https://doi.org/10.32056/KOMAG2026.8

Environmental Monitoring in Green IoT Technology: AIRS as a Scalable Solution for Intelligent Measurement Systems

Received: 26.06.2026

Accepted: 21.08.2026

Published online: 31.08.2026

Mariusz GAŁĄZKA[1]*, Łukasz PENAR[1]

Author's affiliations and addresses:

[1] TECHNIKA IT sp. z o.o.
ul. Toszecka 2
44-102 Gliwice, Poland

*** Correspondence:**

e-mail: sekretariat@technikait.com.pl

Abstract:

The dynamic development of the Internet of Things (IoT) and the growing demand for long-term environmental monitoring have increased the need for energy-efficient, autonomous, and scalable measurement systems. This paper presents AIRS, a modular Green IoT data logger designed for intelligent environmental and industrial monitoring applications. The proposed platform integrates the functions of a data logger, automation controller, and IoT communication node within a single compact device. AIRS supports a wide range of analog and digital sensors and communication interfaces, including RS232, RS485, SDI-12, Ethernet, GSM/LTE, Wi-Fi, Bluetooth, and UHF. A key feature of the system is its advanced energy management architecture, enabling operation in grid-powered, battery-powered, photovoltaic, and hybrid configurations. Field experiments conducted in real environmental conditions demonstrated very low power consumption and high long-term autonomy. In one measurement campaign, the system operated continuously for nearly five months using only a 24 Ah AGM battery, with energy consumption indicating a potential operational time exceeding 450 days without battery replacement. Additional tests confirmed stable operation of photovoltaic-powered configurations even under reduced solar irradiation conditions. The paper also presents practical deployments of AIRS in meteorological stations, maritime monitoring systems, post-industrial area monitoring, and mobile environmental measurement platforms. The obtained results confirm that AIRS combines the flexibility of open-source systems with the reliability and functionality of professional industrial data loggers while maintaining exceptionally high energy efficiency. The proposed solution represents a scalable and sustainable approach to environmental monitoring in accordance with Green IoT principles.

Keywords: Green IoT, Environmental Monitoring, Intelligent Measurement Systems, AIRS

Publisher: **KOMAG Institute of Mining Technology, Poland**

1. Introduction

The dynamic development of the Internet of Things (IoT), the ongoing digitalization of industrial processes, and the growing importance of long-term environmental monitoring have made intelligent measurement systems one of the most significant areas of contemporary research and technological implementation [1, 2]. Distributed sensor networks are playing an increasingly important role in meteorology, hydrology, environmental protection, industry, water management, and precision agriculture [3, 4]. These systems enable continuous measurement of environmental parameters and real-time data transmission to supervisory systems, thereby supporting analytical and decision-making processes.

In the face of climate change, extreme weather events, and the increasing need to protect natural resources, environmental monitoring has become a key component of modern information infrastructure [5]. At the same time, the development of measurement systems requires energy-efficient, autonomous, and robust solutions capable of operating under harsh environmental conditions. Of particular importance is the concept of Green IoT, which focuses on designing sustainable IoT systems that minimize energy consumption while maintaining high functionality and reliability [1, 6].

Contemporary measurement platforms are responsible not only for data acquisition but also for local data processing, analysis, and intelligent management of communication and energy resources [7]. Consequently, a modern data logger has evolved into an intelligent IoT node capable of performing concurrent measurement, communication, and control processes [2, 7]. Increasing attention is also being given to solutions that enable adaptive energy management and automatic anomaly detection in environmental data [6].

A significant challenge remains the provision of long-term energy autonomy [1, 8]. In many applications, devices operate in locations lacking access to power infrastructure, such as protected areas, wetlands, buoys, and remote industrial sites. Therefore, energy-efficient electronic systems, intelligent energy management algorithms, and integration with renewable energy sources-particularly photovoltaic panels - are of critical importance [1].

Commercially available environmental monitoring platforms offer high reliability and extensive communication capabilities; however, they are often associated with high power consumption, limited configuration flexibility, and significant deployment costs [9, 10]. Open-source solutions, on the other hand, provide considerable flexibility but typically exhibit lower environmental robustness and more limited integration capabilities with professional measurement systems [11]. Consequently, the development of modular and energy-efficient platforms that combine high functionality with easy adaptation to various measurement scenarios has become an important research and development direction.

In response to these requirements, the AIRS data logger was developed as a modular Green IoT platform dedicated to the construction of intelligent environmental and industrial monitoring systems. AIRS integrates the functions of a conventional data logger, a measurement controller, and an intelligent IoT node within a single compact device. The platform supports cooperation with a wide range of analog and digital sensors and provides interfaces including RS232, RS485, SDI-12, Ethernet, USB-C, GSM/LTE, Wi-Fi, Bluetooth, and UHF. An additional important feature of the solution is its advanced power management subsystem, which enables operation in grid-powered, battery-powered, photovoltaic, and hybrid configurations [12].

2. Characteristics of the AIRS System

One of the key features of the AIRS system is its high scalability and configuration flexibility. Thanks to its modular architecture, it is possible to create both small autonomous measurement stations and extensive multi-sensor telemetry systems. The data logger enables the simultaneous handling of multiple types of measurement signals, local data processing, statistical calculations, and intelligent management of energy consumption and data transmission. In practice, this means that the platform can be adapted to a wide range of environmental and industrial applications without the need to design separate hardware systems [12].

The AIRS data logger is a modern, compact, and modular measurement device designed for reliable monitoring of environmental and industrial parameters. The system architecture has been developed to ensure high functionality, energy efficiency, and flexible configuration according to user requirements. Owing to its modular design, AIRS can be used both in simple measurement installations and in advanced environmental monitoring, meteorological, and industrial automation systems.

The device integrates the functions of a data logger and an automation controller, enabling simultaneous measurement, analysis, processing, and transmission of data. The system supports a wide range of analog and digital signals, allowing cooperation with various environmental and industrial sensors. Depending on the version, the device can support up to 18 analog channels, including current, voltage, and PT100 resistance temperature sensor inputs. The use of precision measurement circuits and a 24-bit analog-to-digital converter ensures high measurement accuracy and operational stability even under demanding working conditions.

One of the key components of the AIRS data logger is its advanced power supply system, which enables operation from various energy sources. The system can be powered by a DC voltage ranging from 5 V to 30 V and, thanks to MPPT support, can also operate with photovoltaic panels. The built-in lithium-ion battery allows long-term autonomous operation, while the intelligent power management system optimizes energy consumption and extends battery pack lifetime. The very low power consumption makes the device particularly suitable for field installations and continuous environmental monitoring applications.

The data logger is equipped with a modern ARM microcontroller featuring DSP and FPU support, enabling parallel data processing and the implementation of more advanced control algorithms. The application of security mechanisms such as AES encryption, TrustZone technology, and cryptographic accelerators enhances the security of both data transmission and storage. The system also includes a large FLASH memory capable of storing millions of measurement records with user-defined sampling intervals. The sampling interval can be configured from 1 sample/s to 1 sample/day. Increasing the sampling interval reduces energy consumption and limits the bandwidth of the measured signal, while providing the benefit of a longer recording time.

An important advantage of the solution is the wide range of available communication interfaces. AIRS supports RS232, RS485, SDI-12, Ethernet, USB-C, Wi-Fi, Bluetooth, and GSM/LTE communication technologies. This allows seamless integration with numerous telemetry systems, IoT platforms, and industrial infrastructures. Data can be transmitted locally or remotely using protocols such as FTP, FTPS, HTTPS, and Modbus TCP/IP. The flexible architecture also enables the implementation of dedicated communication protocols tailored to the requirements of specific systems.

A major strength of the AIRS data logger is its intelligent device management and the ability to dynamically control the power supply of sensors and measurement modules. The system can automatically adapt its operating mode to current energy and environmental conditions, significantly

Publisher: **KOMAG Institute of Mining Technology, Poland**

reducing power consumption while increasing operational reliability. The solution employs a dedicated scripting language that enables the creation of advanced operational scenarios and communication between devices.

By combining energy efficiency, modular architecture, extensive communication capabilities, and high measurement precision, AIRS represents a modern and versatile solution for intelligent environmental monitoring systems, meteorology, industrial automation, and IoT applications. The device can be deployed both in large-scale measurement stations and in mobile monitoring systems operating under challenging field conditions.

3. Examples of Implementations

The versatility of the AIRS platform has been confirmed through real-world deployments carried out in various operating environments. One example is a meteorological station operating within the Biebrza National Park, which has been continuously monitoring environmental parameters since late 2024. The system employs a hybrid power supply architecture consisting of grid power, battery storage, and photovoltaic panels, ensuring uninterrupted operation even during unexpected power outages. The AIRS platform cooperates with professional environmental sensors, including Vaisala temperature and humidity sensors, wind speed and direction sensors, atmospheric pressure sensors, tipping-bucket rain gauges, and multi-channel soil temperature sensors. In addition, the data logger performs local data processing, including the calculation of average meteorological parameters, while the collected data are transmitted via a GSM network.

Another example of AIRS platform implementation is represented by measurement systems deployed by the Maritime Office in Szczecin. Four autonomous monitoring stations commissioned in 2025 operate under particularly demanding environmental conditions, including ponds, navigation buoys, and remote island locations. These systems utilize hybrid power supply configurations combining grid power, photovoltaic panels, and small wind turbines. The sensors integrated with AIRS include hydrostatic water level sensors, multiparameter meteorological sensors, and laser-based visibility and precipitation sensors. A particularly important aspect of this deployment is the use of industrial radio modems that meet stringent data transmission security requirements.

Another significant application area of the AIRS platform is the monitoring of post-industrial sites and mining waste dumps. In projects carried out for KOMAG and the Central Mining Institute (GIG), AIRS systems cooperate with extensive networks of environmental sensors monitoring soil temperature, humidity, gas concentrations, particulate matter levels, and groundwater parameters. In the GIG installations, particular emphasis was placed on underground deployment of the measurement infrastructure and on the capability to detect early signs of waste dump self-ignition using thermocouples capable of measuring temperatures up to 1000°C. In both cases, autonomous power supply systems and the ability to operate for extended periods without frequent maintenance interventions are of critical importance.

An interesting example of the platform's capabilities is the portable suitcase-based version of the AIRS system, designed as an ultra-low-power autonomous environmental monitoring station intended for operation in remote and difficult-to-access field locations. The system supports solar radiation sensors and, owing to its battery-powered architecture and extremely low energy consumption, can operate autonomously for approximately one year without requiring replacement of the power source.

These implementations demonstrate that AIRS is not merely a conventional data logger but rather a versatile and scalable Green IoT platform integrating environmental measurements, local data processing, intelligent energy management, and multi-channel communication within distributed monitoring systems. The combination of modular architecture, low power consumption, extensive communication capabilities, and flexible configuration makes the solution suitable for a wide range of environmental, industrial, and research applications.

4. Aim of the Study

The aim of this study is to verify the feasibility of using the AIRS system as an energy-efficient and scalable Green IoT platform for long-term environmental monitoring. The analyses focused on evaluating the system's energy efficiency, operational autonomy under various power supply configurations, and its capability to integrate with distributed measurement systems. The main research questions concerned the system's ability to operate autonomously for extended periods under field conditions and the effectiveness of the implemented energy management mechanisms.

5. Materials and Methods

Example measurements aimed at demonstrating the optimization of energy consumption while simultaneously recording environmental parameters were conducted in two measurement series using real industrial applications. In the first series of experiments, input data were provided by a monitoring station measuring the water level in a piezometer. The measurement setup is shown in Figure 1.

Fig. 1. Measuring station. Powered exclusively by battery.
The system operates under real-world conditions in Silesia

The measurement station was designed as a fully autonomous system in which a standard AIRS BASIC data logger was supplemented with a 24 Ah AGM gel battery with a nominal voltage of 12 V. The absence of an external power source (e.g., photovoltaic panels) required particular optimization of the power consumption of all devices included in the system [12].

Water level measurements are performed using a hydrostatic probe communicating via the MODBUS RTU protocol. The probe does not include atmospheric pressure compensation, which means that the recorded pressure value corresponds to the sum of atmospheric and hydrostatic pressure. In addition, the device provides information on the temperature of the measured liquid and its electrical conductivity, enabling more comprehensive analysis of environmental changes.

The measurement setup also includes an AIRS data logger equipped with a high-precision atmospheric pressure sensor. The logger performs a measurement cycle every 15 minutes, storing data in non-volatile FLASH memory. The pressure value obtained from the hydrostatic probe is automatically compensated for atmospheric pressure, allowing the actual water column level in the piezometer to be determined. The recorded data—including battery supply voltage - are subsequently transmitted to a database server at one-hour intervals, enabling continuous system monitoring and remote diagnostics.

The second series of experiments was conducted using the setup shown in Figure 2, with a one-second measurement interval and data transmission every 5 minutes. The power supply system consisted of the same 12 V, 24 Ah AGM battery and a 20 W photovoltaic panel.

Fig. 2. Measuring station with photovoltaic power supply system used in the second series of tests

6. Results

In the first measurement series, the system operated continuously using only the energy stored in the AGM gel battery. Analysis of the power supply voltage data indicates that, between May 27, 2025, and October 16, 2025, the battery voltage decreased from 13.02 V to 12.37 V, as shown in Figure 3. According to literature data and AGM battery open-circuit voltage reference tables (Table 1), a voltage of 12.37 V corresponds to a state of charge slightly above 70%.

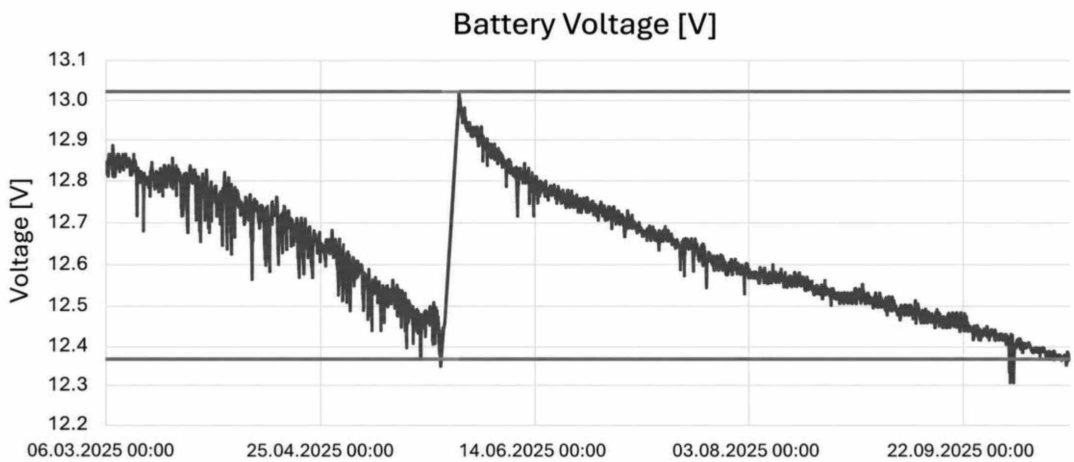

Fig. 3. Measurement results for sampling every 15 minutes and transmission every 1 hour

Table 1. AGM battery charge status in relation to resting voltage

12 Volt AGM Battery State of Charge	
Level	Voltage
100%	13.00 Volts
90%	12.75 Volts
80%	12.50 Volts
70%	12.30 Volts
60%	12.15 Volts
50%	12.05 Volts
40%	11.95 Volts
30%	11.81 Volts
20%	11.66 Volts
10%	11.51 Volts
0%	10.50 Volts

Considering the nominal battery capacity and the permissible discharge voltage (approximately 10.5 V), it can be estimated that the entire measurement system is capable of operating for more than 450 days without requiring replacement of the power source. This result should be regarded as highly favorable, as it indicates that the station can function for over one year in a completely maintenance-free mode. Such a solution significantly reduces operating costs and eliminates the need for frequent service visits related to battery replacement, which is a major advantage for monitoring applications conducted in remote and difficult-to-access field locations.

For systems not equipped with a photovoltaic module, ambient temperature is expected to have a more pronounced effect on battery performance and, consequently, on the achievable operating time. Owing to the autonomous nature of the field installation, maintaining a stable temperature inside the enclosure containing the electronic components and battery is not physically feasible; the plastic enclosure provides only passive protection against external environmental conditions. An extended monitoring campaign is therefore currently being conducted, including measurements of the temperature inside the measurement units, to support future optimization of the power-supply capacity. At present, the operating time can only be estimated using simplified calculations based on nominal battery parameters, while an appropriate safety margin may be provided by oversizing the power-supply system. The performance of the system under other environmental conditions has not yet been experimentally assessed, as the available data are limited to the installations currently in operation. Such investigations are planned for the subsequent years of system deployment.

The results of the second measurement series are presented in Figures 4 and 5. The first voltage-time plot (Figure 5) shows the complete range of the collected data, whereas the second plot (Figure 4) focuses on the most recent data available at the time of recording (early autumn measurements).

Both figures also present the average voltage levels calculated as daily averages. It can be observed that, with the change of season, the average voltage values decreased slightly. However, the measurement station continues to operate within a safe voltage range and still maintains a substantial energy reserve.

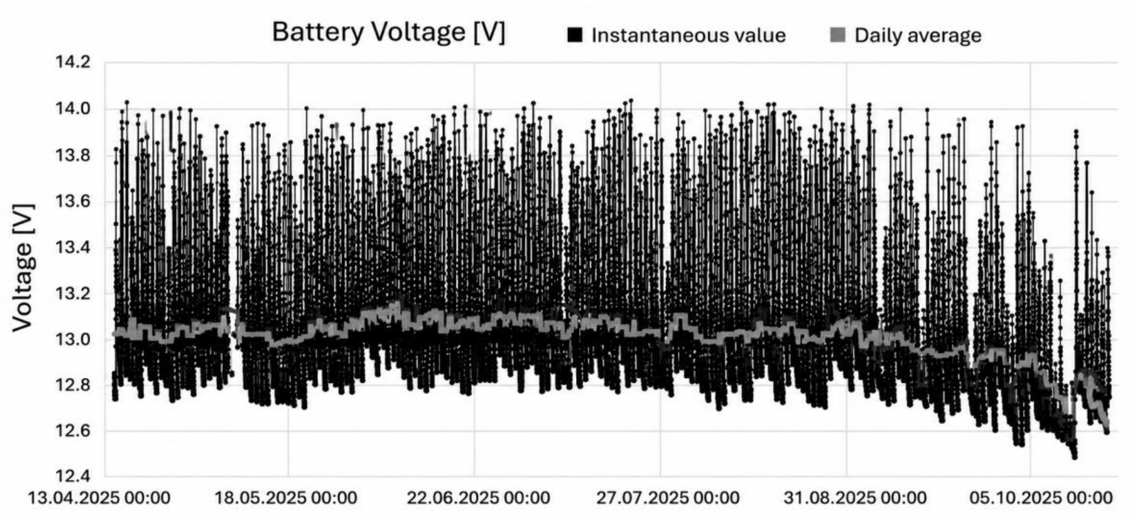

Fig. 4. Power supply voltage over the entire test period.
Instantaneous values and daily average values

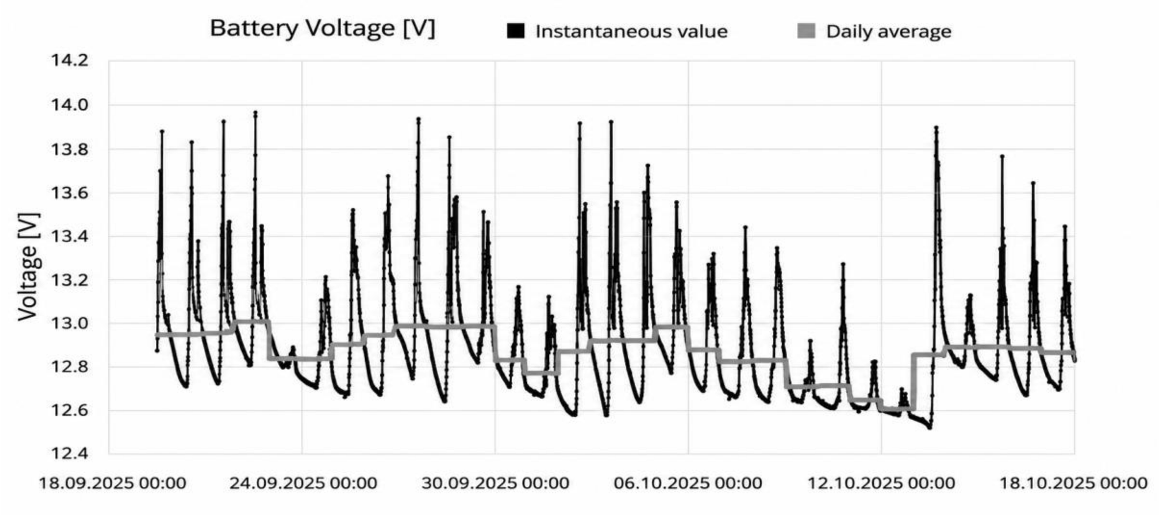

Fig. 5. Power supply voltage for the selected period.
Instantaneous values and daily average values

This case demonstrates that a relatively small power supply system housed in a compact enclosure with a foundation is sufficient to reliably support this measurement setup. Moreover, despite the large volume of collected measurement data, this translates into relatively low costs associated with the construction and operation of the monitoring station.

7. Discussion

The measurement results and technical specifications of the AIRS data logger demonstrate that the device successfully combines the features of modern data loggers with the advantages of environmentally sustainable and open-source solutions. Compared with well-established environmental data loggers, AIRS offers comparable or even superior functionality. For example, the Campbell Scientific CR300 provides six analog channels with a 24-bit ADC and supports RS232 and SDI-12 communication interfaces [5]. However, its disadvantages include a relatively high cost and greater power consumption. The CR300 consumes approximately 1.5 mA in idle mode [13], which still represents a higher energy demand than that of AIRS. DataTaker loggers (DT82E/DT85) offer a large number of channels and advanced functionality [14, 15], but at the expense of higher energy consumption and operating costs. The DT82E consumes approximately 60 mW under low-frequency sampling conditions [16] and more than 1 W during intensive operation [17], requiring a more powerful energy supply system.

Modern IoT solutions are primarily focused on wireless communication and energy efficiency, often at the cost of limiting the number of supported sensors. The Novus LogBox LTE provides LTE Cat-M1/NB-IoT communication and battery operation for up to approximately 80 hours [16, 17], but it offers only two analog inputs and one digital input [16, 17]. In contrast, the open-source Arduino Mayfly platform provides low power consumption - approximately 6.5 mA during operation and 0.3 mA in sleep mode [18] - but requires user integration and offers fewer channels as well as lower measurement accuracy. In practice, commercial solutions provide convenient cloud integration, while DIY platforms offer low cost and flexibility; however, only a limited number of systems combine extensive functionality with exceptionally high energy efficiency.

Compared with competing solutions, AIRS stands out through the number of supported interfaces and measurement channels. The device supports 18 analog channels, including voltage inputs, 4-20 mA current inputs, and PT100 temperature sensors with an accuracy of 0.1%, as well as four independent digital inputs. This number of channels exceeds that of solutions such as the CR300 and LogBox LTE. AIRS is also equipped with RS-232, RS-485, SDI-12, and Ethernet interfaces supporting Modbus RTU/TCP and NMEA protocols. The GSM/LTE module enables cellular data transmission, while the flexible architecture additionally supports integration with Wi-Fi, Bluetooth, and UHF radio modems. As a result, AIRS provides functionality comparable to modern IoT data loggers without compromising the number of supported channels or battery lifetime.

Another important advantage of the system is its flexible power supply architecture. The logger can operate from a 5–30 V DC power source, incorporates an MPPT algorithm for photovoltaic panels, and includes a 5.4 Ah Li-Ion battery. This enables both stationary and fully off-grid operation. The operating temperature range extends from –20 °C to +45 °C, representing a compromise associated with the use of Li-Ion cells while remaining sufficient for most field applications. Conventional industrial data loggers such as the CR300 and DT85 can operate at temperatures up to +70 °C [13, 19], although this typically requires more expensive and robust power supply systems.

Despite its extensive functionality, AIRS achieves extremely low power consumption-below 300 μA in sleep mode - which is superior to many commercial data loggers (CR300: approximately 1500 μA [13]) and comparable to the Mayfly platform (approximately 300 μA [18]). This performance has been achieved through a proprietary power management architecture and intelligent energy management mechanisms that dynamically adjust the operating mode of the device. These solutions are fully aligned with Green IoT principles by increasing energy efficiency while maintaining a high measurement frequency. Furthermore, controllable power outputs allow unused sensors to be switched off, reducing peripheral energy consumption.

These advantages were confirmed by the field experiments. In the first measurement campaign, the AIRS station operated exclusively on battery power for nearly five months - from late May to mid-October—while the battery voltage decreased only from 13.02 V to 12.37 V, corresponding to approximately 30% of the available energy capacity being utilized. Extrapolation of these results indicates that the system could operate for more than 450 days without battery charging or replacement. This finding confirms the exceptionally high energy autonomy of the system. The second measurement campaign, conducted during autumn, further confirmed the stability of operation despite reduced solar radiation conditions.

Publisher: **KOMAG Institute of Mining Technology, Poland**

The energy-consumption measurements were conducted with the AIRS data logger operating under normal field conditions. In this operating mode, individual communication interfaces were activated only when required for sensor interrogation, device configuration, or data transmission. Although the logger provides multiple interfaces - including RS232, RS485, SDI-12, Ethernet, USB-C, Wi-Fi, Bluetooth, and GSM/LTE - its integrated power-management system disconnects the supply from unused modules. Consequently, the mere presence of an interface in the device does not significantly affect the energy balance; its contribution depends primarily on its current demand, activation time, and frequency of use.

In the configuration investigated in this study, USB-C was used only to connect the logger to a computer during initial configuration and maintenance. Wi-Fi and Bluetooth, which provide alternative options for wireless data transmission, were not used because remote communication was performed exclusively through the GSM/LTE modem. The water-quality probe, measuring hydrostatic pressure, temperature, and electrical conductivity, communicated with the logger using the MODBUS RTU protocol over the RS485 interface. The RS232 and SDI-12 interfaces remained permanently unpowered, while the RS485 transceiver was energized only shortly before each measurement and switched off immediately after communication with the probe had been completed. Thus, unused modules remained inactive throughout essentially the entire monitoring period, whereas the interfaces required for measurements and data transmission operated with very low duty cycles.

The potential influence of additional interfaces was estimated under the assumption that each interface would be activated exclusively during sensor sampling or data transmission rather than operated continuously. The reference case was an estimated autonomous operating time of approximately 450 days using a 12 V, 24 Ah AGM battery, corresponding to an average battery current of about 2.2 mA. For RS232, assuming a current demand of approximately 0.3 mA at 3.3 V and an activation time of 6 s - the duration of a single sensor measurement - every 15 min, the additional consumption would be less than 0.1 mAh per day. Under these conditions, the expected operating time would remain approximately 449 days. Similarly, an SDI-12 interface drawing approximately 1 mA at 3.3 V and operating for 6 s every 15 min would contribute less than 0.4 mAh per day, resulting in an estimated autonomy of approximately 447 days. These results indicate that intermittently activated, low-power sensor interfaces have only a minor effect on the overall energy balance.

A greater reduction in operating time can be expected for interfaces used for data transmission. For Ethernet communication, assuming that the W5500 Ethernet controller draws approximately 132 mA at 3.3 V and remains active for 15 s once per hour—the estimated time required to establish a connection and transfer a data file - the additional consumption would be approximately 11 mAh per day. This would reduce the expected operating time to approximately 370–380 days. For Wi-Fi, an assumed current demand of approximately 100 mA at 3.3 V for 15 s once per hour would result in an additional consumption of about 8 mAh per day and an estimated operating time of approximately 430–435 days. Bluetooth transmission, assuming a current demand of approximately 50 mA at 3.3 V for the same 15 s hourly interval, would add about 4 mAh per day, corresponding to an estimated autonomy of approximately 410-415 days. USB-C is handled directly by the main microcontroller and, if used for data transfer for only several seconds once per hour, would have a comparatively small effect on the energy balance, reducing the expected operating time to approximately 440-445 days.

These estimates demonstrate that energy consumption is governed primarily by the duration and frequency of interface activation rather than by the number of interfaces physically integrated into the logger. In particular, continuous operation of Ethernet or Wi-Fi would be incompatible with the approximately 450-day autonomy achieved by the reference configuration. Periodic activation, however, makes it possible to use these interfaces while maintaining an acceptable operating time. The results also underline the importance of duty-cycling not only the communication modules but also their associated voltage regulators, transceivers, and peripheral circuits.

The results presented in this article therefore apply to a specific measurement-station configuration developed according to the client's requirements. Determining the operating time for other combinations of interfaces, sampling frequencies, transmission schedules, or environmental conditions would require additional field investigations. Future installations will build on the experience gained from the present deployment and will include the collection of further operational and maintenance data to support more accurate energy modeling and system optimization. Further development may also involve alternative power sources, such as lithium-ion batteries specifically designed for charging at sub-zero temperatures or primary lithium batteries offering substantially higher energy density. Together with more advanced interface scheduling and power-management strategies, these solutions may reduce construction, installation, and maintenance costs while extending autonomous operation, thereby supporting the principles of sustainable green-IoT monitoring.

From a practical perspective, such a long maintenance-free operating period reduces both operating costs and the environmental impact of the monitoring system. Reducing the number of service visits lowers energy consumption and decreases the carbon footprint, particularly for installations located in remote and difficult-to-access areas. The compact power supply system based on a battery and photovoltaic panel proved sufficient for long-term station operation. Consequently, AIRS aligns well with the concept of sustainable environmental monitoring by combining renewable energy sources, high operational autonomy, and minimal human intervention in system operation.

8. Conclusions

The AIRS data logger represents an innovative solution that effectively addresses contemporary environmental monitoring requirements. The conducted studies demonstrated that the device successfully combines the advantages of advanced data loggers - such as a large number of measurement channels, support for a wide variety of sensors, and remote communication capabilities - with exceptionally low power consumption and the ability to operate for extended periods without access to the power grid. Compared with other commercial data loggers, AIRS offers competitive functionality while achieving significantly higher energy efficiency. At the same time, it eliminates many of the limitations associated with conventional solutions, including the need for frequent maintenance and a restricted number of communication interfaces. The results of the field experiments clearly demonstrate that the designed system achieved its intended objectives by providing long-term, maintenance-free operation while maintaining high measurement quality and sampling frequency. These characteristics make AIRS a valuable tool for long-term environmental monitoring and a promising solution for sustainable monitoring applications in the era of Green IoT.

Acknowledgments

This publication was funded by: Regional Operational Programme of the Silesian Voivodeship for the years 2014–2020 (European Regional Development Fund), Priority Axis I: Modern Economy, Measure 1.2: Research, Development and Innovation in Enterprises. Project title: Realizacja prac rozwojowych poprzez opracowanie prototypu, przetestowanie i wdrożenie na rynek autonomicznego inteligentnego rejestratora sterującego (AIRS) służącego do integracji systemow automatyki z rozległymi sieciami IoT [mplementation of development work through the design, prototyping, testing, and market deployment of an Autonomous Intelligent Recording and Control System (AIRS) intended for the integration of automation systems with large-scale IoT networks].

References

[1] Aazam M., Huh E.N.: Green IoT: Energy Efficiency and Renewable Integration. IEEE Access 2020.

[2] Ashton K.: That ‘Internet of Things’ Thing. RFID Journal 2009.

[3] Gubbi J., Buyya R., Marusic S., Palaniswami M.: Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. Future Generation Computer Systems 2013. Vol. 29, No. 7. pp. 1645–1660. DOI: 10.1016/j.future.2013.01.010.

[4] Li S., Xu L.D., Zhao S.: The Internet of Things: A Survey. Information Systems Frontiers 2015. Vol. 17, No. 2. pp. 243–259. DOI: 10.1007/s10796-014-9492-7.

[5] Xu L.D., He W., Li S.: Internet of Things in Industries: A Survey. IEEE Transactions on Industrial Informatics 2014. Vol. 10, No. 4. pp. 2233–2243. DOI: 10.1109/TII.2014.2300753.

[6] Zhang Y.: Green IoT and AIoT Technologies for Sustainable Monitoring Systems. Sensors 2022.

[7] Shi W., Cao J., Zhang Q., Li Y., Xu L.: Edge Computing: Vision and Challenges. IEEE Internet of Things Journal 2016. Vol. 3, No. 5. pp. 637–646. DOI: 10.1109/JIOT.2016.2579198.

[8] Open-Source Data Logger System for Real-Time Monitoring Applications. Sensors 2021.

[9] Campbell Scientific: CR300 Measurement and Control Datalogger – Technical Documentation. Campbell Scientific 2024.

[10] DataTaker: DT80 Series Data Logger User Manual. Thermo Fisher Scientific 2023.

[11] Arduino Mayfly Data Logger Platform Documentation. 2023.

[12] Technika IT Sp. z o.o.: Dokumentacja techniczna rejestratora AIRS. 2025.

[13] Campbell Scientific: CR300 Specifications and Power Consumption. Available: https://www.campbellsci.com/cr300-specifications [accessed: Oct. 2025].

[14] Amplicon Liveline Ltd.: DataTaker DT82E / DT85 Environmental Data Logger Series. Available: https://www.amplicon.com/products/datataker-dt85-environmental-logger/ [accessed: Oct. 2025].

[15] Amplicon Liveline Ltd.: DataTaker DT85 Features and Channel Configuration. Available: https://www.amplicon.com/products/datataker-dt85-features/ [accessed: Oct. 2025].

[16] Datalogger Inc.: DataTaker DT82E Power Consumption and Performance. Available: https://www.dataloggerinc.com/data-taker-dt82e/ [accessed: Oct. 2025].

[17] Datalogger Inc.: Novus LogBox LTE IoT Datalogger. Available: https://www.dataloggerinc.com/novus-logbox-lte/ [accessed: Oct. 2025].

[18] Campbell Scientific: CR300 Datalogger. Available: https://www.campbellsci.com/cr300 [accessed: Oct. 2025].

[19] EnviroDIY: Arduino Mayfly Data Logger. Available: https://www.envirodiy.org/mayfly/ [accessed: Oct. 2025].

Publisher: **KOMAG Institute of Mining Technology, Poland**