Journal Européen des Systèmes Automatisés
Vol. 57, No. 5, October, 2024, pp. 1349-1358
Journal homepage: http://iieta.org/journals/jesa

IBIS ECO PLATFORM: A Decision Support System for Monitoring and Managing the Energy Performance and Comfort of Existing Buildings

Nicola Cardinale[1], Antonello Pagliuca[1], Valeria Selicati[1*], Rosa Caggiano[2], Andrea Vennera[3], Emiliano Sicilia[3], Andrea Carlo Siciliano[3], Annarita Renda[3], Michele De Buono[3]

[1] Department for Humanistic, Scientific and Social Innovation (DIUSS), University of Basilicata, Matera 75100, Italy
[2] Italian National Research Council-Institute of Methodologies for Environmental Analysis, Tito Scalo 85050, Italy
[3] R&D Department-SCAI Lab, Società del Gruppo SCAI Consulenza Aziendale Informatica, Rende 87036, Italy

Corresponding Author Email: valeria.selicati@unibas.it

https://doi.org/10.18280/jesa.570510

Received: 26 May 2024
Revised: 8 October 2024
Accepted: 18 October 2024
Available online: 28 October 2024

Keywords:
air quality, artificial intelligence, big data, energy efficiency, IoT network

ABSTRACT

The IBIS ECO prototype platform is introduced here as a Decision Support System (DSS) designed to intelligently monitor and efficient management of the energetic performance and comfort of existing buildings. This innovative DSS is user-friendly and prioritizes sustainability by employing wireless IoT equipment that automatically adjusts to each building's unique characteristics. Through integration with IoT networks, big data infrastructure, algorithms, and advanced artificial intelligence models, IBIS ECO conducts predictive analysis, identifying anomalies and discomfort situations at an early stage. During the research phase, the prototype drew insights from two distinct case studies in Basilicata, in southern Italy: a primary school classroom and a university classroom with varying occupancy rates, usage patterns, plant system, and environmental conditions. In its development, IBIS ECO focused on creating customizable dashboards and smart applications to effectively monitor and manage environmental and energy parameters, including microclimatic conditions, resource usage, and infrastructure. Moreover, IBIS ECO serves as a comprehensive tool for energy managers, maintainers, and building occupants, promoting continuous monitoring and enhancing well-being and energy efficiency both indoors and outdoors. Its data-driven approach empowers users' awareness to make informed decisions, leading to energy savings, environmental sustainability, and improved living conditions.

1. INTRODUCTION

In recent years, the spread of solutions using innovative technologies, such as the Internet of Things (IoT), in the context of buildings is spurring the creation of new, increasingly smart buildings that can offer people living in them an advanced living experience in terms of comfort and energy savings [1]. New smart building constructions are based on systems that enable interaction between objects and humans occupying the same environment. At the same time, the modernization and technological upgrade of the existing building stock, which is old and energy inefficient in most countries, has become one of the priority goals of governments [2, 3]. Indeed, the existing building system is responsible for a significant share of greenhouse gas emissions and air pollution and often consumes natural resources such as water and energy inefficiently due to outdated or poorly maintained systems [4].

To address these problems, it is essential to adopt not only design strategies but also automated building management and monitoring systems that aim to improve energy efficiency, reduce greenhouse gas emissions, minimize the use of unsustainable materials, and promote people's health and well-being. In addition to energy efficiency aspects, technological upgrading through the use of buildings has a potential impact on the quality of life of those who live in them in terms of both perceived comfort management and indoor pollution [5]. The DSS IBIS ECO solution presented below supports users in the intelligent and effective management of all types of buildings, including those of historical and artistic heritage, because it is easily installed (thanks to IoT and wireless technologies). The web platform can represent an extremely effective tool for monitoring the main aspects that characterize the environment (including consumption of energy resources, water, etc.), to predict and promptly address any discomfort or emergency situations, thanks to the innovative data-driven approach based on the use of dedicated smart services. These features allow the full potential of IoT networks to be exploited in order to optimize operational efficiency, safety and occupant comfort.

2. RELATED WORKS

The scientific literature proposes several studies and innovative solutions for smart environmental comfort management and energy consumption monitoring but, in most cases, these solutions do not provide relevant suggestions that could induce the inhabitants of the monitored environments to take targeted actions to optimize in parallel the aspects concerning thermal, visual or acoustic comfort and energy consumption [6]. Such approaches could support the figures in charge of managing the monitored environments in achieving adequate comfort levels, while simultaneously reducing energy consumption from the heterogeneous instrumentation used and monitoring expenses related to the management of the facilities themselves. In this regard, the scientific literature presents a variety of IoT solutions for the smart home [7-9] and, more generally, for smart buildings [10-13], diversifying between application domains, frameworks and types of architectures, platforms and algorithms for intelligent management of environments. However, the conditions and regulations governing energy resources and indoor air quality are not standard, but vary from country to country. Thus, the need arises to implement an innovative solution that integrates, processes and extracts knowledge from data retrieved from IoT networks composed of smart nodes and sensors installed in buildings. With this in mind, Ahmed et al. [14] describe the design of an IoT platform for remote monitoring and control of smart buildings by implementing a use case composed of different scenarios (offices, university classrooms, laboratories, etc.) and based on the use of various types of wireless network protocols for communication between components. Similarly, Kumar et al. [15] present a platform for intelligent building management based on an evolving IoT architecture that is secure and energy efficient. Eltamaly et al. [16] propose an IoT architecture for the management of hybrid building systems, as also proposed by the study [14] considering the use case of a university campus in which to implement an IoT network to ensure the communication of the hybrid energy system, showing particular interest in the aspects inherent to the topology, capacity and latency of the network. On the other hand, the analysis conducted by Abir et al. [17] delves into the main key features of IoT smart grid energy systems, paying particular attention to the application of IoT in smart energy systems and the respective security issues related to the use of these technologies as tools for sensing, communication (using various standard wireless protocols) and data processing. In turn, Metallidou et al. [18] delve into aspects of the Internet of Energy (IoE), an implementation of the Internet of Things (IoT) in distributed energy systems whose goal is to reduce energy consumption while improving environmental comfort. The study presents a smart building model based on a smart building cloud platform with IoT architecture for remote and automated control of devices and storage of energy performance recorded by buildings, with the aim of developing eco-conscious behavior in people living in indoor environments, supporting the user in the behaviors to be adopted through data-driven solutions that aim to reduce energy consumption and ensure the comfort of indoor environments. The study [12] proposes an IoT infrastructure tested within the facilities of Aalborg University that leverages the potential of wireless communication protocols to implement a sensor network aimed at ensuring the monitoring of energy-aware indoor environments. A similar framework is proposed by Zhang et al. [11] for indoor environment management based on the use of self-learning thermal models trained using data collected from low-cost IoT sensors to provide reliable thermal comfort assessments. Alsuhli and Khattab [19] focus on the implementation of an IoT platform based on a mixed fog-cloud computing architecture for smart building management, deployed and tested at the prototype level in an indoor laboratory environment to evaluate the ability to detect door/window status and room occupancy/lighting levels. Tushar et al. [10] highlight the enormous potential of IoT architectures in the realization of state-of-the-art systems for smart building management. Such solutions enable the constant monitoring of comfort and energy consumption aspects through IoT applications installed in buildings to manage air conditioning, lighting, ventilation, occupancy and other systems. Contextually, Basnayake et al. [20] present the design and implementation details of a smart controller for automated building management, a cognitive solution based on the use of infrared devices for data collection and artificial intelligence models for making data-driven decisions aimed at improving environmental comfort, without affecting the safety of people living in the environments.

3. METHODOLOGICAL APPROACH

To achieve adequate comfort levels (thermal, visual, acoustic, etc.) and optimize the energy consumption generated in an environment, a multiplicity of aspects must be monitored simultaneously. In addition to taking into account the structural characteristics of the building, aspects that characterize the indoor environment, outdoor weather conditions, and the multiple activities that may be carried out within a building must be considered. In the same physical environment, several activities could in fact be carried out simultaneously: the same room in an office could be used either for a meeting or work party or as a relaxation area to take a coffee/lunch break or to welcome guests. As an example, consider a very crowded university lecture hall where a lecture is in progress. After a few minutes level of CO_2 in the air, the indoor temperature and humidity could increase due to the very presence of people in the room, changing outdoor weather conditions, and the structural nature of the walls (e.g., glass). Without appropriate action, such as opening windows or air conditioners, participants would breathe unhealthy air and perceive discomfort. At the end of the lesson, those in attendance might also leave the classroom without paying attention to turning off the lighting system, the heating/cooling system, or the instrumentation used. In this case, in the absence of timely human intervention, these systems could be left running unnecessarily, generating excess consumption.

The IBIS ECO DSS is able to analyze the data collected from the sensor network installed in the environment (indoor and outdoor) and recognize the scenario that has been configured, providing timely alerts and warning messages that suggest to users the best behaviors and interventions to be implemented (e.g. increasing or decreasing temperature, activating air recirculation systems, opening doors/windows, turning off lighting or unnecessarily running systems, etc.) to be performed to restore comfort in the room, remedying discomfort situations that, if not properly managed, could affect the livability of the rooms and the building's consumption. Specifically, IBIS ECO represents an innovative smart building IoT platform aimed at supporting users (energy managers, maintainers, and environmental inhabitants) in the optimal management of buildings through: (i) the constant monitoring of aspects that influence overall comfort, energy consumption, and the state of the structure and the people living in it; (ii) the integration of outdoor microclimate forecasts; (iii) the analysis of the behaviors, preferences, and needs expressed by the people living in the building and the building context in which it is located; (iv) the formulation of data-driven decisions to support the achievement of adequate levels of comfort, safety, and energy efficiency; (v) a series of smart macro-services that aim to detect anomalies, possible hazardous situations, and support in the predictive maintenance of monitoring systems.

In order to satisfy user needs, DSS offers a series of dashboards that can be customized by user type and can manage and monitor the following environments: building, asset, and room. Specifically, a building may contain one or more assets, which in turn may consist of one or more rooms (physical environment where IoT sensor networks are installed). Assuming that each type of user could be interested in the simultaneous management of multiple monitored environments (building, asset, or room) and that each monitored environment (room) should be managed by a single energy manager, the DSS is based on three different "Building-Asset-Room" configurations.

In the Figure 1, use case A is configured as a building associated with a single asset composed of a single room (a configuration suitable, for example, for the management of a warehouse or industrial building).

Use case B, on the other hand, is configured as a building consisting of several assets composed of several rooms (a case suitable for the management of a residential building in which each apartment corresponds to an asset and the respective rooms represent rooms). A further use case (C) could be represented by a building with a single asset associated with it composed of several rooms (typical single dwelling configuration in which the building coincides with the asset and the individual rooms of the house represent the rooms).

In all cases, the DSS processes in near real time the raw data set collected from the IoT sensor network and extracts knowledge from it, generating structured information to support end users in their decisions.

The DSS is structured into several processing modules and analysis tools that harmonize and make efficient Big Data process management and data analysis through artificial intelligence algorithms and statistical-inferential methods, as reflected in the platform architecture depicted in Figure 2.

The platform combines the IoT network configured for data collection with the DSS architecture equipped with back-end systems (for managing the sensor network, integration of processing units and databases used for data storage) and front-end systems (for managing the user interface).

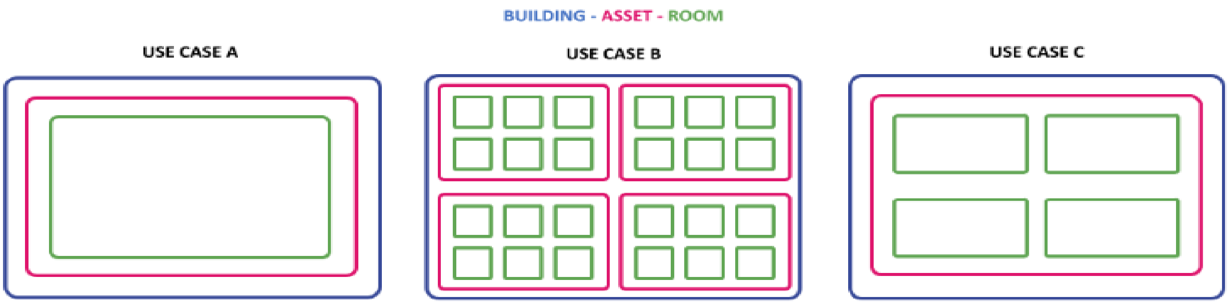

Figure 1. Building-Asset-Room configurations of the application use cases

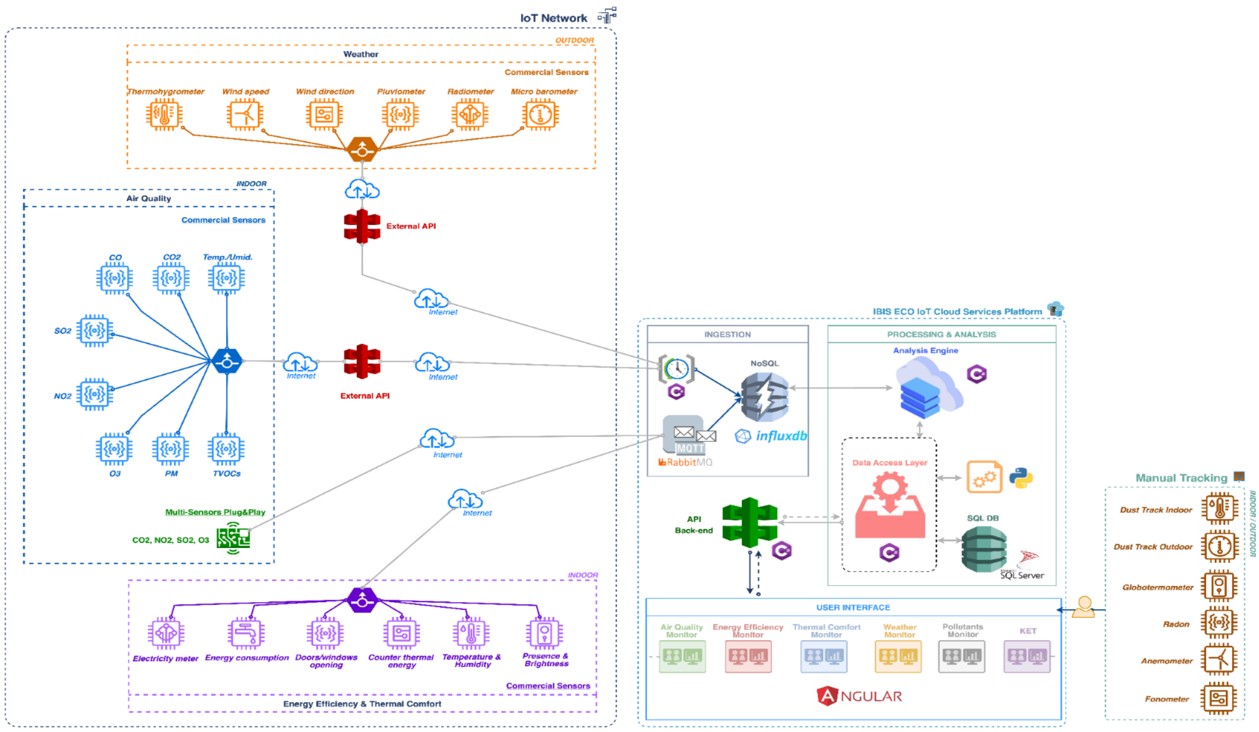

Figure 2. Building-Asset-Room configurations of the application use cases

The IoT network infrastructure enables secure, reliable and durable communication between the macro groups of sensors installed for the detection of : pollutants and indoor environmental parameters (Air Quality), energy consumption and indoor thermal comfort (Energy Efficiency & Thermal Comfort), data from outdoor measurements inherent to weather conditions (Weather), and data collected by specific hand-tracking devices for the measurement of the main phenomena affecting comfort and air quality (Manual tracking). In addition, the IoT network is prepared for the integration of an experimental Plug & Play multisensor device, created in the context of the IBIS ECO project for the detection of pollutant values (CO_2, O_3, NO_2 and SO_2) present in an indoor environment undergoing monitoring [21].

On the other hand, with regard to the breakdown of the DSS into functional blocks, the platform includes the modules:

• Ingestion, for storing and acquiring data sensed by the IoT network through communication interfaces compatible with the specifications of the configured sensor networks;

• Processing & Analysis, for analyzing the acquired data through a relational database and an API stack necessary to ensure interfacing with the dedicated frontend module;

• Presentation, reserved for managing the user interface that allows users to interact with the DSS, monitor environments, and view dashboards for analyzing the sensed data.

Technologically, the platform leverages an interoperable, scalable and secure IoT network architecture based on the concept of agent programming [22, 23]. In particular, the "Ingestion" module is based on a non-relational Influx database, which is highly performant for time series management through Map-Reduce functions typical of Big Data Analytics. The application represented by the "Processing & Analysis" module was implemented using Microsoft's Net technology while the predictive algorithms were implemented in the Python language, using the features made available by the main open-source machine learning libraries. Simultaneously, Microsoft SQL Server was chosen for the persistence of the data generated by the algorithms and all the information supporting the platform. The same technologies were chosen for the realization of the backend application components while for the realization of the frontend application ("Presentation" module) the use of the angular framework was chosen.

4. USE CASE

IBIS ECO DSS, funded under project "IBIS ECO-IoT-based Building Information System for Energy Efficiency & Comfort", realized was tested and put into operation by exploiting data collected from IoT networks configured and installed in the Montemurro School Building in Val d'Agri (Potenza) and in the A208 drawing room of the University Campus of the University of Basilicata in Matera, and depicted in Figure 3 and Figure 4.

After analyzing the specific information needs for each possible user profile (energy manager, maintainer, end user), for both demonstrators, with the support of a team of domain experts, the functionalities have been realized and an optimal configuration of the dashboards has been defined, in order to make the navigation of the platform as user friendly as possible.

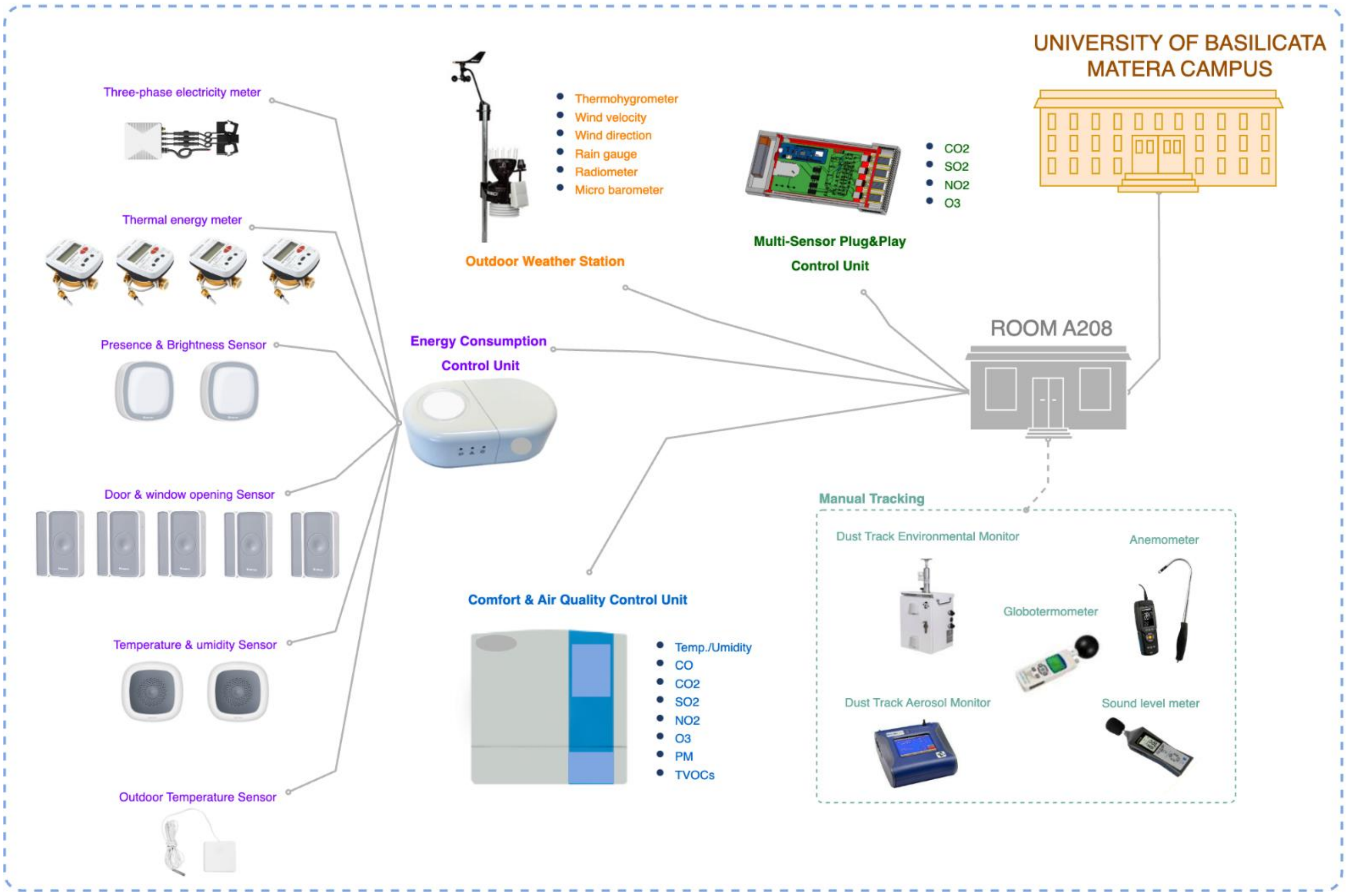

Figure 3. IoT network graph installed in A208 drawing room at University Campus, University of Basilicata, Matera

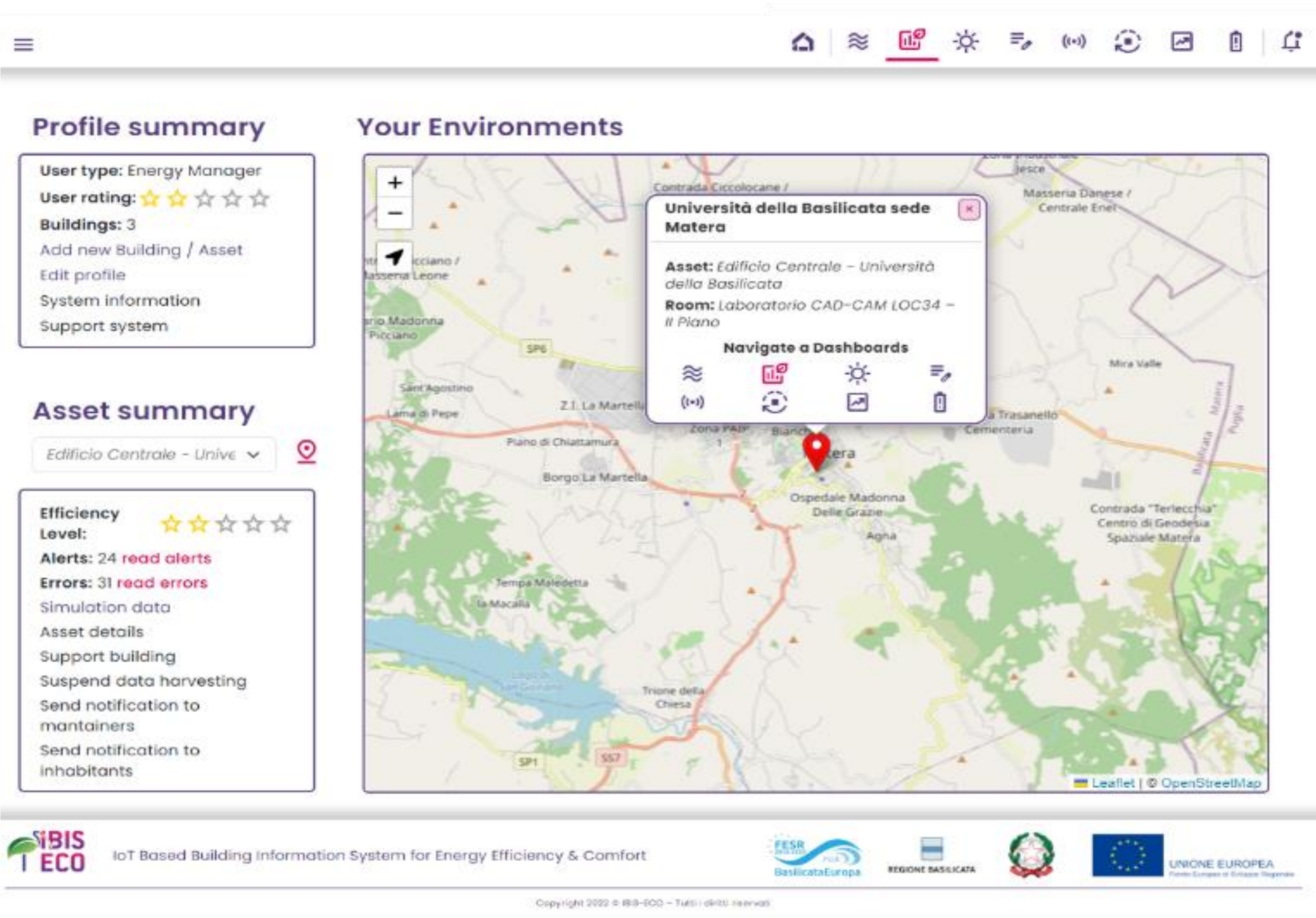

Figure 4. Home page decision support system IBIS ECO

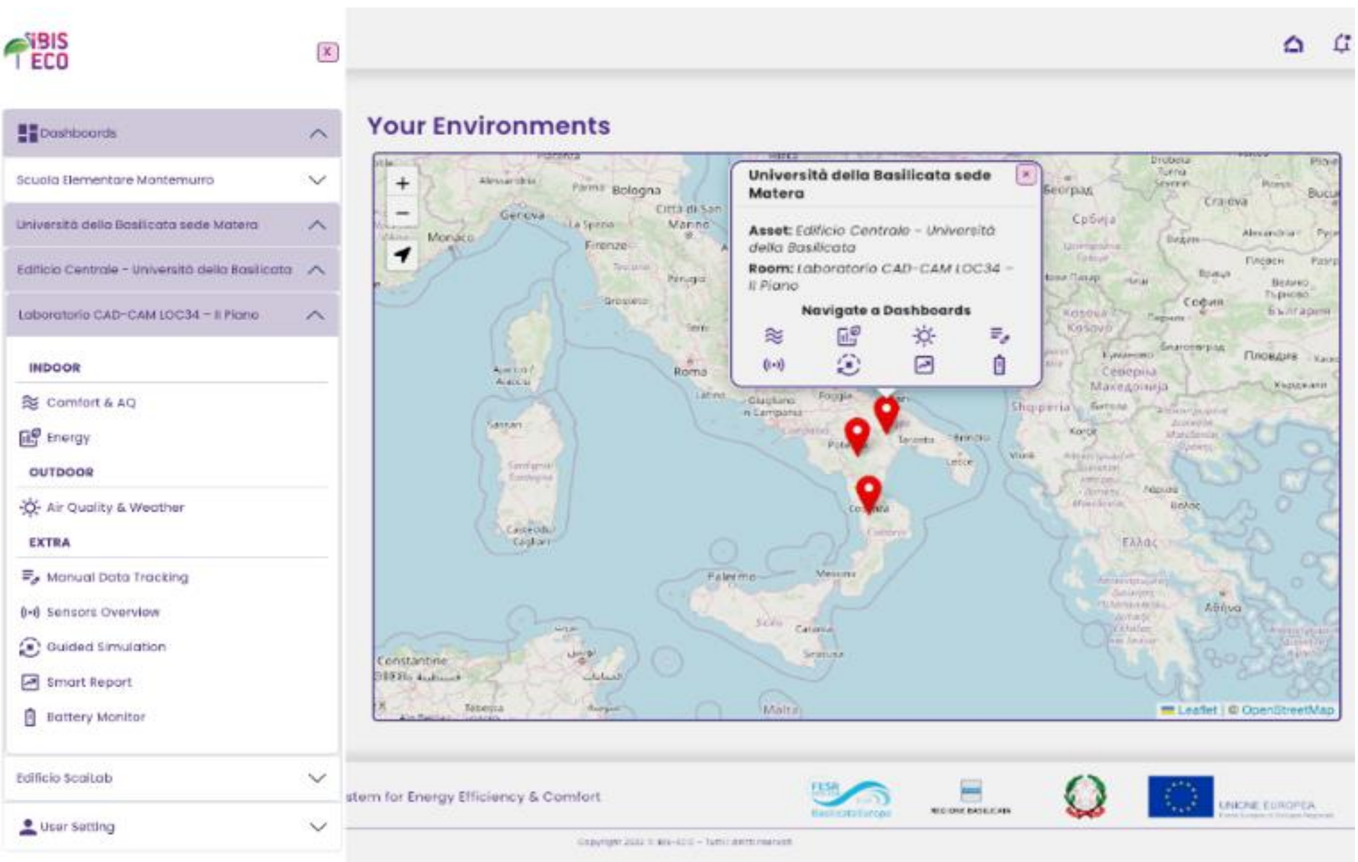

Figure 5. IBIS ECO decision support system navigation

Upon accessing the system, one lands on the DSS homepage from which, after selecting the building of interest (from the map or from the pop-up navigation menu located on the left side of the web page) one can navigate all sections and use the different information tools, as Figure 5 shows.

As can be seen from the menu, the navigation of DSS is divided into three macro sections: Indoor, Outdoor and Extra. The "Indoor" macro section collects within it all the smart tools and services dedicated to managing the aspects that most influence overall comfort and energy consumption in the indoor environments being monitored. Within this macro section it is possible to navigate the analysis modules:

• "Comfort & Air Quality" (Figure 6) reserved for air quality management with specific indicators defined with the support of domain experts and machine learning models for 10-, 20- and 30-minute forecasts of temperature, relative humidity and CO_2 concentration;

• "Energy" dedicated to analyzing and monitoring facilities and energy consumption within the monitored environment (Figure 7), equipped with indicators defined with the support of domain experts and machine learning models for detecting abnormal consumption and forecasting energy consumption for the next three hours, for today and the next days.

Figure 6. IBIS ECO comfort & air quality macro section

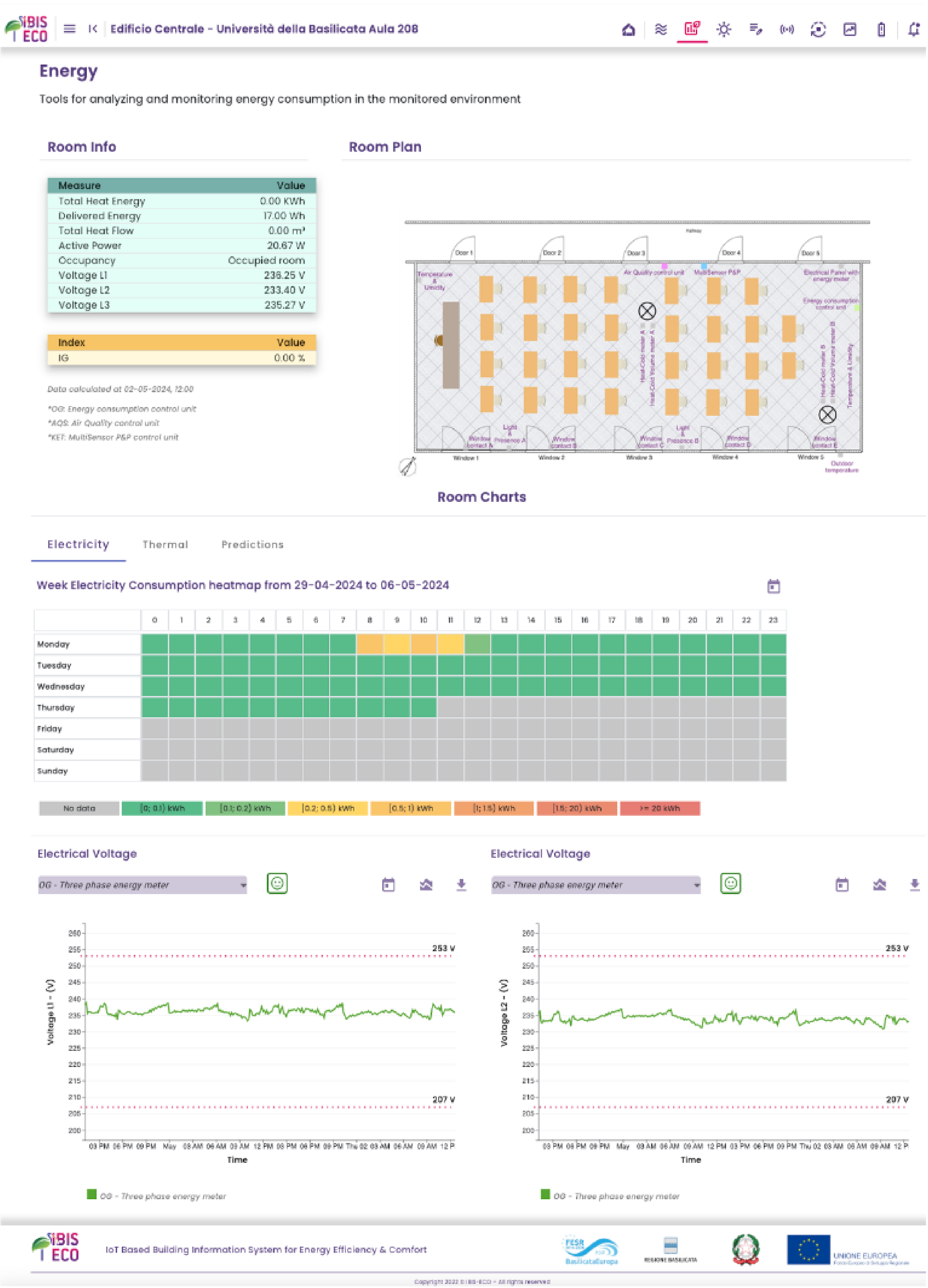

Figure 7. IBIS ECO energy macro section

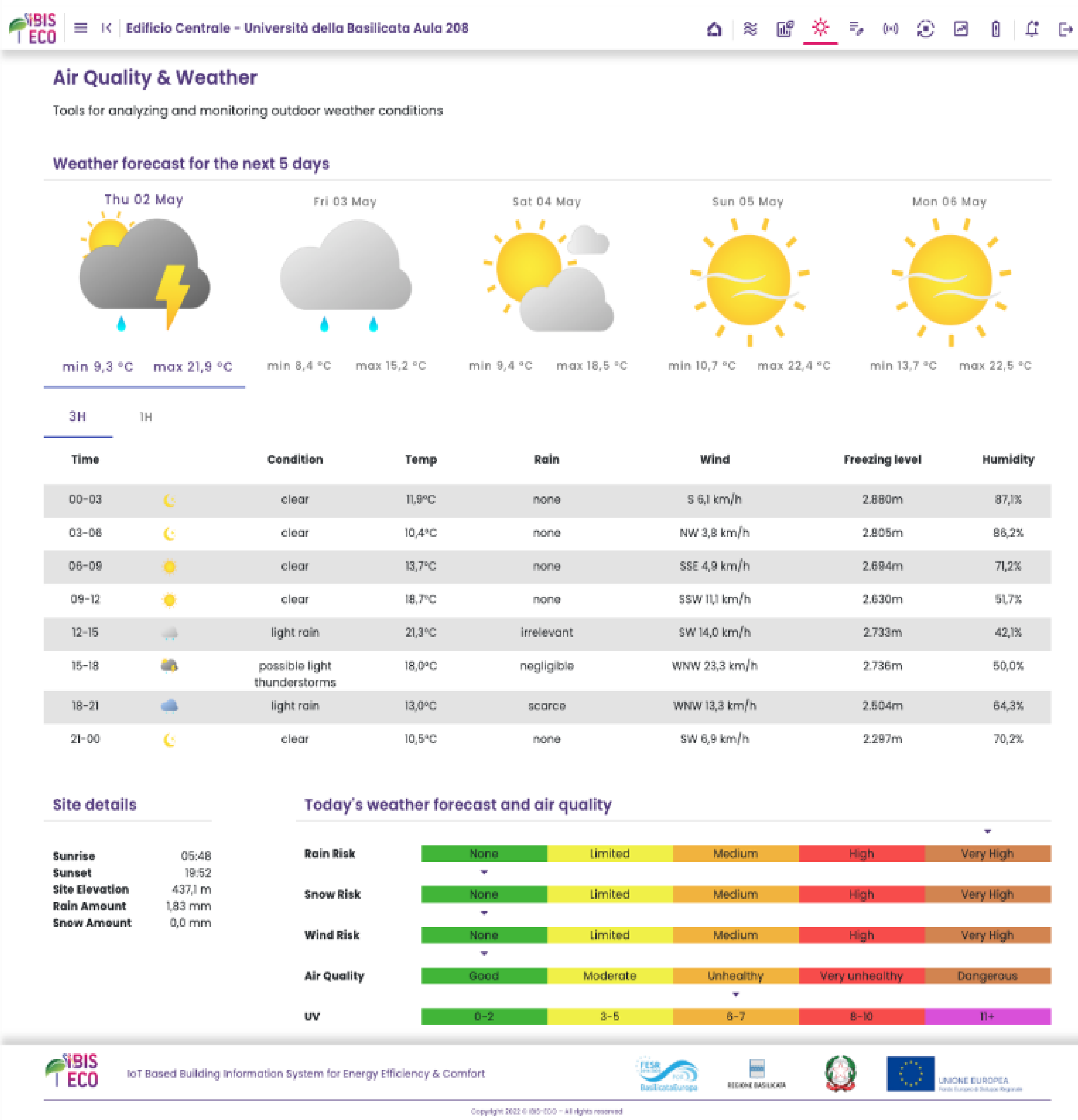

Figure 8. IBIS ECO air quality & weather macro section

Contextually, the "Outdoor" macro section consisting of the "Air Quality & Weather" (Figure 8) module supports DSS users in analyzing and monitoring weather conditions outside the environment subjected to continuous measurements. The module presents a tool based on artificial intelligence models for forecasting hourly and three-hourly outdoor weather conditions for the next five days.

The "Extras" macro section of the DSS groups several analysis modules to support the user in the intelligent management of monitored buildings. In particular, the "Manual Data Tracking" module facilitates the user in analyzing the data collected through manually tracking devices (globe-thermometer, sound level meter, indoor dusttrak, outdoor dusttrak, anemometer and radon) identified by domain experts for achieving overall environmental comfort. The "Sensor Overview" module, on the other hand, represents a useful tool for the user to check the efficiency of individual IoT sensors installed in the monitored environment, measured in number of monthly detections made by the individual sensor compared to the expected value. The machine learning tool "Guided Simulation" allows the user to carry out guided simulations on the air quality of the monitored environment and identify possible actions to be taken if, compared to the actual values detected by the sensors, the room occupancy or the state of the doors and windows were different from what was actually detected by the IoT network, guiding the user through messages that invite indoor air regeneration. "Smart report management," on the other hand, represents a tool for the automatic generation of smart reports containing the graphical and tabular processing generated by the various sections of the DSS while the artificial intelligence tool called "Battery Monitoring" allows the user to estimate the remaining useful life (RUL) of the lithium batteries (remaining charging cycles) that power the IoT network's low-impact sensors used for data collection in the monitored environment [24].

Furthermore, from the header of the DSS web page, it is possible to access the "Alerts and errors management" section, which is reserved for the management of alert notifications sent by the DSS to report any operational warnings, abnormal or dangerous situations.

5. CONCLUSIONS

The evolution of decision support systems for energy management of building well-being and livability is strongly supported by the advent of low-impact IoT networks for indoor and outdoor detection.

This study introduced the IBIS ECO solution, a DSS that leverages the potential of innovative IoT networks to detect information on key environmental and energy parameters within any type of building. The information properly acquired and processed thanks to Cloud, Big Data and AI technologies integrated in the DSS, is proposed to users through interactive and user-friendly dashboards. An innovative system capable of providing highly customized suggestions because it is based on the evidence provided by the data acquired in near real time. The platform is able to guide both expert users and simple users of buildings in performing the most effective and efficient actions to improve comfort levels and reduce energy consumption.

ACKNOWLEDGMENT

This research was conducted as part of the IBIS ECO "IoT-based Building Information System for Energy Efficiency & Comfort" project funded under the ERDF Operational Program 2014-2020-Action 1B.1.2.2. Public Notice: "Complex Research and Development Projects 'CORES'"-Thematic Areas: "Energy and Bioeconomy"-CUP G49J19001400004.

REFERENCES

[1] Minoli, D., Sohraby, K., Occhiogrosso, B. (2017). IoT considerations, requirements, and architectures for smart buildings-Energy optimization and next-generation building management systems. IEEE Internet of Things Journal, 4(1): 269-283. https://doi.org/10.1109/JIOT.2017.2647881

[2] European Council. Direttiva europea EPBD-Testo approvato il 12 aprile 2024 dal Consiglio europeo. https://www.europarl.europa.eu/doceo/document/A-9-2023-0033-AM-068-068_IT.pdf.

[3] Hsu, D., Andrews, C.J., Han, A.T., Loh, C.G., Osland, A.C., Zegras, C.P. (2023). Planning the built environment and land use towards deep decarbonization of the United States. Journal of Planning Literature, 38(3): 426-441. https://doi.org/10.1177/08854122221097977

[4] United Nations Environment Programme. (2023). Global status report for buildings and construction—Beyond foundations: Mainstreaming sustainable solutions to cut emissions from the buildings sector. United Nations Environment Programme, 2024. https://doi.org/10.59117/20.500.11822/45095

[5] Firdhous, M.F.M., Sudantha, B.H., Karunaratne, P.M. (2017). IoT enabled proactive indoor air quality monitoring system for sustainable health management. In 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), Chennai, India, IEEE, pp. 216-221. https://doi.org/10.1109/ICCCT2.2017.7972281

[6] Tekler, Z.D., Low, R., Blessing, L. (2022). User perceptions on the adoption of smart energy management systems in the workplace: Design and policy implications. Energy Research & Social Science, 88: 102505. https://doi.org/10.1016/j.erss.2022.102505

[7] Singh, S., Roy, A., Selvan, M.P. (2019). Smart load node for nonsmart load under smart grid paradigm: A new home energy management system. IEEE Consumer Electronics Magazine, 8(2): 22-27. https://doi.org/10.1109/MCE.2018.2880804

[8] Shakerighadi, B., Anvari-Moghaddam, A., Vasquez, J. C., Guerrero, J.M. (2018). Internet of things for modern energy systems: State-of-the-art, challenges, and open issues. Energies, 11(5): 1252. https://doi.org/10.3390/en11051252

[9] Choi, J.S. (2019). A hierarchical distributed energy management agent framework for smart homes, grids, and cities. IEEE Communications Magazine, 57(7): 113-119. https://doi.org/10.1109/MCOM.2019.1900073

[10] Tushar, W., Wijerathne, N., Li, W.T., Yuen, C., Poor, H.V., Saha, T.K., Wood, K.L. (2018). IoT for green building management. arXiv Preprint arXiv: 1805.10635. https://doi.org/10.48550/arXiv.1805.10635

[11] Zhang, X., Pipattanasomporn, M., Chen, T., Rahman, S. (2019). An IoT-based thermal model learning framework for smart buildings. IEEE Internet of Things Journal, 7(1): 518-527. https://doi.org/10.1109/JIOT.2019.2951106

[12] Wu, Y., Wu, Y., Guerrero, J.M., Vasquez, J.C., Palacios-García, E.J., Guan, Y. (2020). IoT-enabled microgrid for intelligent energy-aware buildings: A novel hierarchical self-consumption scheme with renewables. Electronics, 9(4): 550. https://doi.org/10.3390/electronics9040550

[13] Elsisi, M., Tran, M.Q., Mahmoud, K., Lehtonen, M., Darwish, M.M. (2021). Deep learning-based industry 4.0 and internet of things towards effective energy management for smart buildings. Sensors, 21(4): 1038. https://doi.org/10.3390/s21041038

[14] Ahmed, M.A., Chavez, S.A., Eltamaly, A.M., Garces, H.O., Rojas, A.J., Kim, Y.C. (2022). Toward an intelligent campus: IoT platform for remote monitoring and control of smart buildings. Sensors, 22(23): 9045. https://doi.org/10.3390/s22239045

[15] Kumar, A., Sharma, S., Goyal, N., Singh, A., Cheng, X., Singh, P. (2021). Secure and energy-efficient smart building architecture with emerging technology IoT. Computer Communications, 176: 207-217. https://doi.org/10.1016/j.comcom.2021.06.003

[16] Eltamaly, A.M., Alotaibi, M.A., Alolah, A.I., Ahmed, M.A. (2021). IoT-based hybrid renewable energy system for smart campus. Sustainability, 13(15): 8555. https://doi.org/10.3390/su13158555

[17] Abir, S.A.A., Anwar, A., Choi, J., Kayes, A.S.M. (2021). IoT-enabled smart energy grid: Applications and challenges. IEEE Access, 9: 50961-50981. https://doi.org/10.1109/ACCESS.2021.3067331
[18] Metallidou, C.K., Psannis, K.E., Egyptiadou, E.A. (2020). Energy efficiency in smart buildings: IoT approaches. IEEE Access, 8: 63679-63699. https://doi.org/10.1109/ACCESS.2020.2984461
[19] Alsuhli, G., Khattab, A. (2019). A fog-based IoT platform for smart buildings. In 2019 International Conference on Innovative Trends in Computer Engineering (ITCE), Aswan, Egypt, pp. 174-179. https://doi.org/10.1109/ITCE.2019.8646480
[20] Basnayake, B., Amarasinghe, Y., Attalage, R. (2017). Artificial intelligence based smart building automation controller for energy efficiency improvements in existing buildings. https://www.semanticscholar.org/paper/Artificial-Intelligence-Based-Smart-Building-for-in-Basnayake-Amarasinghe/053a55a1848fb3fa320788d0426409a95ba40d83.
[21] Santagata, A., Pace, M.L., Bellucci, A., Mastellone, M., Bolli, E., Valentini, V., Orlando, S., Sani, E., Failla, S., Sciti, D., Trucchi, D.M. (2022). Enhanced and selective absorption of molybdenum nanostructured surfaces for concentrated solar energy applications. Materials, 15(23): 8333. https://doi.org/10.3390/ma15238333
[22] Shi, W., Cao, J., Zhang, Q., Li, Y., Xu, L. (2016). Edge computing: Vision and challenges. IEEE Internet of Things Journal, 3(5): 637-646. https://doi.org/10.1109/JIOT.2016.2579198
[23] Morabito, R., Cozzolino, V., Ding, A.Y., Beijar, N., Ott, J. (2018). Consolidate IoT edge computing with lightweight virtualization. IEEE Network, 32(1): 102-111. https://doi.org/10.1109/MNET.2018.1700175
[24] Verrina, V., Vennera, A., Renda, A. (2024). LSTM-based battery life prediction in IoT systems: A proof of concept. In Proceedings of the Statistics and Data Science 2024 Conference—New Perspectives on Statistics and Data Science, pp. 322-327. https://unipapress.com/book/proceedings-of-the-statistics-and-data-science-2024-conference/.

NOMENCLATURE

AI	Artificial Intelligence
API	Application Programming Interface
DB	Database
DSS	Decision Support System
IoT	Internet of Things
PM	Particular Matter
TVOC	Total Volatile Organic Compounds