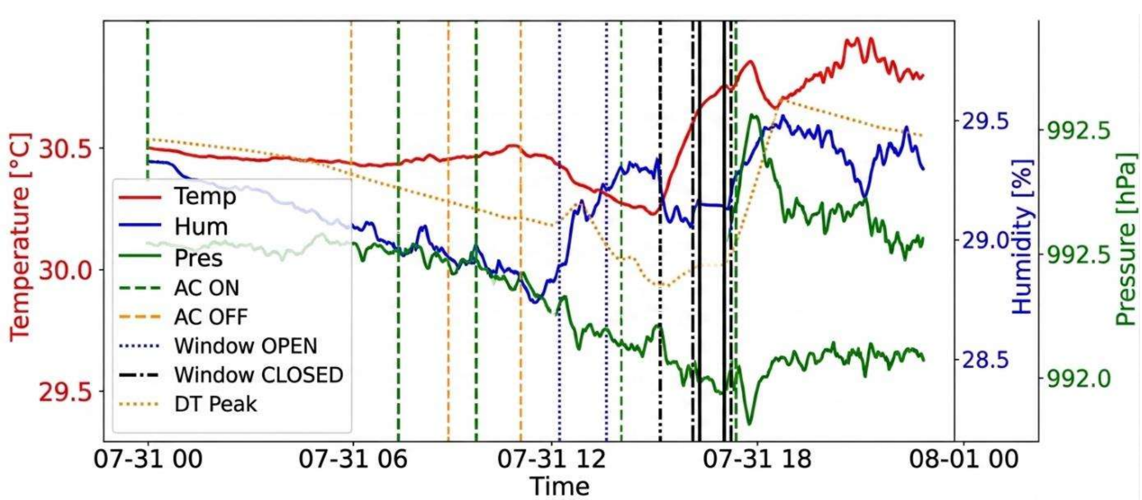


**Fig. 7** Identified event by Gemini

| Event | Real | ChatGPT | Gemini |
|---|---|---|---|
| Sunrise | 5:27 | 5:35 | 5:30 |
| Sunset | 20:27 | 20:30 | 20:30 |
| Activations of the AC | N/A | 2 | 4 |
| Opening and closing the window | N/A | 2 | 2 |

**Tab.4** Summary of the AI analysis

The results show that both LLMs can identify patterns characteristic of opening and closing windows and turning the air conditioning on and off with fairly high precision. Although the graphs look similar, Gemini provided a more comprehensive analysis and could identify more events. Gemini concluded that air conditioning is highly effective at rapidly reducing both room temperature and relative humidity, creating sharp microclimates on the floor. However, this cooling efficiency was severely compromised by untimely window operations. Opening the windows during the hottest midday hours allowed ambient outdoor heat to flood the space, causing a rapid thermal runaway that peaked at an uncomfortable 32.7 °C. Both LLMs could also predict the times of sunrise and sunset with an uncertainty of around ±5 minutes. Although these patterns are not evidence or confirmed by a person or other valid data, it was found that LLMs or other AI tools can help analyze the data and draw conclusions about the effectiveness of air conditioning and heating devices. Next, the data will be analyzed by involving real AI experts from STU.

**Conclusion**

he aim of the REBECCA - Renewable Energy for the Creation of a Balanced Ecological Carbon Agenda project is to develop new knowledge and procedures for the future decarbonization of the energy systems of selected university buildings and workplaces, and to create a replicable model for the conditions in the Slovak Republic. One of the key aims is to develop an innovative concept to effectively reduce the need for primary energy, in line with the transition to a green and low-carbon economy, adaptation,, and increased resilience to climate change, in cooperation with small and medium-sized enterprises. Effective data collection is the key to optimization studies. IoT solutions and smart devices may significantly ease this process. For this purpose, the GaSens environmental tool has been selected. At FEI STU, 10 GaSens devices were installed in 4 offices, 2 classrooms, 3 laboratories, and 1 outdoor location to measure outdoor environmental parameters. The monitoring was divided into two phases: the summer and winter seasons. The summer season focuses on assessing the effectiveness of the air conditioning system and the winter season focuses on the heating. The gathered data has the required granularity to identify the desired patterns. The first analysis involving two LLMs clearly demonstrates the possibility of using AI. Subsequently, the data will be analyzed with AI experts at STU. Once the effectiveness of the heating and cooling system has been assessed, the potential energy and financial savings will be assessed, and recommendations will be drawn.

*Acknowledgement*
*This work has been Founded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I04-03-V02-00033 Rebecca.*

**References**

[1] M. Behul, et. all: *System for Monitoring of Environmental Conditions in Laboratories*, Advances in the Application of Smart Devices and AI in the Nuclear Domain (SAI-ND 2026), May 15, 2026, FEI STU Bratislava.

[2] M. Vojs, et. all: *Universal Platform for IoT Device Monitoring, Data Collection and Control*, Advances in the Application of Smart Devices and AI in the Nuclear Domain (SAI-ND 2026), May 15, 2026, FEI STU Bratislava.

[3] P. Faško, et. all *Klimatologické zhodnotenie roka 2025*, Slovenský hydrometeorologický ústav (SHMÚ), Jan. 19, 2026. [Online]. Available: https://www.shmu.sk/sk/?id=1698&page=2049

[4] Slov-Lex. (2016). *Zákon č. 99/2016 Z. z.* https://www.slov-lex.sk/ezbierky/pravne-predpisy/SK/ZZ/2016/99/

[5] Bright Data. (n.d.). *Zero-shot learning*. https://brightdata.com/blog/ai/zero-shot-learning