The Impact of IoT- Enabled Energy Management Systems on Hotel Operating Costs and Sustainability Outcomes

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***Abstract*—** Hotels use a significant amount of energy for numerous operations, which has a negative impact on the environment and raises operational costs. The development and deployment of an Internet of Things (IoT)-based energy management system for hotels is the main topic of this master's thesis. The study makes use of real-time data monitoring, analytics, and automation to lower operational costs, optimize energy use, and improve sustainability. The integration of IoT devices, sensors, and data analytics methods is examined in the thesis as a means of delivering useful information and promoting reasoned energy management decisions. The results help the hotel business adopt energy-efficient techniques, save costs, and increase sustainability.

***Keywords*—** Internet of Things, Hotels, Energy Savings, Sensors.

I. Introduction

The Internet of Things (IoT) has emerged as a game-changing technology in recent years with the potential to alter many industries, including the hospitality industry. Energy management systems in hotels are one application where IoT deployment has a lot of potential. The need for sustainable solutions that can reduce operational costs and advance environmental sustainability has been sparked by the escalating energy crisis worries and the outrageous levels of energy usage in the hotel industry. In fact, hotels and other forms of lodging are responsible for 2% of the 5% global CO2 that the tourism industry emits [1].

The current state of the world's energy supply is urgent and requires quick care [2]. The hospitality sector, which is notorious for using a lot of energy, significantly adds to this dilemma. Hotels have seen a large increase in energy usage for heating, cooling, lighting, and other operational needs as a result of rising demand for comfortable and luxurious rooms [3]. In addition to creating environmental problems, this excessive energy use drives up operational costs for hotel owners and management.

A large amount of a hotel's operating expenses is related to and the cost burden is increased by the ongoing increase in energy prices. Striking a balance between giving visitors a comfortable experience and properly controlling operational costs is difficult for hoteliers. Exploring novel technologies and approaches that can optimize energy use, save costs, and improve sustainability is becoming increasingly important.

The development of IoT presents fresh possibilities for enhancing hotel energy management. Hotels can gather real-time data on energy consumption, spot inefficiencies, and adopt focused steps for energy optimization by connecting IoT devices and sensors with existing energy infrastructure. Hotel owners and managers could benefit from granular insights into energy usage trends via IoT- enabled energy management systems, enabling them to make wise decisions and put energy-saving measures into practice [4].

II. Case Study

A. IoT potential and adequacy

To understand how IoT can help hotels reduce their costs, it is important to understand what IoT sensors are and how they operate. The main stages are:

- Data collection: To track and gather information on energy use, IoT sensors are strategically placed all around buildings or surroundings. These sensors can monitor variables including temperature, humidity, occupancy, light intensity, and power consumption consequences for sustainability.
- Data Transmission: For processing and analysis, the gathered data is sent wirelessly or over connected connections to a central hub or cloud-based platform. Various protocols, including Wi-Fi, Bluetooth, and LoRaWAN (Long Range Wide Area Network), can help in communication.
- Data analysis: After the data is transferred to the central hub or cloud platform, it is examined using a variety of algorithms and machine learning methods. The analysis helps in finding patterns, anomalies, and chances for energy-saving within the gathered data.
- Energy Optimization: IoT-enabled devices can make wise decisions to optimize energy use based on the knowledge gathered through data analysis. For instance, based on occupancy and temperature information, the HVAC (Heating, Ventilation, and Air Conditioning) system of a smart building can be dynamically controlled. In sections that are not inhabited, lights can

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be automatically adjusted or turned off. Equipment that consumes a lot of energy can be controlled based on demand or consumption trends.

- Automation and control: IoT sensors make it possible to automate and manage systems and equipment that use a lot of energy. Energy usage can be optimized in real-time by integrating IoT with actuators, such as smart thermostats, smart plugs, or motor controllers. These devices can be remotely operated or set up to function according to predetermined rules or schedules.

B. Hotel characterization

Hotels are one of the largest consumers of energy in the hospitality industry [6]. Several factors, including lighting, laundry, cooling, heating, ventilation systems, and air quality systems, among others, influence the amount of energy used in hotels which comes at a hefty price to the operations´ financial success [7]. As a result of an increase in tourists and the country's thriving tourism industry, Portugal's lodging activities now consume significantly more energy. When the source of energy used for consumption is examined, 96% of it is electric, 3% is natural gas, and 1% is propane gas [8].

The hospitality sector prioritizes client comfort and high-quality service. The demands placed on these factors frequently result in significant, sometimes excessive high energy usage [9].

For that reason, energy management is crucial to mitigate environmental problems, lower energy consumption and increase hotels' sustainability. Air conditioning, ventilation, lighting, hot water production, and space heating account for 75% of a hotel's energy use [10].

Additionally, as of July 1, 2021, Decree-Law 101-D/2020 [11] mandates that hotels promote energy conservation and the use of renewable energy sources in their structures. Other measures include:

- Energy consumption rationalization plans must be created and put into effect by hotels with an annual energy consumption of more than 500 toe (tons of oil equivalent).
- Energy certification is required for all lodging establishments with more than 50 rooms. This certification evaluates the building's energy performance and identifies opportunities to increase energy efficiency.
- Energy audits are required every four years for hotels with annual energy consumption of more than 500 toe (tons of oil equivalent).

The hospitality industry has witnessed an increase in understanding of its operations' environmental impact in recent years. Hotels are among the most energy-intensive of all building categories. They can therefore have a significant energy consumption and environmental impact, particularly in well-known tourist locations [17].

Meanwhile, there has been an increasing awareness of the necessity of effective resource management, especially regarding energy usage. Conventional energy management systems are unable to supply the precise, real-time data needed to make decisions that satisfy sustainability objectives as well as lower expenses.

For that reason, the proposed IoT-enabled system operates at the forefront of technology to monitor energy usage patterns in real-time and flexibly within hotel premises. This feature makes it possible to react proactively to variations in demand and identifies opportunities to maximize energy use.

C. Proposed IoT System

The proposed IoT system is made up of several parts, each responsible for a certain function and interconnected to create a successful and efficient IoT system. This layer includes sensor devices responsible for gathering information from the environment such as energy and water consumption and temperature. Therefore, in this work, it was used the developed LoRa sensor devices for gathering information about temperature as shown in Figure 1, water consumption display, and an amperometric clamp for energy consumption monitoring. Because it contains all the system's functionality, dashboard software, and database information, the Raspberry Pi is the component of hardware that is most important. The data is received and sent to the various IoT system entities by the network layer of the Internet of Things architecture.

Fig.1 Developed sensor board with temperature and light sensor

A free home automation program called Home Assistant supported the application layer in this research. This software in which devices can be integrated allows the guests to see information on a dashboard.

Data services, LoRa and Wi-Fi sensor devices gather and supply the system with data, which is then analysed and displayed on dashboards for home assistants. Because savings are carefully tailored for each room, it is feasible to manage energy and comfort from the dashboard in the most effective way. User engagement can alter system efficiency.

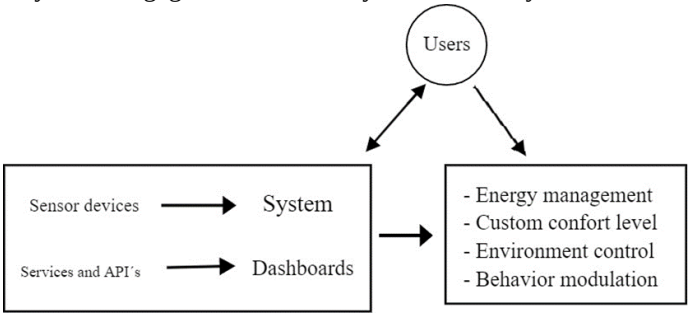

Fig. 2 Schematic of system interaction schematic between each key

In the Network Layer, the information gathered from the

sensors is safely transmitted to the destination. LoRa is a low-power, low-cost technology intended for low data rates and a large transmission range that can connect with hundreds of sensors installed in hotel rooms through a single gateway.

This technology works well for sensor applications where battery-powered devices are easier to set up because they require low power and have good coverage. Devices don't need to be portable but need to gather data frequently or have easy access to the main power source for then be able to connect with apps and web services using this technology.

Calculating monthly and daily costs per customer is of paramount importance to hotels for several crucial reasons. Firstly, it provides a detailed overview of the direct financial impact of each guest on the hotel's operations, allowing for a more accurate analysis of the expenses and revenues associated with each stay. The calculations provided a precise overview of the costs in euros, consumption in kilowatt-hours (kWh), and litres (L) associated with each client, forming a solid basis for effectively managing financial resources, optimizing prices, and maximizing profitability.

Additionally, by knowing the costs associated with each client, hotels can adopt smarter and more personalized pricing strategies. These calculations also make it possible to identify areas of waste and greater inefficiency, driving the implementation of resource management measures, which in turn contributes to environmental sustainability and the hotel's image of corporate responsibility. The analysis of monthly and daily costs per client is a fundamental strategic tool for the efficient management of hotel businesses, benefiting both financial performance and the hotel's sustainable reputation.

Two hotels located in the city of Lisbon were analysed using real cases. Using data provided by the two hotels, in a proper working system, the average monthly and daily water and energy costs were calculated over three months.

The results of this analysis were used to show the actual water and energy average costs that hotels have per guest per day, per guest per month, and the total of all guests over a whole month. Therefore, in a later stage of this work, alongside with the data obtained through the survey, it was possible to calculate the real savings the hotel can make by using an IoT system that allows data to be visualised in real-time.

Energy

$$Average\ consumption\ per guest\ per\ month = \frac{Total\ monthly\ consumption\ (Kwh)}{Total\ number\ of\ guests\ per\ month}$$

$$Average\ consumption\ per\ guest\ day = \frac{Average\ consumption\ per guest\ per\ month}{Days\ of\ the\ month}$$

$$Energy\ consumption\ of\ the\ stay = \ Average\ consumption\ per\ guest\ per\ day \times length\ of\ stay\ \times n^{o}\ of\ guests$$

Water

$$Average\ consumption\ per guest\ per\ month = \frac{Total\ monthly\ consumption\ (L)}{Total\ number\ of\ guests\ per\ month}$$

$$Average\ consumption\ per\ guest\ day = \frac{Average\ consumption\ per guest\ per\ month}{Days\ of\ the\ month}$$

$$Water\ consumption\ of\ the\ stay = \ Average\ consumption\ per\ guest\ per\ day \times length\ of\ stay\ \times n^{o}\ of\ guests$$

D.Main Results and reflections

TABLE I AVERAGE DAILY CONSUMPTION PER PERSON IN HOTEL A

Hotel A	Energy (kWh)	Water (L)
January	0.96	7.68
February	0.59	6.67
March	0.50	6.25

TABLE II AVERAGE DAILY CONSUMPTION PER PERSON IN HOTEL B

Hotel B	Energy (kWh)	Water (L)
January	0.54	8.87
February	0.43	7.95
March	0.31	6.61

What would be the total consumption costs for Hotel A in March?

$$Total\ cost = (Electricity\ (kWh) \times Avg.Cost\ €\backslash kWh) + (Water\ (L) \times Avg.Cost\ €\backslash L)$$
$$Total\ cost = (111.191\ (kWh) \times 0.07\ €) + (1{,}386{,}000\ (l) + 0.04€) = 13064.44€$$

What would be the real cost of a stay at Hotel B for 3 guests for 14 days in January?

Average energy consumption per guest per day in January = 0.54 kWh

kWh cost = 0.15 €

$$Total\ energy\ cost = 0.54\ kWh\ \times 0.15€\ \times 3 \times 14 = 3.40€$$

Average water consumption per guest per day in January = 8.87 L

L cost = 0.0019€

$$Total\ water\ cost = 8.87\ l\ \times 0.0019€\ \times 3 \times 14 = 0.71€$$

$$\underline{Total\ cost = 3.40€ + 0.71€ = 4.11€}$$

III. Conclusions

The present paper explores the possible advantages of integrating Internet of Things-based energy management systems in hotels. These kinds of applications go beyond simple cost-cutting and instead promote sustainability and operational effectiveness.

The results of this study offer compelling evidence that integrating IoT technology in hotels not only could reduce costs but also greatly encourage visitors to adopt sustainable behaviours.

The findings of this study provide a useful road map for hotels as they keep navigating the difficult balancing act between economic viability and environmental responsibility.

By utilizing IoT technologies to encourage environmental awareness, hotels can improve their operational effectiveness, cut expenses, and project a more sustainable image all at once. This study's demonstration of the integration of technological innovation and guest engagement not only conforms to modern standards for ethical business conduct but also opens the door for a more strong and sustainable future for the hospitality industry.

Examining how IoT-based energy management systems interact with smart building technologies creates opportunities for further study aimed at improving sustainable hotel management practices. The intended objective is to create a smoothly functioning ecosystem that maximizes energy efficiency and elevates visitor experiences.

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REFERENCES

[1] "Hotel Energy Solutions (HES) | UNWTO." Accessed: May 25, 2023. [Online]. Available: https://www.unwto.org/hotel-energy-solution

[2] "Hospitality trends: The impact of an energy shift." Accessed: Dec. 06, 2023. [Online]. Available: https://hospitalityinsights.ehl.edu/hospitality-trends-energy-shift

[3] "Hotel Energy Consumption Statistics and Lessons Learned." Accessed: Dec. 06, 2023. [Online]. Available: https://www.buildingsiot.com/blog/hotel-energy-consumption-statistics-and-lessons- learned-bd

[4] "Car et al. - 2019 - INTERNET OF THINGS (IOT) IN TOURISM AND HOSPITALIT.pdf." Accessed: Dec. 06, 2023. [Online]. Available: https://d1wqtxts1xzle7.cloudfront.net/66894304/293-internet-of- things-iot-in-tourism-and-hospitality-opportunities-and-challenges-libre.pdf?1620613150=&response-content-disposition=inline%3B+filename%3DInternet_of_Things_Iot_in_Tourism_and_Ho.pdf&Expires=1701887611&Signature=IVramI60WiGgbhXZ4oG67Nv7CZ~oaPpCJedr~TXh1tpehbe4uKEdbFXEOt- jEGdAasrvvPBh-43oQoogshTRkaCmfOa4FlOcnpps4-XZx20nwCQSkgcQQThyDH6PZloaPDXJNgsHWRRNa1YPo1-8qEMZzdiow1h6XSCfbvdgqr5X2HcaJf7rGCxJZ6twPZfDAO2FtJ4PlIPJHASaEuiCM7E6qKT9TjaCQgvG58CGuZa4I4fgswPgWDAdGA09zweoJbZu-90pRBvjH4HHfVIIgPS7Wph-SEI4mZBu2MyEjfAi57Uy747O8efFp6yFwR33r5gmFzR0pSaV0ArQJrUZig &Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

[5] "Hóspedes nos alojamentos turísticos: total e por tipo de estabelecimento." Accessed: Apr. 18, 2023. [Online]. Available: https://www.pordata.pt/portugal/hospedes+nos+alojamentos+turisticos+total+e+por+tipo+de+ estabelecimento-2614

[6] R. S. Arenhart, A. M. Souza, and R. R. Zanini, "Energy Use and Its Key Factors in Hotel Chains," Sustainability, vol. 14, no. 14, Art. no. 14, Jan. 2022, doi: 10.3390/su14148239. https://doi.org/10.3390/su14148239

[7] P. Thollander, S. Backlund, A. Trianni, and E. Cagno, "Beyond barriers – A case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden," Applied Energy, vol. 111, pp. 636–643, Nov. 2013, doi: 10.1016/j.apenergy.2013.05.036. https://doi.org/10.1016/j.apenergy.2013.05.036

[8] "mbp_setorhoteleiro_ena_ppec2017_2018.pdf." Accessed: Apr. 18, 2023. [Online]. Available: https://www.erse.pt/media/4s4gfzdv/mbp_setorhoteleiro_ena_ppec2017_2018.pdf

[9] J. C. Wang, "A study on the energy performance of hotel buildings in Taiwan," Energy and Buildings, vol. 49, pp. 268–275, Jun. 2012, doi: 10.1016/j.enbuild.2012.02.016. https://doi.org/10.1016/j.enbuild.2012.02.016

[10] T. Tsoutsos, S. Tournaki, C. A. D. Santos, and R. Vercellotti, "Nearly Zero Energy Buildings Application in Mediterranean Hotels," Energy Procedia, vol. 42, pp. 230–238, 2013, doi: 10.1016/j.egypro.2013.11.023. https://doi.org/10.1016/j.egypro.2013.11.023

[11] "Decreto-Lei n.o 101-D/2020, de 7 de dezembro | DRE." Accessed: Apr. 21, 2023. [Online]. Available: https://dre.pt/dre/detalhe/decreto-lei/101-d-2020-150570704

[12] "Document Display | NEPIS | US EPA." Accessed: Apr. 21, 2023. [Online]. Available: https://nepis.epa.gov/Exe/ZyNET.exe/P1004NH9.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000009%5CP1004NH9.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL

[13] R. Goel, T. Singh, S. L. Sahdev, S. K. Baral, and A. Choudhury, "Impact of AI & IOT in Sustainable & Green Practices Adopted in Hotel Industry and Measuring Hotel Guests' Satisfaction," in 2022 10th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Oct. 2022, pp. 1–5. doi: 10.1109/ICRITO56286.2022.9965152. https://doi.org/10.1109/ICRITO56286.2022.9965152

[14] B. Mataloto, J. C. Ferreira, and R. P. Resende, "Long Term Energy Savings Through User Behavior Modeling in Smart Homes," IEEE Access, vol. 11, pp. 44544–44558, 2023, doi: 10.1109/ACCESS.2023.3272888. https://doi.org/10.1109/ACCESS.2023.3272888

[15] S. Mandal, S. Kumar, and P. Ranjan, "Smart IoT-based Water Monitoring System using Redundancy Elimination Strategy," in 2021 IEEE Bombay Section Signature Conference (IBSSC), Nov. 2021, pp. 1–4. doi: 10.1109/IBSSC53889.2021.9673314. https://doi.org/10.1109/IBSSC53889.2021.9673314

[16] D. Shiming and J. Burnett, "Energy use and management in hotels in Hong Kong," International Journal of Hospitality Management, vol. 21, no. 4, pp. 371–380, Dec. 2002, doi: 10.1016/S0278- 4319(02)00016-6. https://doi.org/10.1016/S0278-4319(02)00016-6

[17] R. Priyadarsini, W. Xuchao, and L. S. Eang, "A study on energy performance of hotel buildings in Singapore," Energy and Buildings, vol. 41, no. 12, pp. 1319–1324, Dec. 2009, doi: 10.1016/j.enbuild.2009.07.028. https://doi.org/10.1016/j.enbuild.2009.07.028