Sacred Spaces: A Data-Driven Study of Indoor Environment Quality, Energy Efficiency, and Management Practices in Sri Lankarama Temple, Otahuhu, New Zealand

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EXECUTIVE SUMMARY

Temples, such as Sri Lankarama Temple, situated at Otahuhu, New Zealand, are important for their cultural, spiritual, architectural, and communal significance. They act as hubs for cultural preservation, education, meditation, and social interaction. Because poor air quality can cause discomfort, decreased cognitive function, respiratory problems, and long-term degradation of temple materials, it is imperative that temples maintain a clean, stable, and healthy indoor environment. A careful and context-sensitive approach is needed to strike a balance between IEQ and energy efficiency. While minimizing energy use is essential, through avoiding excessive use of fans, air conditioning, and artificial lighting, inadequate ventilation and humidity control can result in poor IEQ while will negatively impact the building and it occupants.

The aim of the study is to analyse the relationship between indoor Environment quality (IEQ), energy consumption, and building management practices across different spaces, identifying key inefficiencies and proposing data-driven strategies to optimise both occupant health and energy efficiency. As religious buildings are often overlooked in environmental and energy studies, this research aims to fill a critical gap by providing a data-driven analysis of how indoor conditions, energy usage, and operational practices interact in such settings. The temple comprises a range of diverse spaces, including prayer rooms, meditation halls, a kitchen, a library, and communal areas, each with different occupancy patterns and functional demands. The study was guided by five key objectives: to assess the compliance of IEQ with recommended international thresholds for temperature, humidity, and carbon dioxide, to Compare IEQ performance across different rooms within the temple, to analyse energy building consumption and the contribution of IEQ appliances, to investigating current practices influences the temple's energy efficiency and IEQ, recommend strategies to enhance IEQ while maintaining efficiency through synthesis of qualitative and quantitative data.

A mixed-methods approach was used to accomplish these goals. Using Internet of Things (IoT)-based sensors (EnviroQ), environmental data was gathered continuously for 30 days during Aril 2025, measuring CO_2, temperature, and relative humidity in six indoor spaces using 8 sensors. As a result, more than 15,000 data points were obtained and subjected to statistical and descriptive analysis. An overview of the appliances in each room and the temple's monthly electricity bills were used to estimate energy consumption. The building manager was also interviewed in a semi-structured manner to evaluate the temple's maintenance procedures, equipment usage, and air circulation. The findings demonstrated that the temple's overall IEQ performance, recorded 70.88% of temperature readings falling within the comfortable 20–24°C range, the temperature levels were relatively well-controlled. Additionally, areas such as the kitchen and meditation hall showed improved thermal consistency. On the other hand, humidity was a consistent problem in almost every area, with over 96% of recorded values surpassing the suggested upper limit of 60%. The open living room, kitchen, and prayer rooms were especially troublesome because of the high moisture content.

With regards to CO2 level, more than 90% of readings falling within acceptable range (below 1000 ppm). Prayer Room 2 showed alarming results, with over 54% of CO_2 readings above the above the acceptable threshold, suggesting insufficient ventilation during periods of high occupancy. It was specially the case during certain occasional and cultural activities. On the other hand, open living room and library maintained excellent air quality with regards to CO2 level due to natural ventilation.

High energy consumption did not always translate into better IEQ, according to energy analysis. Even though they consumed the most electricity, the kitchen, prayer rooms, and meditation halls continued to have high humidity and occasionally poor air quality. Conversely, low-energy areas like the library demonstrated strong IEQ results, indicating that well-planned, passively ventilated areas can sustain comfort levels without consuming a lot of energy. The majority of management practices were found to be reactive. The main source of ventilation was natural; mechanical systems were only employed for special occasions. Decisions were typically made based on observation rather than data, and there were no real-time monitoring systems in place. Building operators, who are mostly volunteers lacked environmental control and energy efficiency training, and there were no specific rules in place to control the use of, HVAC, lights, or other equipment in different rooms.

The results led to specific room-specific recommendations, such as adding CO_2-triggered ventilation systems in high-occupancy rooms, installing dehumidifiers in high-humidity areas, upgrading to energy-efficient appliances, and putting smart controls and thermal curtains into place. To promote responsive, data-driven environmental management, it was also suggested that volunteers receive basic training and a real-time IEQ dashboard.

The study makes significant contributions in spite of these limitations. It illustrates the importance of implementing energy audits, qualitative interviews, and quantitative sensor data to create a comprehensive picture of building performance. It also shows how modern environmental monitoring and energy optimisation techniques can greatly benefit sacred spaces, even though they are traditionally run. By implementing these suggestions, Sri Lankarama Temple could enhancing occupants/visitors comfort, safeguarding health, while cutting down on energy waste. By doing so, it can become a model for sustainable architecture of spiritual spaces, contributing to preservation of its cultural and spiritual mission. The impact and applicability of this approach will be expanded through future research that includes integrated energy and IEQ metering, long-term monitoring, and comparative studies across multiple heritage sites.

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Abbreviations

IEQ - Indoor Environment Quality

CO_2 - Carbon dioxide

^{0}C - Celsius

ppm – Particles per millions

1: Introduction

1.1 Background of the Study

Over the past few years, the world has focused on sustainable building practices and methods has grown stronger and Indoor Environmental Quality (IEQ) and energy efficiency have been in the spotlight. The two aspects are crucial not only in business or residential premises but also in religious and social places like temples, mosques and churches. These rooms have complex functions, they serve as a place of spiritual worship, socialization, learning and support. Nevertheless, regardless of their importance and common application in the open space, they are commonly left out of the mainstream discourse concerning the building performance and environmental sustainability (Mirzaei et al., 2020).

Sacred places such as Sri Lankarama Temple in Otahuhu, New Zealand, offer a unique research context due to their distinctive architectural features, fluctuating occupancy patterns, and specific cultural and operational requirements. Unlike commercial buildings, where structured, data-driven facility management is commonly practiced (Delzendeh et al., 2017), temples often operate on limited budgets and rely heavily on volunteer-based maintenance (Freeman, Jankovic, & Watson, 2022). This reliance frequently results in a lack of systematic monitoring and control of indoor environmental conditions, which can adversely affect occupant health, comfort, and overall building sustainability (Evans, Jeon, & Boswell, 2021). Furthermore, the absence of formal indoor environmental quality (IEQ) management may hinder efforts to align with energy efficiency and health standards applicable to sensitive cultural spaces (Niza, Bueno, & Broday, 2023).

Optimal IEQ is of essence in places where groups of people gather over long durations of time. Indeed, poor air quality, characterized by elevated levels of carbon dioxide (CO_2), unbalanced humidity, as well as subpar temperature, may result in fatigue, headaches, respiratory problems, and even impaired cognitive function (Kapuya & Nyembwe, 2024). These problems have a higher importance in sacred spaces where clarity of mind and emotional peace are greatly needed. Nevertheless, the systems that are employed to keep the IEQ at acceptable levels, especially heating, ventilation, and air conditioning (HVAC) are usually among the biggest energy consumers in buildings(Anand et al., 2022). This poses a conflict between the need to provide comfort and well-being to the occupants and the achievement of energy conservation, particularly in nonprofit institutions where finances are low and technically skilled persons are hard to come by.

Real-time monitoring of the environment and the use of smart sensor technologies present an auspicious way of dealing with this challenge. These technologies, combined with the information on energy consumption and with the qualitative information provided by the temple management and users, can assist in creating a more detailed picture of the existing practice and highlighting improvement opportunities. By implementing this data-driven process, religious organisations such as the Sri Lankarama Temple can make their facility management practices more sustainable and well-informed without having to sacrifice their spiritual or community-based missions.

Thus, this study aims at investigating the interdependence of IEQ, energy consumption, and building management operations in the Sri Lankarama Temple. Through the evaluation of the quantitative sensor measurements and qualitative feedback the anticipated outcome of the research is to present practical recommendations concerning the optimal design and operation of sacred spaces which balance the wellbeing of the occupants with energy conservation and a sustainable environment.

1.1 Problem Statement

Regardless of the rising concern on sustainability in the built environment, a considerable number of community-based and religious buildings are under-performing with regard to energy performance and indoor environmental quality (IEQ) (Niza et al., 2023). In comparison to the commercial buildings that are becoming extensively furnished with smart monitoring and control systems, sacred places like temples, churches and mosques, still tend to stick to the traditional, reactionary building management approaches. Such establishments usually have weak financial and technical background, and therefore, they are not able to adopt the contemporary solutions in terms of environmental monitoring or energy efficiency measures.

Such challenges are reflected by the case study - Sri Lankarama Temple in Otahuhu. Even though it is a crucial cultural and spiritual center of the Sri Lankan community in Auckland, its environmental and energy management systems have not undergone the systematic assessment and modernization with technology. An early observation and anecdotal evidence of temple users and managers indicate the possible inefficiency of HVAC utilisation, inappropriate scheduling of appliances, and unreliability of climatic control that might result in a high energy draw and unsatisfactory indoor air quality (Homod, 2018). These are especially problematic considering the long period of time that the people are likely to spend in the sacred spaces with low IEQ practically affecting the comfort, health and well-being of the occupants (Al horr et al., 2016; Evans, Jeon, & Boswell, 2021).

What adds even more to the problem is the absence of empirical data that could be used to support these apprehensions or indicate the way toward making things better. A lack of real-time and precise data on environmental conditions, e.g., temperature, humidity, and CO_2 levels, or records of energy use patterns. does not allow the management of the temple to make decisions based on evidence about operational performance or sustainability (Niemelä, Saarinen, & Kalliomäki, 2022). This gap in knowledge does not just limit active intervention, but also long-term optimisation of resources becomes minimal (Aliero et al., 2022) .

As a way of answering these questions, this study attempts to fill the data and knowledge gap by undertaking a holistic, data-driven evaluation of the temple's indoor environment and energy consumption. Through the implementation of smart sensor technologies, the study of energy bills, and qualitative interviews with stakeholders of the temple, the research aim is to identify particular areas of energy wastage and provide viable strategies that are sustainable (Anand, Cheong, & Sekhar., 2022). The long-term aim is to make aware superior management procedures that maximise occupant experience and environmental performance towards developing strategies that can be adopted by other analogous community religious establishments (Freeman, Jankovic, & Watson., 2022).

1.2 Aim of the Study

This study aimed to analyse the relationship between indoor Environment quality (IEQ), energy consumption, and building management practices in a sacred space. The purpose is to identify key inefficiencies and propose data-driven strategies for optimising both occupant health and energy efficiency.

1.3 Research Objectives

To achieve this aim, the following objectives were set to be achieved:

1. Assess the compliance of IEQ with recommended international thresholds for CO_2, temperature, and humidity.
2. Compare IEQ performance across different rooms within the temple.
3. Analyse energy building consumption and the contribution of IEQ appliances.
4. Investigating current practices influences the temple’s energy efficiency and IEQ.
5. Recommend strategies to enhance IEQ while maintaining efficiency through synthesis of qualitative and quantitative data

1.4 Research Questions

1. How frequently do IEQ parameters in the temple exceed recommended thresholds?
2. Are there significant differences in IEQ conditions across different spaces?
3. What is the pattern of energy consumption in the temple, and how do IEQ-related appliances contribute to overall energy use?
4. What current practices influence the temple’s energy efficiency and IEQ?
5. What integrated strategies can be recommended to enhance IEQ while maintaining or improving energy efficiency, based on a synthesis of quantitative data and qualitative insights?

1.5 Significance of the Study

The research is important in at least three respects, especially in the environment of community-owned religious buildings, which work as an outcast in the spectrum of the research on the sustainable building practices. Although the concepts of IEQ and energy efficiency have been widely discussed in commercial and residential facilities, temples are under-researched, although they can be studied as one of the high-occupancy communal environments.

Most of these institutions have limited sources of funds and technical resources including the Sri Lankarama Temple. It does not have formal mechanisms of tracking the quality of the environment or energy efficiency. This means that potential improvements of occupant well-being and costs of operations thanks to smart technologies have been under-researched. This work covers this gap as it provides an evidence base evaluation of the temple in terms of environmental and energy performance on the basis of its real-time sensor data, consumption of energy, and operational analysis.

The research can serve as an effective example, which can be emulated by other religious and community buildings in order to achieve the right balance of comfort, sustainability of the buildings, and cost-efficiency due to the characteristic identification of areas of inefficiency and the recommendations that are tailored to address them. Moreover, both quantitative and qualitative (interview-based) results integration allows building a complete picture of the way that building management practices influence IEQ and energy consumption.

It will allow informing building management decisions, empower non-professional building managers to make more informed decisions to manage the indoor environment, and show how low cost, data- driven solutions can be used even where the buildings are volunteer-run and/or non-commercial. Finally, the study has some academic contributions to scholarly publications as well as to the actual practice of sustainability in the built environment.

1.6 Scope of the Study

The study described in this thesis involved monitoring IEQ levels in six rooms in the Sri Lankarama Temple for one month using eight smart IEQ sensors. It also involved the study of energy bills, and 1 semi-structured interview with the building manager. Although the findings cannot be projected to represent the situation in all temples, the methods and findings can be applied to any sacred space that would like to know some optimisation strategies.

1.7 Structure of the Report

The report will be organised around five important chapters, each of which comprehensively addresses the research problem and its extended implications:

Chapter 1: Introduction

In this chapter, the researcher provided an overview of the study, the background, and the context within which the research is framed. It states the problem description, research aim and research questions, and it also highlights the importance of the research. The chapter provides the justification of the study in indoor environmental quality (IEQ) and energy performance in sacred places with specific reference to Sri Lankarama Temple.

Chapter 2: Literature Review

The chapter is a critical review of the available literature in the field of IEQ, energy efficiency, and sustainable building management practices. It touches upon theories applicable to the topic (environmental sustainability and stakeholder engagement) and reveals the gaps in the literature (particularly, with regard to sacred or community buildings management). This review offers a theoretical basis or the study.

Chapter 3: Research Methodology

Chapter 3 provides the research design and methodology that were used in the study. It outlines the mixed-methods framework, namely, the mixed-methods smart sensor technologies to collect the quantitative data and qualitative interviews with the temple management. Data analysis procedures, ethical considerations, and research limitations of the design are also outlined in the chapter.

Chapter 4: Findings and Discussion

This chapter presents the empirical results of the environmental monitoring and the qualitative interviews. Data are discussed and analysed in relation to the research goals, with the support of the existing literature. The discussion shows the most relevant patterns, inconsistencies, and findings that outline the situation of IEQ and energy management in the Sri Lankarama Temple.

Chapter 5: Conclusion and Recommendations

The last chapter provides a summary of the key findings and what they imply in terms of the sustainable management practice in sacred spaces. It presents useful suggestions and recommendations to temple administrators and stakeholders, and future research directions. The chapter ends by reiterating that data-driven approaches possess the possibility of improving the well-being of occupants and the environmental performance of religious institutions.

2 Literature Review

2.1 Introduction

The Indoor Environmental Quality (IEQ) and energy performance are known as important parts of sustainable building performance, especially when it comes to buildings that are used to house various public functions. With the ever-increasing environmental concern and related energy implications, academic and industry interest has grown to optimise the indoor environment to improve the well-being of the occupants with minimal effect on the environment and low operational costs (Munaro, Tavares, & Bragança, 2021).

In this chapter, review of the existing literature related to IEQ, and energy efficiency is carried out, and special attention is paid to the discussion of the use of smart technologies in the management of buildings. It addresses technical standards and performance benchmarks of important IEQ parameters, including temperature, humidity, carbon dioxide (CO_2) and air quality. It also analyses the trends and developments of smart building systems, such as sensor-based monitoring, automated controls and real-time data analytics, that have the potential to provide solutions to better indoor environments and energy optimization (Sadeghi et al., 2021).

In addition, the chapter covers the unique issues that are presented by multi-use community buildings and sacred spaces, which in most cases include odd occupancy schedules, tiny budgets, and even smaller infrastructure. Such obstacles may prevent the adoption of effective energy and environmental management. This review establishes the background to research by exposing the missing links in existing studies and practice with regard to utilising smart environmental monitoring and energy data analysis to enhance sustainability performance in religious buildings such as the Sri Lankarama Temple.

In addition to that, the knowledge of IEQ and energy performance in sacred buildings is not only related to the need to ensure that the technical standards are met, but also to the need to recognize the cultural value and the use patterns that are not similar to commercial or residential buildings. These areas tend to have high usage at certain times then long durations of no occupancy, and this creates special issues in ensuring that there is a constant environment without excessive energy expenditure. As a result, sustainability plans of such buildings should be based on time and social aspects as well as interventions using technology. (Miloshevikj et al., 2023).

What also complicates the situation is the fact that the architecture of sacred buildings is very diverse and standardisation of sustainability interventions is especially challenging. Historic construction techniques, unusual materials, or non-standard spatial arrangements may be present in the temples, mosques, and churches, as well as other places of worship, which complicate the installation and work of modern HVAC and monitoring devices. The heritage aspects usually curtail the level of retrofitting that can be done, particularly in historically or artistically valuable buildings (Himeur et al., 2022).

Further, religious spaces are usually used in a multifunctional manner, i.e. not only as a space of worship and meditation, but also as a space of education, celebration, and even shelter during a time of crisis. This functional plurality brings in diverse environmental demands during the day or week, and it is hard to optimise conditions regularly. IEQ approaches in such environments, thus, demand responsive and user-friendly design philosophy (Chatzimanoli et al., 2020).

Of importance is also the realization of how the community values and the collective identity inform expectations of comfort and environmental stewardship in such spaces. As an example, in one religious tradition it is virtuous to live in slightly austere environmental conditions, in the other one a clean, cool and fragrant atmosphere is part of the ritual. Any sustainability-driven change should take into consideration these perceptions to prevent cultural insensitiveness or adoption resistance (Evans et al., 2021).

Lastly, the chapter does not disregard the fact that smart building systems innovations, when carefully implemented, can serve to facilitate both the energy and spiritual atmosphere. Contextually aligned innovations include discreet sensors, automated incense ventilation, lighting that can be programmed to match the timing of rituals, etc. Sri Lankarama Temple is a good case to discuss these possibilities, since it is a real-life setting where culture, community, and sustainability should collaborate (Freeman et al., 2022).

2.2 Review of Literature

The following section presents a review of the literature available on the IEQ, energy efficiency, smart monitoring systems, and management practices and how each of these topics applies to multi-use and community buildings, which also includes religious locations.

2.2.1 Indoor Environmental Quality (IEQ)

IEQ can be defined as the sum and the performance of the indoor environment in a building as observed and felt by the occupants. It relates to a set of environmental conditions, such as indoor air quality, thermal comfort (temperature and humidity), lighting, acoustics and ventilation. Optimal IEQ is necessary to ensure the health and comfort of the building occupants and their productivity, cognitive functions and well-being (Ackley et al., 2024; Frontczak et al., 2020).

IEQ has gained increasing interest in recent years, not only regarding its psychological and physiological effects but also in places that demand a high degree of mental concentration and emotional comfort like sacred spaces. Research indicates that bad IEQ does not only impact respiratory health but also leads to mental fatigue and reduced spiritual involvement, which is essential to the success of religious practices and social connection. These buildings are designed to be places of spirituality and compromised environmental conditions can disrupt rituals, concentration and interpersonal harmony, which are all parts of the experience and operation of these buildings. The feeling of reverence that may be sought in such an environment may be lost due to emotional disconnection or distraction brought about by physical discomfort caused by heat, stale air, or bad lighting (Bluyssen, 2021).

Indoor air quality (IAQ) is one of the most important elements of IEQ, and specifically, carbon dioxide (CO_2) level is used as an indicator of sufficiency of ventilation and density of human occupancy. The American Society of Heating, Refrigerating and Air-

Conditioning Engineers (ASHRAE, 2025) suggest keeping the concentrations of CO_2 in occupied spaces at a level which must not exceed 1000 parts per million (ppm). Cognitive impairments, such as a reduction in the quality of decision-making, and feelings of tiredness and drowsiness, may increase if this limit is exceeded (Broadway et al., 2025). Researchers have given empirical evidence on the association of high CO_2 concentrations with poor cognitive functions such as, information-use, strategy and initiative, which are more fundamental in learning and working conditions (Taha et al., 2025). Moreover, the religious premises with large groups of people staying inside a building over a long time may have a spike in CO_2 very quickly, and this fact proves the importance of real-time monitoring and responsive ventilation systems (Niemelä et al., 2022).

Another important parameter that affects IEQ is humidity. The relative humidity of the indoor environment should be maintained at an optimum level of 30% to 60% to ensure health and comfort (Sakhare & Ralegaonkar, 2014). Humidity that is either below or above this range may cause numerous problems. Elevated humidity provides an optimal condition in the growth of molds, dust mites and microbial contaminants that may aggravate breathing difficulties, asthma and allergic symptoms (Hope & Simon, 2007) (Vardoulakis et al., 2015). On the other hand, dry weather might lead to dry skin, sore eyes and throat, and displacement, especially in air-conditioned or heated areas.

Humidity is also a key factor in conservation of artefacts and furnishings in sacred buildings, most of which contain culturally and spiritually valuable objects. Extended contact with improper humidity levels may destroy wooden buildings, textiles, manuscripts, and artworks, thereby introducing the aspect of heritage conservation to the IEQ debate. The sensitivity of these frequently irreplaceable items makes IEQ systems in these buildings have to strike a balance between human comfort levels and conservation requirements, often necessitating zoned environmental control or microclimatic control in certain zones of the space. (Valentim, Martins, & Silva, 2023)

Ventilation is one of the most important processes that help control the air quality and humidity. Acceptable levels of air exchange are ensured by adequate ventilation systems that assist in clearing the pollutants generated indoors and introducing fresh outdoor air regularly. Indeed, by decreasing the build-up of indoor pollutants such as CO_2 and volatile organic compounds (VOCs) as well as airborne pathogens, which are circulated because of poor ventilation, the occupant health and satisfaction and cognitive performance will be improved (Fisk et al., 2011).

The existing studies also suggest the possible advantages of the integration of natural ventilation strategies, particularly in the climatic zones of tropics and subtropics, where mechanical systems can be too expensive or culturally invasive. Building design and orientation can therefore play a leading role in affecting the success of passive IEQ management strategies. In this regard, the knowledge of architectural design and the ventilation pattern of religious structures is even more crucial to ensure sustainable indoor conditions. Such measures can be clerestory windows, courtyards, tall ceilings, or latticed facades that are common in most traditional religious buildings and have built-in advantages in terms of air circulation and temperature control (Lee, Choi, & Kim, 2021)

2.2.2 Energy Efficiency in Buildings

Energy efficiency in buildings is the tactical employment of technologies, design procedures, and occupant behaviours that lowers energy utilisation without decreasing comfort, functionality, or indoor air quality (Maghsoudi Nia et al., 2022). It is now considered a pillar of sustainable building operations because it allows building owners to decrease the operational cost of the building, minimise greenhouse gas emissions and ensure long-term care of the environment.

Over the past years, energy efficiency has been not only an operational target but a regulatory and ethical requirement, especially when it comes to climate change mitigation (Kent et al., 2023). Energy targets and carbon reduction measures are being adopted in building performance standards all over the world. As an example, the International Energy Agency (IEA) has stated that buildings consume about 30 percent of the world energy consumption and almost 28 percent of emissions of energy-related CO 2, which is why it is of utmost importance to minimize consumption in the sector (International Energy Agency (IEA), 2022).

The latest developments in smart building technologies have considerably elevated the capacity of buildings to detect and control energy consumption. High-efficiency HVAC systems, programmable thermostats, occupancy sensors, and automated controls of lighting and shading, are a few of the innovations that add up to extensive energy savings (Aliero et al., 2022). These technologies permit real-time modification of inside conditions subject to occupancy designs, environmental situations and time-of-day plans. According to research studies, the overall energy use of buildings can be lowered by 20% to 40% due to the incorporation of such systems, depending on several factors, including the level of technological implementation, building typology, and user behaviors (Martani et al., 2012,) (Delzendeh et al., 2017).

Moreover, the cloud-based systems and the Internet of Things-driven devices currently enable building managers to remotely control the energy systems and adjust the settings to achieve the balance between the demand and efficiency. There is an emerging trend in the integration of machine learning algorithms to be used in predictive control which can pre-adjust systems according to weather forecasts and occupancy predictions (Pan et al., 2023). This automation potential has been particularly handy in commercial buildings whose usage patterns are irregular, like temples or community halls, where standard programming does not match to the changing activity schedules.

Nevertheless, regardless of the promising perspectives of these technologies, their real efficiency strongly depends on the human and operational factors. Adua's (2020) and Liang et al.' (2019) studies point out that the behaviour of occupants, maintenance of systems, and scheduled operating programs are important factors that could determine whether the expected energy savings from HVAC systems materialise. To give an example, the most energy-efficient HVAC system may contribute to inefficient use of energy if it is used at times when no one is in a building or when a building is underoccupied. (Aune et al., 2009) call attention to the fact that one of the most widespread problems hindering the energy efficiency objectives is ineffective or improper timing of HVAC operations.

These problems are even more acute in the sacred and community-use facilities where the technical expertise is less, and the equipment scheduling is frequently based on the intuition of volunteers instead of the systematic programming. According to (Kent et al., 2023), the lack of specific protocols and feedback systems can lead to the users disabling the energy-saving features or ignoring maintenance warnings, which cancels out any potential advantages.

The potential of energy-efficient technologies should be maximised, and this can be achieved through the application of a holistic approach, which implies combining technical measures with strategies encouraging behavioural change and occupant awareness. According to (Janda, 2006), feedback systems that include energy dashboards, usage reports and real-time energy monitoring tools can be used to engage the users more and encourage more energy-conscious behaviours. Education and training programs can also be used to enforce the energy-saving behaviours in the maintenance staff and the users of the buildings (Pietrapertosa et al., 2021).

Another key element that will be required in enhancing energy-saving behaviours among the maintenance personnel and ordinary users of the building is education and training programs. These may involve seminars on effective use of appliances, seasonal adjustment of HVAC systems or even energy literacy classes. Kirchner-Krath et al. (2024) note that specific sustainability training on non-expert building users, including volunteers or religious custodians, can result in long-term behavioural changes and institutionalise energy-responsible practices (Kirchner-Krath et al., 2024).

When it comes to religious or sacred buildings, such measurements will have to be tailored to suit irregular occupancy, event-based use, and cultural practice sensitivity. As an example, smart systems may be programmed to have adjustable modes to suit festivals or large events and at the same time have minimal energy consumption when there is no activity. Such an adaptive control approach is enabled by the current building management systems, which are becoming more modular, scalable, and affordable to non-commercial environments (Ukoba et al., 2024).

In general, building energy efficiency should not be considered as an engineering problem that fits all, but rather as an interdisciplinary project integrating technology, human behavior, organizational culture, and contextual knowledge. And, as this paper will illustrate further in the example of the Sri Lankarama Temple, data-driven interventions, occupant involvement, and low-cost automation can, together, play an important role in improving the sustainability outcomes of under-resourced, culturally important settings

2.2.3 Smart Monitoring Systems

The smart monitoring systems are a revolutionary way of indoor climate control and energy management in buildings. Such systems are based on an array of interconnected environmental sensors that constantly monitor the values of CO_2 concentration, temperature, humidity, and particulate matter (PM) (Sung & Hsiao, 2021). These technologies can help facility managers and building operators ensure the indoor environment stays optimal and energy-wasting and operational inefficiencies are reduced to a minimum by delivering real-time data and analytics (Dong et al., 2019).

The low cost and accessibility of wireless sensor networks (WSNs) and Internet of Things (IoT) platforms have made the use of smart monitoring systems even more prevalent, making it economical to implement both in large-scale commercial structures and smaller community infrastructure (Alsafery et al., 2023). By being integrated with building automation systems (BAS), these intelligent sensors do not only gather environmental data but also communicate with control systems in real-time to optimise comfort and operational efficiency.

The underlying benefit of smart monitoring is that it provides unceasing feedback and anomaly detection, enabling active and flexible environmental management. These systems, as (Homod, 2018) remarks, permit the optimisation of the indoor environmental quality (IEQ) by automatically adjusting the settings of HVAC systems, the level of ventilation, or the lighting depending upon the real-time variations in occupancy or air quality. This flexibility would be of great interest, especially in areas with variable occupation rates, like community centres, schools, and places of worship (Ukoba et al., 2024). In addition, cloud-based analytics and machine learning algorithms to identify complicated patterns or forecast system failures using historical data are also available on modern platforms (Pan et al., 2023).

Practical experience notes the advantages of intelligent monitoring in improving the comfort of the occupants and efficiency. And, as one example, (Arbizzani et al., 2023) reported 15% to 25% increases in perceived indoor comfort when facility managers used IEQ dashboards, which present the data collected by sensors in easy-to-read formats. Such positive changes were explained by the fact that, due to data-driven interventions, it became possible to react to the changes in the environment in a timely manner, e.g., increasing CO_2 concentration or temperature variations. Moreover, such dashboards can increase transparency, which allows non-technical personnel and stakeholders, including community leaders or building caretakers, to contribute to facility decision-making.

Besides optimising the indoor conditions, intelligent monitoring systems also enable predictive maintenance approaches. These systems are able to identify the early indication of appliance inefficiencies, ventilation clogs, or HVAC failures by establishing the trends in appliances and environmental performance over time (Pan et al., 2023). Recent research on smart facility management shows that predictive analytics can cut unplanned downtime and related costs by up to 30 percent. This enables facility managers to rectify some possible problems before they develop into expensive failures or energy-wasting ones (Hanafi et al., 2024), thus minimising downtime and maximising the service life of the crucial building systems.

Nonetheless, these benefits notwithstanding, the acceptance and assimilation of the smart monitoring technologies into the building management culture is not uniform across the board, especially when speaking of the small-scale buildings, community buildings, or religious buildings (Walker & Rowlinson, 2007). The common constraints to these settings include low technical know-how, economic limitations and rarely do they know the benefits of having real-time environmental data in the long run. According to Da Costa et al. (2024), the ability to interpret or act on the data is one of the main limitations of community-based facilities, despite the proper collection of the data. Consequently, the insights produced by sensors are not necessarily used successfully in operational decisions, which reduces the prospective value of such systems (da Costa et al., 2024).

Recent literature suggests to overcome these challenges the co-design of user-friendly interfaces that meet the needs of non-specialist users, practical training and community workshops to develop local capacity (Kirchner-Krath et al., 2024). In especially sacred or volunteer-based environments, smart monitoring systems need to be not only technically sound, but also socially flexible, so that their insights can be actionable by people with little technical knowledge.

2.2.4 Religious and Community Buildings

Houses of worship and community structures constitute a distinctive category of the built environment, which is usually underrepresented in the popular studies of energy and environmental performance (Peçanha Enqvist et al., 2018). These buildings, used as temples, mosques, churches and community halls serve a very crucial role in the social and spiritual life yet have very unique set of challenges with regards to environmental sustainability and energy efficiency. Although they are socially relevant and widespread both in urban and rural contexts, they are largely excluded in the significant discussions on green buildings and smart infrastructure (Mirzaei et al., 2020).

The studies in this field are not so numerous. Nevertheless, (Nguyen and Jones.,2020) are one of the few studies that identify some widespread problems that influence the energy performance of this type of building. According to the authors, this type of building is intermittent and greatly variable in occupancy, so it is hard to use the standard techniques of energy management developed for office or school buildings with a predictable schedule (Kent et al., 2023). These bi-weekly or monthly heavy uses, (e.g. religious ceremonies, community gatherings, seasonal festivals. etc.), often result in ineffective HVAC system operation and ineffective use of the lighting system, especially when old or poorly maintained systems are installed. In addition, the prediction of occupancy is particularly challenging in sacred buildings because of the irregular attendance and cultural calendars and events, which further restricts the use of automated systems without modification (Niza et al., 2023).

Also, a good number of these buildings are managed by religious groups or volunteers who have little facility management expertise and supporting infrastructure. There is usually no systematic practice in monitoring and maintenance, which results in a waste of energy and poor IEQ and failure to effectively respond to the comfort demands of the occupants (Huang et al., 2013). The absence of planned maintenance schedules and preventive measures compounds the inefficiency of systems that are already past their service lives or are operating near to their service lives. Moreover, most of the buildings that are run by volunteers in the area of religion use reactive measures, which only respond to complaints of discomfort when it is severe, instead of ensuring a constant level of performance using proactive controls (Kirchner-Krath et al., 2024).

There is also a lack of professional management structures to make it more difficult to gather and assess data that might be used to make specific improvements. The benefits of such technologies are constrained even in cases where the smart monitoring tools have been installed because there are no institutional mechanisms to interpret and act on the data (da Costa et al., 2024).. As an example, the data on the environmental conditions measured by smart sensors in real-time is commonly underutilised or neglected because of a lack of training or interface accessibility, which prevents effective decision-making.

There is another dimension to this complexity, that is, the cultural and spiritual meaning of such spaces. Certain rituals and religious practices entail particular indoor environment conditions, e.g., high temperatures in meditation, high ventilation rates when incense is used, or limited lighting during religious ceremonies that can be incompatible with general energy-efficiency measures (Yadav & Choudhary., 2020). Such specialised needs impose further limitations on the optimisation of energy consumption, especially where the traditional efficiency strategies like dimming the lights or reducing the HVAC output are seen as incompatible with the sacredness or soundness of the ritual experience. Such needs require delicate design and operation strategies that need to be considerate of religious customs and aim at being environmentally responsible.

In general, the enhancement of the energy and environmental performance of religious and community buildings requires a context-based approach. It should be efficient, culturally appropriate, affordable, and user-friendly especially in low resource and volunteer-run environments. Additional studies ought to increase interdisciplinary collaboration between building scientists, anthropologists, and spiritual communities to create new, inclusive sustainability solutions.

2.2.5 Building Management Practices

The management of a building has to be appropriate to sustain the IEQ and ensure energy efficiency. Nevertheless, when applied to religious and community buildings, the issue of management practices is usually subjected to structural and operational constraints, which impede optimal functioning. Having a well-planned infrastructure in these settings might not perform well because of the constraints on human capital, institutional knowledge and availability of funds.

A number of these common obstacles are highlighted by existing research. One of the problems is that facility managers, caretakers and volunteers who are usually assigned to run these buildings, lack the technical knowledge to do so. (Alsafery et al., 2023) report that most of the people occupying these positions are not familiar with smart building systems and the analysis of sensor-based data, thereby limiting their capability to make decisions regarding ventilation, lighting, and energy in these buildings. Lack of formal training in environmental management or building systems also restricts the optimisation of operations by the staff (Kirchner-Krath et al., 2024). Moreover, the gap in knowledge exists in the interpretation of the long-term trends or carrying out preventative diagnostics, which is why data-driven management is hard to reach even in the presence of technologies.

The challenge is also multiplied by budget constraints. Indeed, as (Ginks & Painter., 2017) noted, the main issue is that community and religious buildings usually do not have enough financial resources to access modern energy-efficient appliances, perform retrofitting, or install integrated monitoring systems. This vulnerability of finances results in the dependency on manual, ad-hoc processes and the minimum technological interventions (Rispoli & Organ, 2019). Such budgetary constraints are especially constraining in volunteer-based operations where funding is donor-based and maintenance decisions are influenced by the seasonality of funds. When this happens, even inexpensive measures such as sensor-based thermostats or automatic lighting tend to be delayed or put on the backburner.

Furthermore, the management of these facilities is often operated using anecdotal responses and experiences instead of making use of digital and multi-faceted data to make decisions. According to (Park et al., 2019), numerous facility managers use oral complaints or visual observation to determine the state of the environmental conditions, leading to a slow reaction to IAQ problems or poor energy consumption. Such reactive approach of management may lead to the long-term exposure to suboptimal conditions, particularly during high-use times. The lack of real-time alerts and available dashboards means that the variation in CO_2 , humidity, or thermal comfort will only be addressed when it causes dissatisfaction among the users.

Besides these internal limitations, there are also external impediments that concern regulatory and institutional assistance. Numerous houses of worship and community facilities are not subject to either mandatory compliance regimes in energy auditing or performance benchmarking. Therefore, they are not considered in the citywide or national plans of energy reduction. Lack of government incentives or guidance documents more specific to non-commercial, sacred-use facilities expands the gap between potential and actual sustainability performance (Kent et al., 2023)

In addition, the variety of building typologies and usage patterns of community and religious buildings requires the possibility to customise management strategies. The one size fits all is seldom the answer and the building managers have to resort to trial and error or even borrowing the ideas of other industries. Such contexts have low scalability of sustainable management practices due to the absence of customized tools or case-specific advice (Peçanha Enqvist et al., 2018).

In order to fill such gaps, research suggests capacity-building interventions. (Abrahams & Bradfer-Lawrence, 2023) suggest designing specific training resources, technical assistance services, and monitoring interfaces that would be conveniently adjusted to the needs of non-expert users. These efforts may enable caretakers and community decision-makers to take a proactive approach, implement energy-saving habits that do not cost a lot, and in the long-term switch to smarter building operation. Engagement in the buildings without professional facility managers can be facilitated greatly by tools that provide user-friendly summaries, icon-based notifications, or data visualisations integrated into smartphones. Also, participatory monitoring methods and community-based data interpretation have been promising in enhancing building performance with the application of shared awareness and gradual behaviour change (Niza et al., 2023).

Lightweight, cost-effective management tools have been successfully tested in pilot projects in sacred buildings and have shown encouraging results. These involve energy dashboards simplified to the needs of low-literacy people, peer-to-peer training between volunteers, and incorporating IEQ into the religious account of stewardship. These methods are low-barrier entry points to scaling best practices and integrating sustainability into the culture of the community (Pan et al., 2023).

To sum up, although there are technical solutions, the whole system of building management in religious and community facilities requires strengthening of institutions. The key to making sure that energy-efficient technologies do not only get installed but also used and maintained efficiently is training, budgeting sustainability, and inclusive operation models.

2.3 Gaps in the Literature

Even though there has been an increase in interest with regard to sustainable building practices and intelligent environmental monitoring, there are still large gaps in the literature, especially when it comes to sacred buildings, as well as, community buildings. Although the energy efficiency and IEQ are increasingly becoming known in the residential and commercial sectors, religious and community buildings have not been studied extensively, either in the academic or practical contexts.

Firstly, there is still a dearth of empirical research studies that have specifically considered religious or community-based facilities. In particular, these buildings form a significant part of the overall building stock, yet are typically left out of the mainstream building performance research studies because of their sporadic usage profiles and sensitivity to culturally based operational needs. The buildings impose specific environmental and managerial issues which are not comparable to commercial or residential cases, and at the same time are insufficiently researched. Such an exclusion is supported additionally by the fact that religious and community institutions are not involved in the national energy benchmarking schemes, which leaves their operating characteristics mostly uncharted (Mirzaei et al., 2020).

Secondly, the majority of the existing studies are inclined to use either a technological or a behavioural approach, with a little combination of one-off quantitative measurement of IEQ and qualitative assessment of building management systems. Such a piecemeal strategy ignores the interaction of environmental information, occupant comfort and operational pattern required for more accurate and representative predictive maintenance. As an example, technologies can be installed without teaching the users to interpret sensor data or behavioural surveys can be carried out without relating the results to the current environmental conditions. The combination of user behaviour, sensor-based data and environmental analytics is not often present in the existing literature regarding sacred spaces (Niza et al., 2023)..

Thirdly, the little research is done about how cultural and spiritual practices define environmental requirements and sustainability priorities in these spaces. Religious rituals tend to have certain thermal, lighting or acoustic preferences that conflict with overall sustainability actions. Nevertheless, little research is available on how these ritualistic conditions can be honored and at the same time enhance energy performance. The inability to consider these subtle needs contributes to the incompatibility between the available technological solutions and their acceptance or relevance in sacred contexts (Yadav & Choudhary, 2020).

Lastly, there is a paucity of research that has either suggested or actualised comprehensive, data-guided action plans that simultaneously streamline IEQ and energy use, particularly in low-resource or volunteer-operated facilities, like temples and community centres. These gaps point to the necessity of comprehensive, context-responsive research which could be used to make practical interventions in underrepresented building types. A significant absence of long-term intervention studies or post-occupancy assessment of these buildings also restricts the comprehension of the long-term effect of any implemented system or program (Pan et al., 2023).

In addition, the issue of digital literacy and data accessibility is seldom taken into consideration during the implementation process of smart technologies in such spaces. Although sensors and dashboards are implemented in a few pilot projects, little is understood about the continued use, understanding, and feedback processes by occupants of buildings. According to (Kirchner-Krath et al., 2024), the adoption of sustainable technology should not only focus on the technological preparedness, but also the organisational culture and interpretation/response ability.

Lastly, despite the growing ambitions of policy initiatives on net-zero buildings and climate adaptation, the religious and community buildings are frequently not included because of scale, visibility, or perceived complexity. The study would be enriched by frameworks that show how such spaces can achieve their more general sustainability objectives with the help of low-cost, flexible, and culturally congruent practices without undermining their primary spiritual purpose. Filling this gap will involve participatory and collaborative research approaches that will give a voice and lived experience of those who oversee and utilize sacred spaces.

2.4 Summary

Overall, the literature available implies the necessity of further research in the sphere of indoor environmental quality, energy performance, and facility management, especially in non-commercial, community-based buildings. The available literature on smart technologies, occupant behaviour, and building operations is very useful; however, it does not reflect the intricate nature of religious or community environments. Consequently, mixed-method, case-based studies, incorporating real-time IEQ measurement, thorough analysis of energy consumption, and qualitative information on management procedures in these buildings are evidently required. The case of the Sri Lankarama Temple study fills this gap by investigating the potential of smart technologies and building analytics in a resource-constrained setting of cultural value. By providing this combined effort, the study aims to come up with viable recommendations that are technically sound and socially acceptable and will add new information to the body of knowledge in the field of sustainable building operation and management and community based environmental monitoring.

3 Methods

3.1 Research Method and Design

The current study adopted a mixed-methods case study design to understand the interaction among IEQ, energy performance, and building operation patterns in the Sri Lankarama Temple. The combination of the quantitative and qualitative approaches will allow comprehending the research problem in a holistic manner, as it will enable recording both the numeric environmental performance indicators and the context-rich insights of the stakeholders.

3.1.1 Quantitative Method

Quantitative research involves a type of research method that is systematic and objective, whereby it aims at investigating phenomena through the collection and analysis of numerical data. This approach is based on positivist philosophy that postulates the possibility of measuring reality and explaining it based on what can be seen with the available empirical evidence. Quantitative approaches are especially appropriate when the research aims at detecting patterns, relationships, or causal connections among the variables, and frequently resort to mathematical methods in order to facilitate such outcomes.

In this research study, the quantitative information was gathered using the IEQ sensors (as a temperature, humidity, and CO_2 levels recorder) and energy bills (collected monthly), to perform statistical evaluations (analysis of trends, exceeding of thresholds, and the spatial discrepancy of the results provided across temple rooms).

Quantitative research is qualitative - as (Neuman. 2014) writes, it pays attention to measurement, hypothesis testing and prediction, with the tools being more structured, like surveys, sensors or official records. (Mahardini et al., 2024) also stress that quantitative research is applicable when the researcher needs to test the objective theories by studying the connections between variables.

The smart environmental sensors were used to gather quantitative data by measuring the main IEQ parameters, including CO_2 concentration, temperature, humidity, and energy consumption during a certain time. This information offered impartial facts about the environmental performance of the building and the patterns of its functioning.

3.1.2 Qualitative Method

Qualitative research is a non-probabilistic, interpretive method which aims at uncovering meanings, experiences and these are reflected through high description information. Based on either constructivist or interpretivist paradigm, qualitative research studies strive to learn how individuals make sense of the world in which they live and of interpersonal relations, and most often they involve the methods of interviews, observations, content analysis.

In the current research the presenter used qualitative measurement using semi-structured interview conducted with the building manager of the temple. This provided the researcher with a better understanding of appliances usage, energy management behaviors, and outlook on sustainability that cannot be quantified by mere numbers.

(Tuli, 2011) argues that qualitative approaches are useful to investigate issues that can be complex and depend on the context, and particularly adequate in the case of the case study when it is important to understand subjective experiences. On the same note, (Merriam and Tisdell. 2016) emphasise that qualitative research is loose and dynamic because a researcher can dig deeper, depending on the reaction of the participants.

To supplement this, qualitative information was obtained using a semi-structured interview of the temple's building manager. The interview aimed to understand comfort, maintenance procedures, decision-making, and limitations to applying energy-saving or environmental monitoring systems. The research design made it possible to have the breadth and depth in the knowledge of interaction among technological, behavioural, and organisational factors within a sacred space.

The methodology used in this case study was purposely selected because it is commonly used when the investigated phenomena are complex and real-world and need to be studied in context. It helps to examine the Sri Lankarama Temple in a thorough way as a bounded system, and the integration of mixed methods allows to make sure that the empirical evidence and human experiences are taken into account in the research findings. Such a design not only makes the validity of findings stronger but also improves the external validity of findings to be applied in the context of comparable communities and religions.

3.2 Data Collection Method

The study presented a mixed-method research design, which helped to combine quantitative and qualitative sets of data and gain comprehensive insights into the links between the indoor environmental quality (IEQ), energy consumption, and building management procedures carried out at the Sri Lankarama Temple. The data collection process took place in April 2025 for 30 days and included installing environmental sensors (EnviroQ) and gathering utility bills and an interview with the building manager of the temple.

The data collection process was conducted over 30 consecutive days in April 2025, covering a full month of environmental monitoring within the temple premises. This period was considered sufficient for the analysis required for several reasons. First, a 30-day continuous monitoring period allows for capturing daily and weekly environmental variations, including patterns linked to occupancy, activities, and routine operations of the temple. Such a timeframe is commonly used in indoor environmental quality (IEQ) studies to obtain reliable baseline data (Du et al., 2023; Niemelä et al., 2022).

The month of April was chosen for data collection as it is the peak time for temple's operational activity. Due to Sinhala New Year celebration within this month, as this is the major national event the temple welcomes most visitors during this time. Many people attend the New Year festival. Moreover, several meetings of the organizing committee and volunteers were held during the preparation period.

3.2.1 Quantitative Data Collection

- **IEQ Monitoring**

The main quantitative data was obtained based on real-time environmental monitoring with EnviroQ sensors, which were installed in six functional areas in the temple with strategic planning. Eight devices were used to roll out to provide redundancy and spatial coverage. These sensors were constantly taking a record of:

a) Carbon dioxide (CO_2) levels (parts per million – ppm)
b) Temperature (°C)
c) Relative humidity (%)

High-resolution data (hourly for 30 days) were recorded and provided an opportunity to reveal time dependencies and individual exceedance of the international IEQ limits.

The recommended IEQ standard thresholds to measure compliance were the following:

a) Co_2 concentration: <1000 ppm (ASHRAE, 2025)
b) Temperature: 20°C to 24°C (thermal comfort range) (Sikram, 2018)
c) Humidity: 30% to 60% (range to prevent mold growth and discomfort) (Liang et al., 2019)

To obtain correct readings of the ambient, the individual sensors were mounted at about 1.2-1.5 meters above the floor level and not in the direct airflow paths (e.g., windows, vents, or HVAC outlets). Before deployment the sensor calibration was checked.

- **Sensors used**

EnviroQ Indoor Environmental Quality (IEQ) sensors were the main instruments which were used to collect quantitative environmental data in the study. Such multi-purpose digital sensors are specially intended to monitor indoor air parameter in real time where they have impact on occupant health, comfort and sustainability performance.

The IEQ sensors used are known as EnviroQ and the technical specifications reflects the ABS/polycarbonate plastic was used to make the EnviroQ. For convenience of installation, the device uses a wall mounting bracket and has a low profile and technical specifications are indicated in Table 1.

Table 1: Tether EnviroQ device technical specifications

Measurements	**127*127*40mm**
Weight	+-171g (without batteries) +-307g (with batteries)
Power input: Batteries	6 number of AA 1.5V (3 years battery life)
Temperature Accuracy	Units: °C -20°C to 85°C +/- 0.2°C
Relative Humidity	% 0–100% ± 2%
Carbon Dioxide	0–5000 ppm ± 30 ppm

Powered by the Mains Any 5V 0.5A DC power supply can supply power to the terminal block in the EnviroQ. Connectivity Specifications. The EnviroQ is accessible in all RCZ4 Regions and uses a high-power radio transmitter/receiver that runs on the Sigfox network in Australia, New Zealand, South America, Hong Kong, and Southeast Asia are Sigfox Regions RZ4. Temperature, Humidity and Carbon Dioxide readings in Every five minutes, three readings on average are sent to the Tether cloud every fifteen minutes.

- **Sensor Capabilities**

In this project, sensory devices EnviroQ were set to monitor the following parameters of the environment on an hourly basis:

a) Thermal comfort and assessment of HVAC performance require indoor temperature to be maintained in the `comfort range within the range with the range between 20-24.

b) Relative Humidity (RH%) RediBuilt roofing membranes contain Relative Humidity (RH%) to minimize the effects appear. This gauges the degree of humidity in air. The levels that are beyond the 30-60 percent will encourage mold to grow or leave one in discomfort.

c) CO_2 is significant in showing ventilation efficiency and occupancy load. The higher concentration (excess of 1000 ppm) may harm mental abilities and comfort during prolonged exposure (ASHRAE, 2019).

All these variables on every sensor were preset to record and save the timestamped values of readings that would be exported and analyzed statistically. The sensors will operate on a fluctuated lighting, temperature condition and people movements environment thus applicable in such a multi-purpose facility as a temple.

- **Data Logging and Storage**

Every EnviroQ unit has a built-in data logger allowing the storage of thousands of data points. In this case, the sensors were set to record data after every hour within a 30-days period. The data are to be downloaded on the monitoring period-end out of USB or wireless synchronization, according to the model of the unit.

The resulting dataset included:

a) Each parameter has a time stamped value
b) Device ID
c) Location ID

These data were subsequently cleaned, missing value checks were made and the data was imported into SPSS and Excel to be analyzed for descriptive and inferential analysis.

Sensor data were saved in CSV format and pre-processed in Microsoft Excel and SPSS. Metadata contained timestamps, location identifiers, and device IDs, which provided the possibility to conduct a strong comparative and temporal analysis across rooms.

- **Energy Usage Monitoring**

Besides the IEQ monitoring, the energy consumption of the month of April 2025 was evaluated based on electricity bills at the facility which indicated that the total consumption in the month was 633 kWh. This data was quantitative data that was compared with IEQ records including temperature, humidity and CO_2 that were recorded on an hour-by-hour basis and made a time-matched analysis of energy performance.

It was analysed with specific interest to determine the patterns whereby the consumption of energy was most likely to be heightened as a result of IEQ needs especially during high-temperature times or peak occupancy incidences. As an example, temperature reached maximum at 12:00 PM to 3:00 PM, and CO_2 had high levels during ceremonies that corresponded with the HVAC peak at sites such as the Kitchen, Meditation halls, and the Prayer Room 2.

Moreover, the time and frequency of HVAC usage was speculated by comparing temperature regulated areas that are high in similarities (e.g. Library and Kitchen) and areas that vary widely (e.g. Break Room and Prayer Rooms). The comparison revealed that higher energy input was normally required inively maintaining the IEQ standards and the regions with lesser energy consumption portrayed worse air quality or inability to control the levels of heat, thus attesting to the correlation of energy expenditure and the level of indoor comfort.

The cross-referencing energy use estimates and the IEQ variation according to time and location was a methodological strategy that was employed to make sure that the assessment process was based on both the environmental performance and the reality of operations, as initially planned in the research design.

With both IEQ and energy data combined, one can easily analyse how optimal IEQ can affect energy-saving efforts.

3.2.2 Qualitative Data Collection

To complement the quantitative data collected from sensors and utility records, a qualitative interview was conducted with the temple's building manager, who also acts as the nominee of the chief monk. The building manager was selected based on his expertise and in-depth knowledge of the temple's operations, making him a key informant for this study.

As the person responsible for overseeing both religious functions and day-to-day management of the complex, the building manager holds direct knowledge of the building's infrastructure, including its HVAC systems, appliance usage patterns, ventilation practices, and energy management routines. His involvement in both operational and maintenance aspects enables him to provide valuable insights into practical challenges, occupancy behavior, and decision-making processes that influence the indoor environment and energy consumption.

Furthermore, in religious institutions such as temples — often run by community volunteers or religious leaders — the building manager plays a central role in balancing spiritual activities with facility management, making his perspectives critical for understanding the unique operational context of the site (Aune et al., 2009; Freeman et al., 2022).

This research study involves an interview with the building manager. As such, a Human Ethics Approval was required to ensure that the interview protocols met Massey University's requirements for the ethical conduct of research. An ethics consideration application was rated as a low-risk research ethics study (number: 4000029842).

An interview protocol was followed that examined the following topics:

a) What kind of smart technologies (e.g., HVAC controls, smart lighting, automated ventilation), sensors (occupancy sensors) are presently in the temple and how many times do they get used?
b) Have you noticed that the operation of the HVAC systems impacted on the energy cost-effectiveness of the temple or the electricity bill?
c) Ever wondered how the comfort of visitors or staff members has been influenced by indoor conditions like the temperature of the room as they meditate or the quality of air in an event that has many people?
d) Have you had any difficulties, whether in the course of functioning or maintenance of the smart systems in the temple (technical challenges, costs, or skills)?
e) What do those who visit the temple and work there think of technology use? Do they accept them, doubt, or want an upgrade?

The interview was recorded with written word document its transcript created and these were properly handled as per ethical rules. The data we collected provided useful interpretations that enhanced the understanding of the quantitative findings.

Relating both data types collected in this study makes it possible to cross-check facts from several sides, which in turn adds confidence to the research.

3.2.3 Case Study Building

- **Overview of the Sri Lankarama Temple**

The temple journey began in a converted house in 1999, and over the years, it has developed into a spiritual haven. With the help of loyal people, the temple was extended and necessary features added like areas for "sil" observation and the reflective Budu Medura. The presence of the revered Bhodi tree and a dignified Chithya in the landscape now adds peace to the area. Additional elements, like the Sakman Maluwa, add to the temple's enlightening ambiance. The temple now serves as a representation of devotion and solidarity, providing everyone who seeks refuge within its hallowed walls with a traditional Sri Lankan temple experience.

The Temple, which covers an area of 1852 square meters and is located at 11 Pukeora Road, Ōtāhuhu, Auckland, is 14.5 km from the city center (Figures 1 & 2).

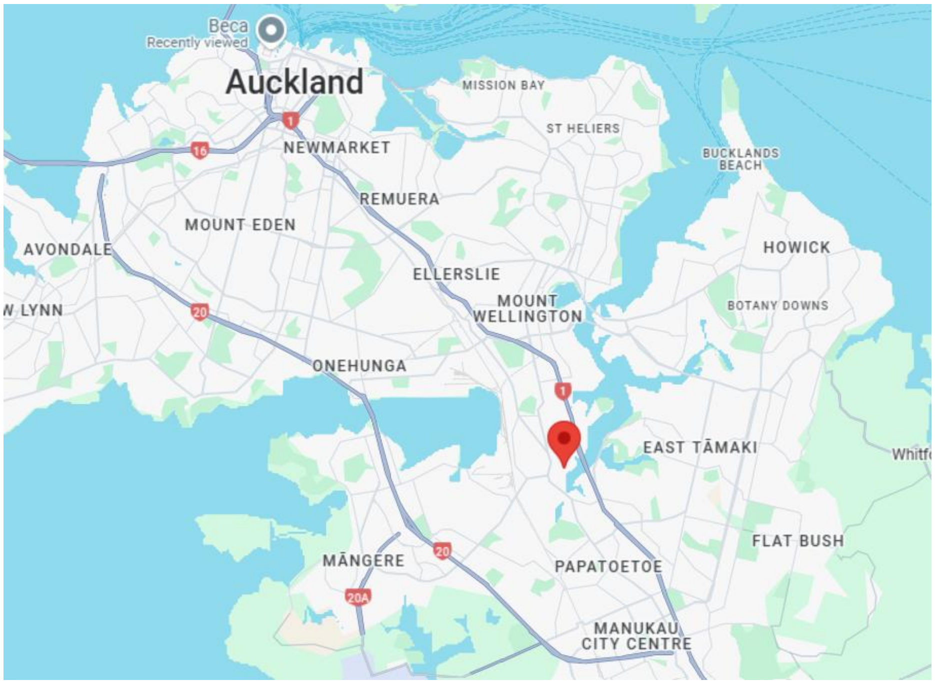


Figure 1: Existing Location (from Google Map)

The temple, outlined in blue in the aerial map, has a perimeter of 175.3 meters. It consists of three main building sections, constructed in two phases:

Part 1 and Part 2 of the building were constructed in 2005, and Part 3 was added later in 2013. No significant modifications or renovations have been made to any of the structures since their initial construction.

- **Building Functions:**

Part 1: Primarily used for pilgrimage-related activities and spiritual gatherings, which contains Prayer room, Breakroom for setup daily activities for warships and Meditation Hall.

Part 2: Contains the Open Living room/dining hall, kitchen, washroom facilities, and a library. This section supports the daily operations of the facility and caters to visitors' needs.

Part 3: Serves as the residential quarters for the monks, with three to five monks currently residing there on a permanent basis.

Figure 2: Existing Site (From Auckland Counsil GeoMap)

The temple serves the Auckland region, including areas such as Auckland Central, South Auckland, and the North Shore. On a typical day, the temple used around 30 visitors, with each visitor spending an average of 1.5 hours on-site. Services and spiritual support are provided by the resident monks and volunteers.

"Moreover, this study focuses exclusively on the most commonly used areas (Part 1 and Part 2) of the temple. Part 3, which comprises the monks' residential quarters, was excluded to avoid potential disturbance to their private living space during the research process."

- **Building Layout and Device Placement**

Each EnviroQ was placed in the key rooms to be monitored in the temple (Table 2). These rooms are the functional public spaces used for religious activities. They have the library, kitchen, open living area, meditation hall, prayer room and break room

- **Overview of Layout**

The building spans two main wings:

Left Wing (West-East orientation):

a) Library
b) Toilet & Bathroom
c) Kitchen
d) Open Living Room

Right Wing (North-South orientation):

a) Meditation Hall
b) Prayer Room
c) Break Room

Every room had one EnviroQ sensor to monitor the real-time data for CO_2, temperature, and humidity.

- **Device Placement Strategy**

Table 2 shows the locations of the devices placed in each room. The strategy was to ensure each room received sufficient covered of monitored IEQ levels. For the mediation hall which has a greater room area,, two devices were placed to obtained data that is representative of the room’s IEQ readings (see Figure 3).

Table 2: Device Placement Strategy

No	Room	Code	Device No	Device Label	Room area/ (m^2)
1	Library	LI	BEI-14	EnviroQ LI	54.00
2	Kitchen	KI	BEI-15	EnviroQ KI	50.40
3	Open Living Room	OLRI	BEI-16	EnviroQ OLRI	67.95
4	Meditation Hall	LHI1	BEI-17	EnviroQ LHI1	71.25
		LHI2	BEI-19	EnviroQ LHI2	
5	Prayer Room	PRI	BEI-20	EnviroQ PRI	52.50
		PR2	BEI-21	EnviroQ PR2	
6	Break Room	RI	BEI-22	EnviroQ RI	24.00

- **Floor plan and Device Layout Diagram**

The floor plan and sensor locations are illustrated in Figure 3, which shows the layout of the Sri Lankarama Temple and the positions of each EnviroQ sensor and highlights the space usage and rooms. The availability of doors and windows is indicated as shown. The prayer room, break room, and meditation hall can be combined into a single hall when necessary. Moreover, the open living room is directly exposed to the outdoor environment, with approximately 80% of its walls enclosed by building walls and temporary partitions.

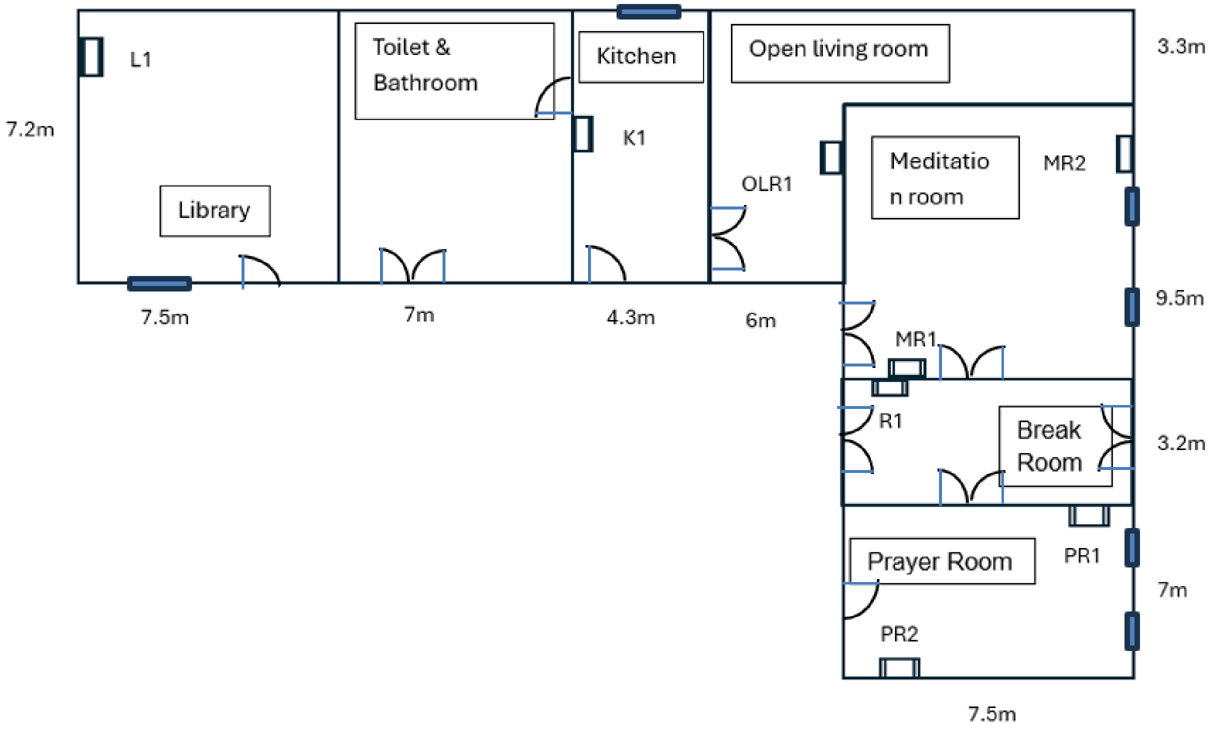


Figure 3: Floor plan and device layout diagram

- **Appliances List**

The temple has a wide variety of appliances, and each has a different purpose, Table 3 shows that the Library, Meditation Hall, and Prayer Room are equipped with HVAC systems, affecting thermal comfort and energy consumption. The Kitchen has high-wattage appliances, while the Meditation Hall has TV, projector, multimedia unit and HVAC systems for long-term conditions. The Prayer Room's HVAC unit maintains acceptable air quality during rituals and full visits.

Table 3: Appliances List in each space

Area	Appliance	Description
Library	HVAC	LG S12AWN-U47 Cooling Capacity 3460W Heating Capacity 3930
Kitchen	Electric Water heater	Rheem 180 ltr 3kW

	Dishwasher	Starline-M2
	Washing Machine	Active 8.5kg1660 W
	Microwave (5 Units)	Sharp-Invertor
	Electric Oven	Haier
	Hospitality equipment	Federal 1500W
	Refrigerator	LG-GF-L677SL
Meditation Hall	HVAC (2 Units)	Daikin Cooling Capacity 1520 W Heating Capacity1660W
	TV	55 inch
	Projector	Panasonic
	Multimedia Unit	Dynamix
Prayer room	HVAC	Mitsubishi Coolong Capacity-1550W
		Heating Capacity 1590W

3.2.4 Data Analysis Techniques

This study incorporated both quantitative and qualitative data analyses to provide extensive information on the IEQ, energy consumption patterns, and management of the Sri Lankarama Temple. Each of the research objectives was addressed using statistical testing, trend identification and thematic interpretation.

- **Quantitative Analysis**

Two main datasets were used in the quantitative aspect of the study; hourly sensor measurements of IEQ parameters (CO_2, temperature, and humidity) and monthly energy consumption data obtained using electricity bills and appliance usage records.

In the first step, SPSS was used to compute descriptive statistics (mean and standard deviation) of each IEQ parameter. Also, the proportion of time that each of the measured variables was above the set limits (e.g., $CO_2 < 1000$ ppm) was calculated to determine the adherence to indoor air quality guidelines. Such exceedance percentages played a key role in understanding the IEQ performance of different areas in the temple (Al horr et al., 2016).

Inferential statistical tests were performed to compare the environmental conditions in the six spaces that were monitored. Depending on the type of distribution of data (normal or not normal) a One-Way ANOVA model or Kruskal-Wallis was applied to ascertain the existence of significant differences among rooms, in respect to each IEQ parameter. When significance difference among variables of different spaces were observed, post-hoc test were conducted to investigate where the differences lie. (Du et al., 2023).

- **Qualitative Analysis**

The transcribed interview was subjected to six steps in thematic analysis as outlined by (Braun and Clarke., 2006).

a) Acquaintance with Data: The interview data was thoroughly read through and noted upon any common trends as well as the operational setting.
b) Seeking Themes: On the basis of collected responses, these were categorized on a larger theme: Appliance Efficiency, Occupancy Challenges, and Upgrade Barriers.
c) Themes: Themes reviewed were checked as coherent and referring to the research through specific objectives.
d) Theme definition and naming: names were given to each theme in order to nail its central idea down.
e) Generation of the Report: Themes that were in harmony with the data related to building performance.
f) Producing the report

- **Ethical Considerations**

This research study involves an interview with the building manager. As such, a Human Ethics Approval was required to ensure that the interview protocols met Massey University's requirements for the ethical conduct of research. An ethics consideration application was rated as a low-risk research ethics study (number: 4000029842).

Appropriate permission was obtained from the temple's management to use the temple as a case study and for the IEQ monitoring exercise. Informed consent was signed by the building manager for the interview. The voluntary nature of the study, its purpose and scope were explained well in advance using a Participant Information Sheet and Consent Form.

The anonymisation of all identifying information was done to ensure the preservation of the confidentiality of the temple and the people occupying it. The process of participation was strictly voluntary, and the participant was informed that he could pull out at any stage without incurring any loss.

4 Findings and Discussion

4.1 Introduction

This chapter discusses the research findings. The IEQ monitoring data (CO_2 levels, temperature, humidity), the analysis of energy consumption, and the data obtained with the help of the semi-structured interview are combined to evaluate how the environmental parameters and energy consumption are correlated with facility management at the Sri Lankarama Temple. These results are addressed with respect to the research aims and accompanied by appropriate literature.

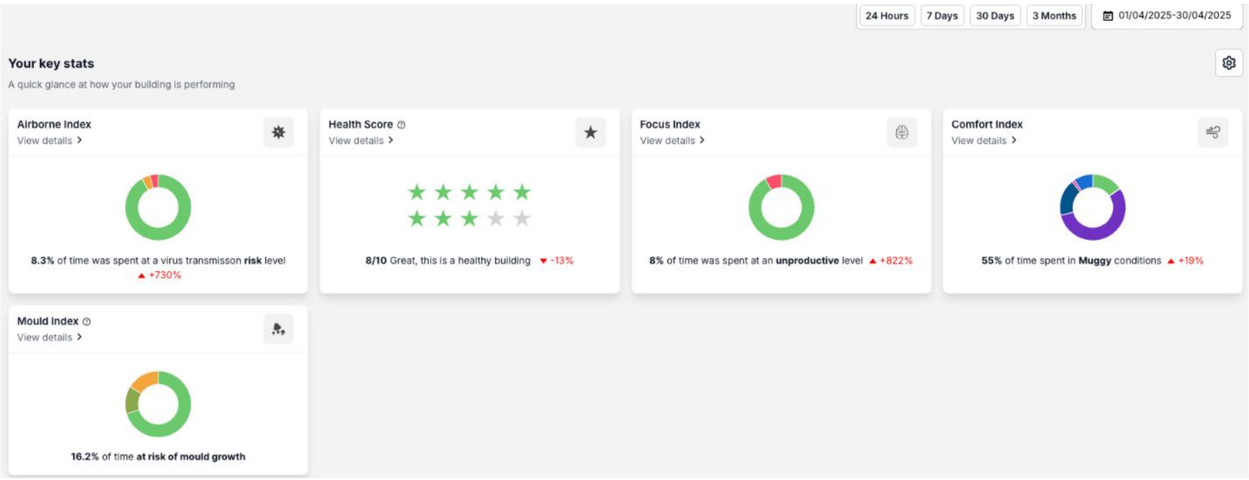
4.2 Quantitative Findings

4.2.1 Examine the overall IEQ pattern

- **Performance indicators**

The IEQ sensors were connected to an IoT platform named “Tether HQ”, which calculated some key IEQ performance indicators as presented in Figure 4. These indicators include Airborne index, Health score, Focus Index, Comfort index and Mould index between April 1 to 30, 2025.

The Airborne Index indicates that 8.3% of the time the IEQ pose a risk of transmission of the virus., The Health Score is still rather high (8/10), albeit on the same note, 8 per cent of the time on the Focus Index. According to the Comfort Index, muggy conditions took up 55% of the time. Moreover, in 16.2%.



Your key stats

A quick glance at how your building is performing

Airborne Index
View details >

8.3% of time was spent at a virus transmisson risk level ▲ +730%

Health Score
View details >

8/10 Great, this is a healthy building ▼ -13%

Focus Index
View details >

8% of time was spent at an unproductive level ▲ +822%

Comfort Index
View details >

55% of time spent in Muggy conditions ▲ +19%

Mould Index
View details >

16.2% of time at risk of mould growth

Figure 4: Performance indicators from Tether monitoring app

- **Mould risk**

Figure 5 indicates the mould risk pattern of all spaces. From 1st to 17th April, the values fluctuated. At first, all these locations are in the “Very Low Risk” area, but in mid- and late-April, Kitchen, Prayer Room 1, and Prayer Room 2 rose to the “Low” and even “Moderate Risk” levels, which can only be attributed to constantly high humidity. Meditation Hall 1 and prayer room 1 present the highest alarming increase that has gone beyond moderate risk. The library, in contrast, exhibits minimal mould risk, still being in the zone of steady environmental control.

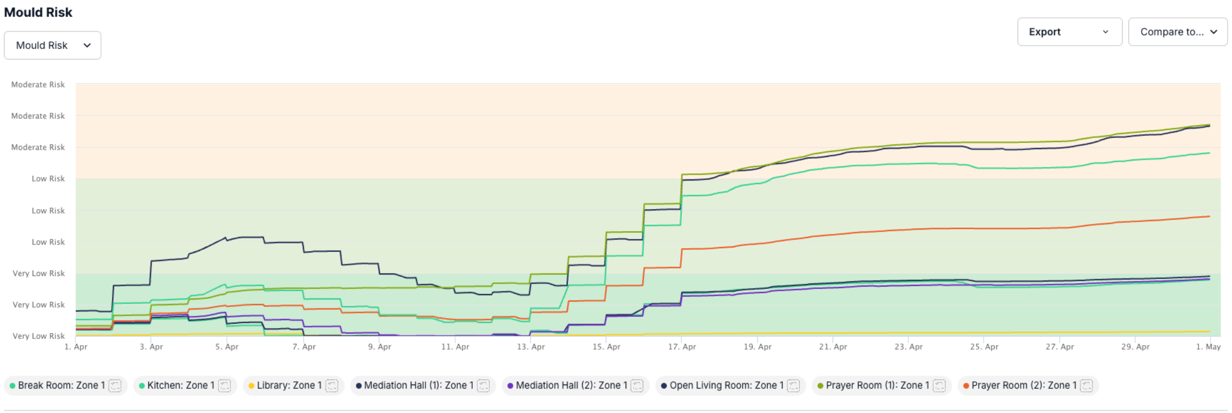


Figure 5: Mould risk pattern of all spaces during April 2025

4.2.2 Objective 1: Assess the overall IEQ pattern of the building and its compliance with recommended international thresholds for Co_2, temperature, and humidity.

- **Overall Observations for IEQ Parameters**

An overview of the indoor environmental quality (IEQ) variables in the Sri Lankarama Temple is provided in Table 4. The analysis of IEQ parameters was conducted using 4,913 CO_2 records and 5,626 temperature and humidity records, respectively. Recorded temperature values, which range from 13°C to 27°C with a mean of 20.65°C and a standard deviation of 1.550. With a mean value of 76.06% and a standard deviation of 9.917%, humidity levels exhibit a wider range, from 0% to 100%. With a mean of 658.81 and a standard deviation of 290.719, CO_2 concentrations range widely, from 376 ppm to 4,756 ppm, and the mean value was 658.81 ppm.

Table 4: Overall summary of IEQ parameters across all spaces

IEQ Parameter	**N**	**Min**	**Max**	**Mean**	**Std. Deviation**
Temperature	5626	13	27	20.65	1.550
Humidity	5626	0	100	76.06	9.917
CO_2	4913	376	4756	658.81	290.719

- **Temperature pattern change**

The daily mean variation in temperature for the entire complex in April 2025 is shown in Figure 6. The temperature range that was recorded was 19°C to 23°C. From April 1 to April 4, the temperature stayed comparatively constant between 21.00°C and 21.70°C, then dropped to 20.50°C on April 5. After that, it increased once more, reaching a high of 21.50°C on April 6th, before gradually dropping to its lowest point of 19.00°C on April 10th.

Temperatures ranged from 19.30°C to 20.90°C between April 11 and April 18. On April 19, there was a significant increase in temperature, reaching a maximum recorded mean temperature of 23.00°C. This trend continued into April 20. Following the peak, the temperature decreased once more to 19.20°C by April 25th. Towards the end of the month, it increased slightly and ranged from 20.40°C to 21.00°C. With two distinct peaks, April 6 and April 19 and a noteworthy trough on April 10, the data show regular, moderate fluctuations.

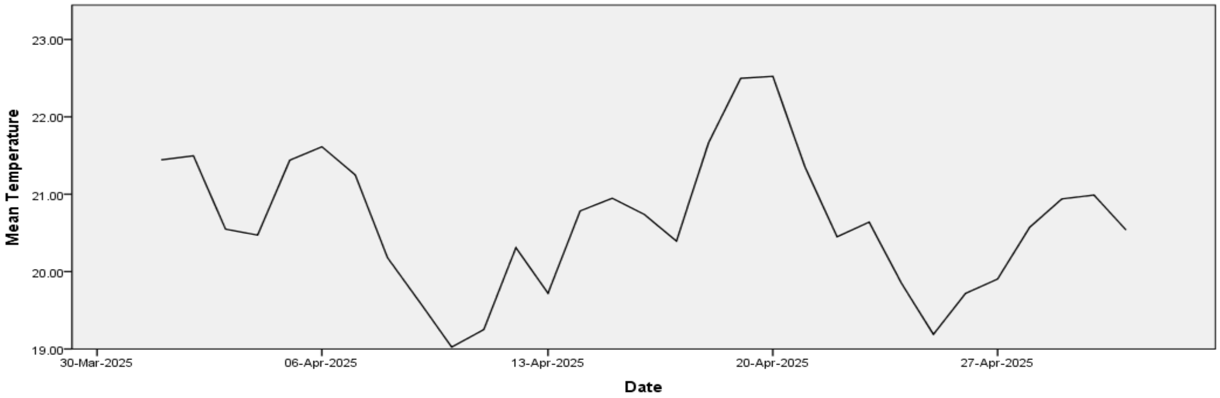


Figure 6: Daily mean temperature change of the whole complex throughout the month

The mean temperature of the entire complex across different weekdays is shown in Figure 7. The weekly temperature trend was between 20°C and 21°C. Monday had the highest mean temperature, at about 21.00°C. Sunday and Saturday were not far behind, both approaching 21.00°C.

From Monday, when the mean temperature was 21.00°C, to Thursday, when it was precisely 20.00°C, there was a slow decrease in temperature. The mean temperature was 20.75°C on Tuesday and 20.70°C on Wednesday. Following Thursday's minimum, the temperature increased slightly on Friday to around 20.15°C, and then noticeably on Saturday, returning to around 21.00°C. This indicates that the temperature dropped in the middle of the week before steadily rising over the weekend.

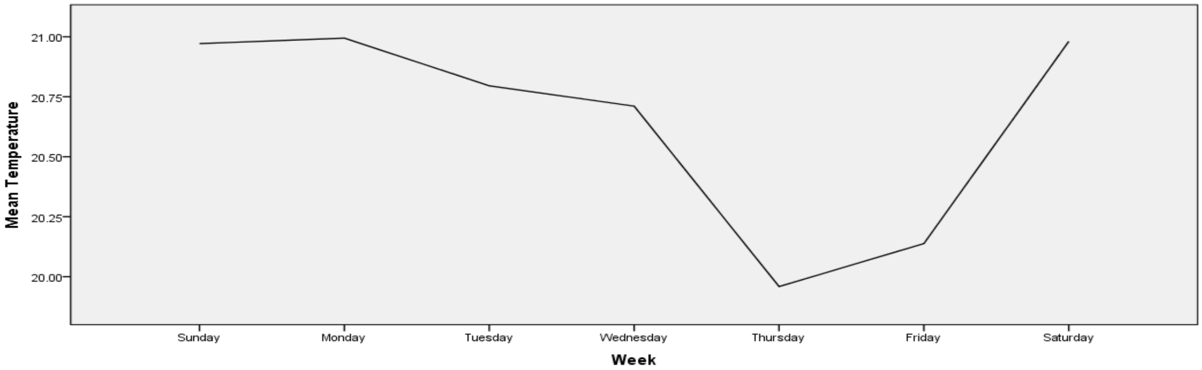


Figure 7: Mean temperature of the whole complex on different weekdays

Looking into the variation of mean temperature during the 24 hours of the day (Figure 8). The lowest temperature ever recorded was 19.60°C at 6:00. The temperature remained relatively low between 0:00 and 8:00, ranging between 20.50°C and 19.60°C. Temperatures began to progressively increase after 8:00, peaking between 15:00 and 16:00, from 19.60°C to 22.00°C.

Around 17:00, the temperature began to decline after reaching this altitude, and by 23:00, it had dropped from 21.90°C to 20.20°C. The temperature curve exhibits a diurnal pattern, with lower values reappearing as the night wears on, from a minimum of 19.60°C at 06:00 to a high of 22.00°C at 15:00.

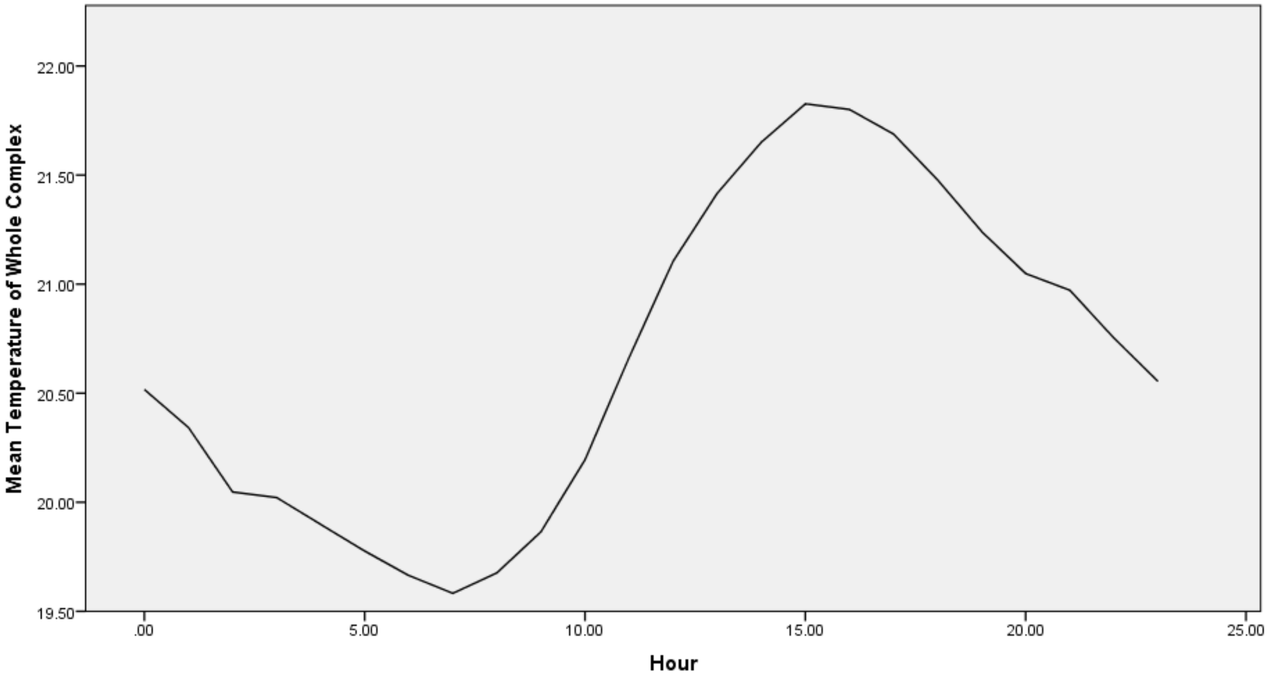


Figure 8: Mean temperature of the whole complex throughout the day

Figure 9 depicts the count of temperature values observed during the month of April. The temperature ranges from 13.20°C to 26.00°C, with the maximum counts occurring between 19.00°C and 23.00°C. Lower numbers at extremes below 17.00°C and above 24°C indicate fewer occurrences of extremely cold or very warm temperatures. The peak frequency between 21.00°C and 22.00°C indicates the most prevalent temperature range. The data shows a bell-shaped distribution, with temperatures falling symmetrically at both ends.

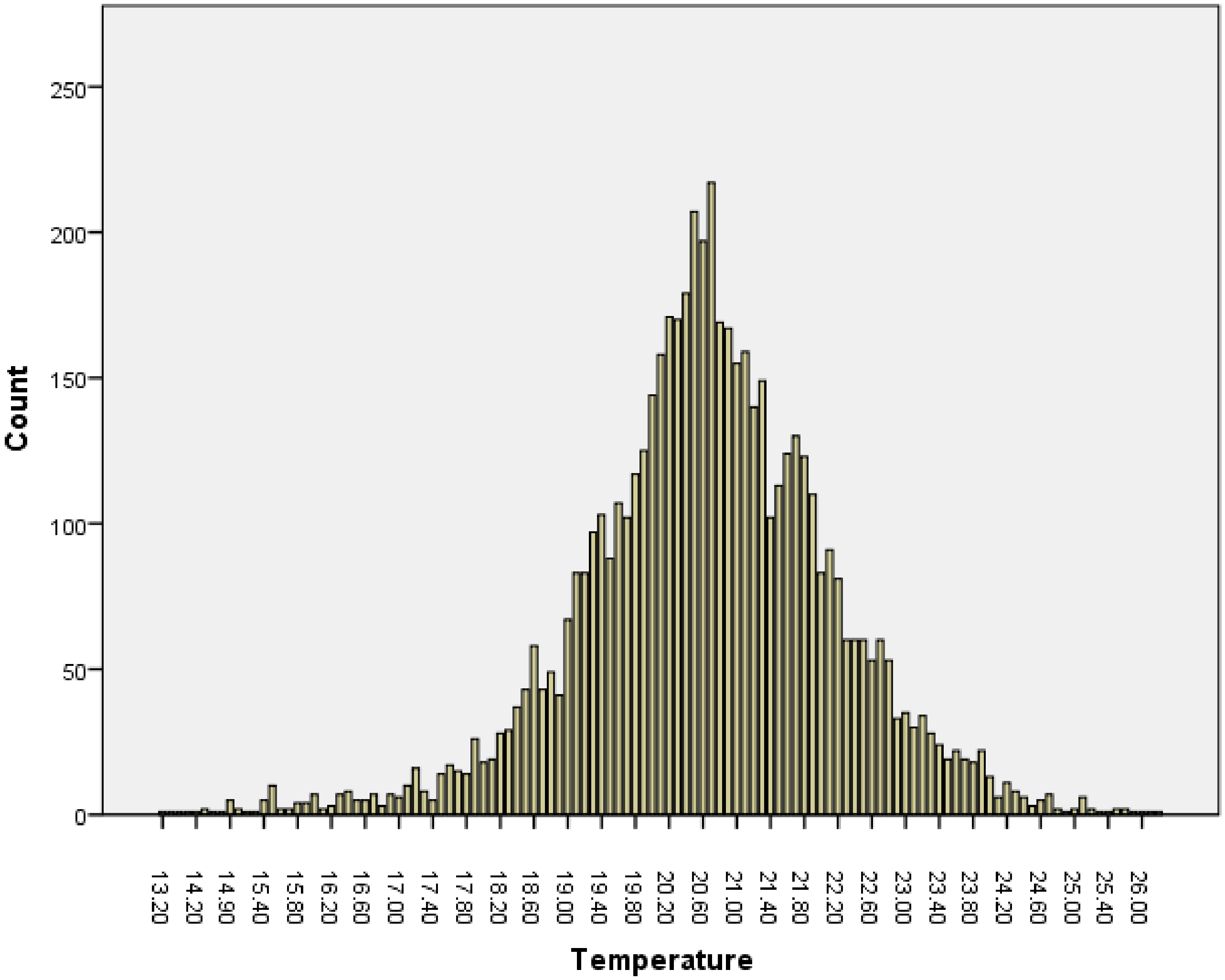


Figure 9: Cluster monthly temperature level throughout the Day

Table 5 indicates that 3,982 temperature records (or 70.88%) are within the recommended range, while 1,636 records (or 29.12%) are outside of it, from a total of 5,618 records collected across all spaces.

Table 5: Overall out-of-range temperature data for the month

All spaces	Total number of Records	Records outside of recommended range	Percentage of records outside the recommended range/(%)	Records within recommended range	Percentage of records within the recommended range/(%)
Overall	5618	1636	29.12%	3982	70.88%

- **Humidity pattern change**

The mean humidity for the whole complex throughout the period of the month is shown in Figure 10 below. All of the humidity readings were consistently over the 60% upper threshold and varied throughout the month. The highest quantity was 87% towards the end of the month and on April 5th and 19th. The lowest readings were around 64% on April 10 and 65% on April 24, 2025.

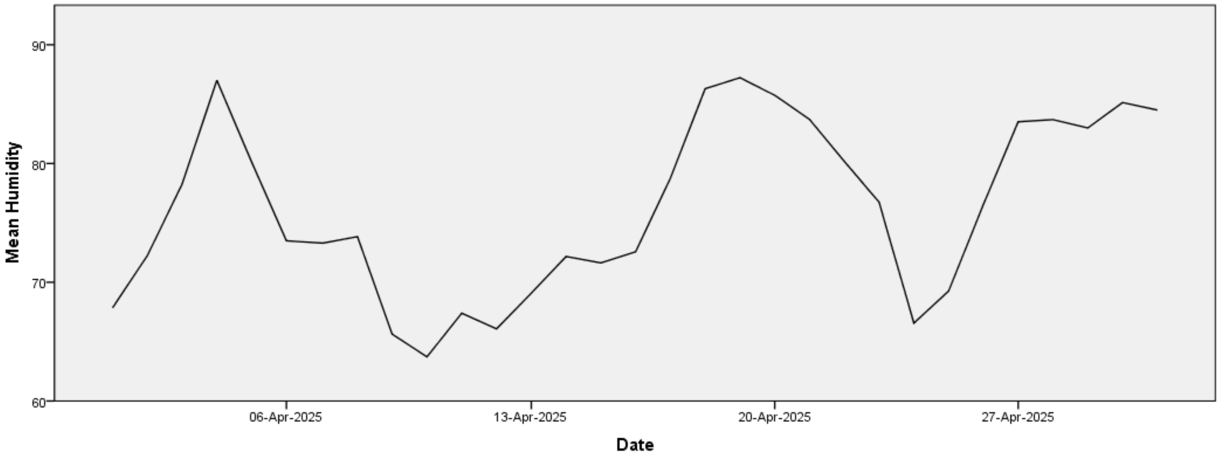


Figure 10: Mean humidity of the whole complex throughout the month

The mean humidity levels throughout the week reveals in Figure 11. Mondays recorded the highest humidity 78%. A gradual decline in humidity is observed from Monday to Thursday, with levels dropping to 72%, the lowest point of the week. However, from Thursday onwards, humidity levels rise sharply, culminating in a peak of around 77% by Friday, Saturday and Sunday.

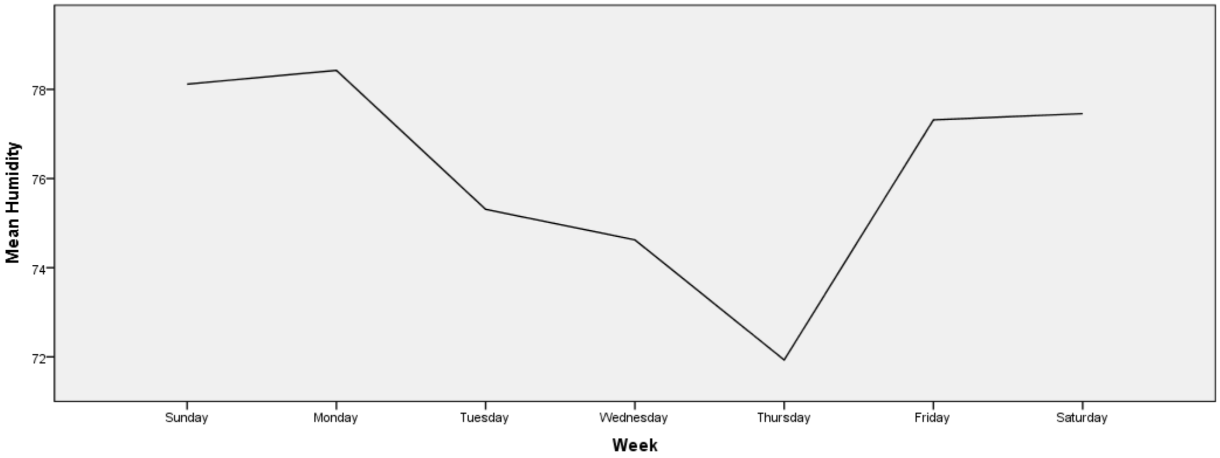


Figure 11: Mean humidity of the whole complex different weekdays

The mean humidity for the whole complex over the duration of a day is shown in Figure 12. It progressively rises from midnight (76.5%) until nine in the morning, reaching a peak of almost 78.5%. then drop sharply to 73.5% at 15.00, then rise steadily to 76% in the middle of the night.

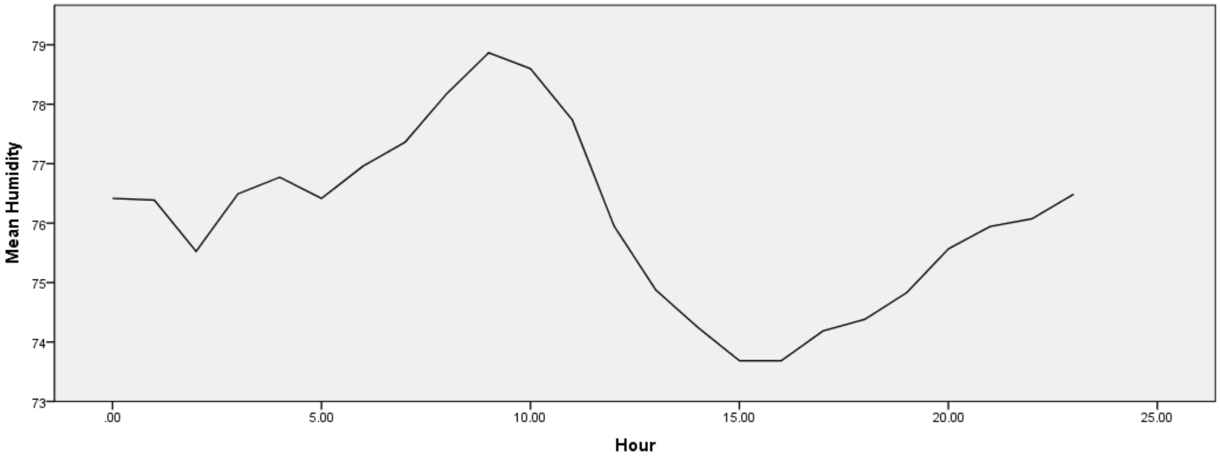


Figure 12: Mean Humidity of the whole complex throughout the day

The figure13 illustrates the frequency of humidity levels throughout the month of April 2025 versus data counts, with the majority of occurrences between 60% and 100%, spanning from 20 to 250 counts. Reduced humidity levels (0-60%) exhibit minimal counts (1-20).

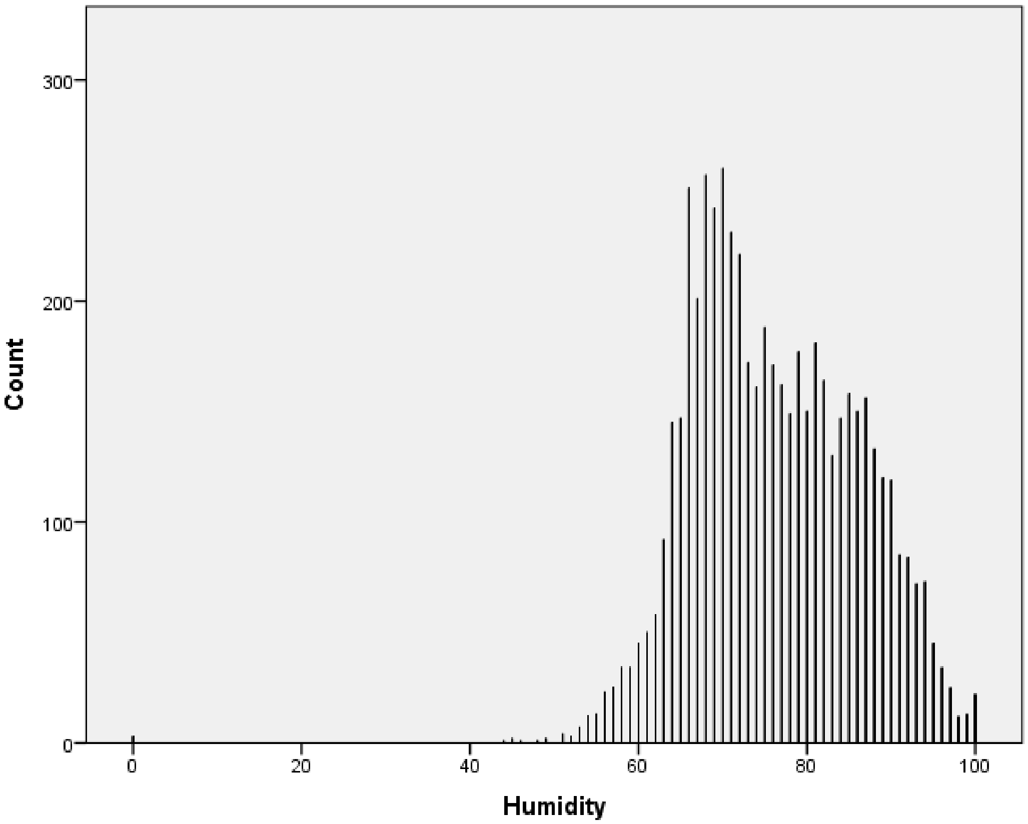


Figure 13: Cluster monthly humidity level throughout the Day

Table 6: Overall out-of-range humidity data of the month

Whole building	Total number of Records	Records outside of recommended range	Percentage of records outside the recommended range	Records within recommended range	Percentage of records within the recommended range
Overall	5618	5411	96.32	207	3.68

- **Carbon Dioxide (CO_2) Pattern Change**

Figure 14 displays the mean daily CO_2 concentration for the entire complex throughout April 2025. Beginning at about 490 ppm on April 1, 2025, the CO_2 levels gradually rise until they reach roughly 750 ppm on April 6. The next day, there is a discernible decline to about 590 ppm, and from April 8 to April 18, there are variations between 600 ppm and 740 ppm.

On April 19, there is a noticeable spike, with the mean CO_2 level reaching its highest point of the month at about 1,050 ppm. Following this peak, CO_2 concentrations gradually decrease, reaching about 580 ppm by April 25. For the rest of the month, they then vary slightly between 540 ppm and 600 ppm.

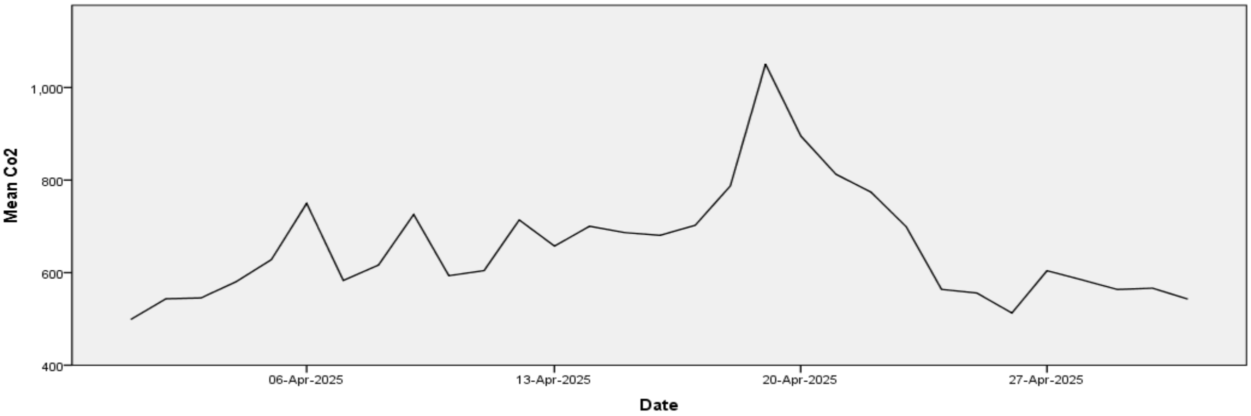


Figure 14: Mean CO_2 of the whole complex throughout the month

The mean CO_2 levels throughout the complex over different weekdays are shown in Figure 15. On Saturday and Sunday, the mean CO_2 concentration is at its highest, around 730 ppm. After that, the levels gradually drop to roughly 670 ppm on Monday, 640 ppm on Tuesday, and the lowest point, 600 ppm, on Thursday. The mean CO_2 levels then gradually rise, reaching about 660 ppm on Friday.

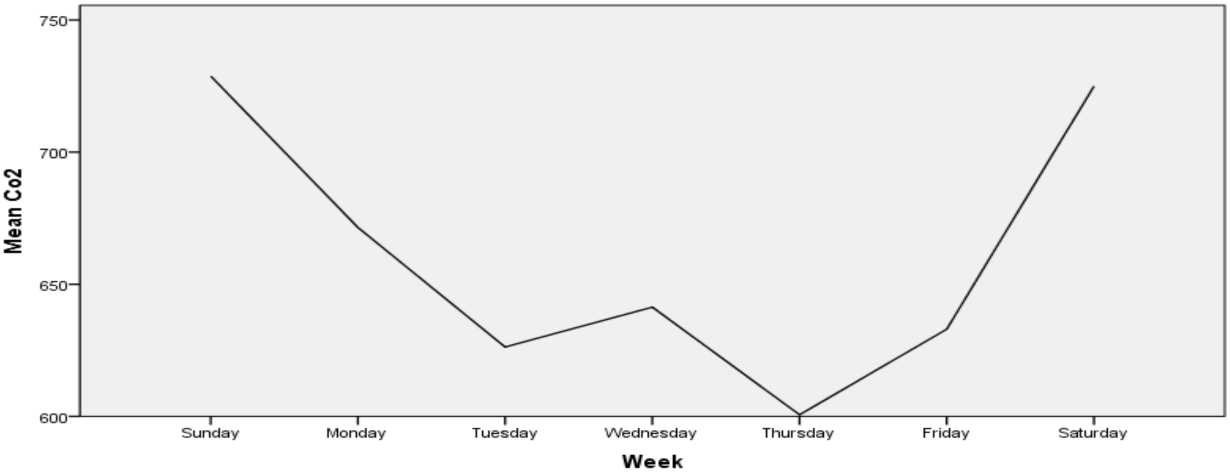


Figure 15: Mean CO_2 of the whole complex different weekdays

Figure 16 shows the mean level of CO_2 over the period of 24 hours. It shows several important facts. The amount of CO_2 in the air changed slightly between 00:00 and 13:00, going from 640 ppm to 625 ppm. At 13:00, the mean CO_2 level is about 625 parts per million, which is the lowest amount ever measured. After this, CO_2 levels slowly increase, becoming most noticeable between 15:00 and 21:00, 680 ppm to reaching a peak of 730 ppm.

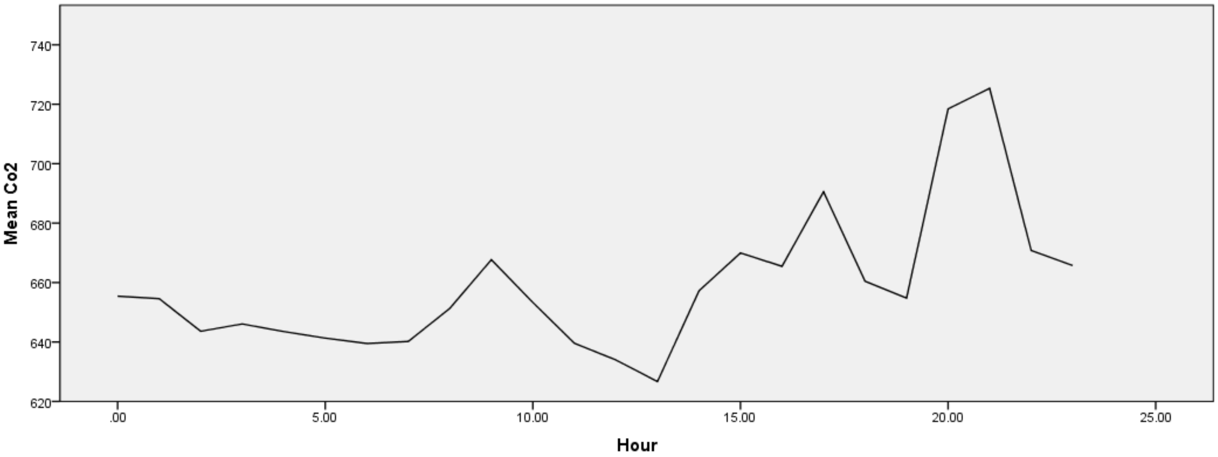


Figure 16: Mean CO_2 of the whole complex throughout the day

Figure 17 illustrates the complex's monthly CO_2 levels throughout the day. The most frequently occurring concentration is indicated by the fact that the majority of CO_2 readings are concentrated between 400 ppm and 1,200 ppm. At approximately 600 ppm, the maximal frequency is observed, with the maximum count of approximately 60 occurrences. The frequency of CO_2 measurements experiences a significant decrease after 700 ppm, indicating a substantial decrease in the occurrence of higher concentrations. Very few instances have been recorded, and values exceeding 1,500 ppm. Although outlier CO_2 levels can reach as high as 5,000 ppm, they are exceedingly rare, with each occurrence occurring only once or a few times.

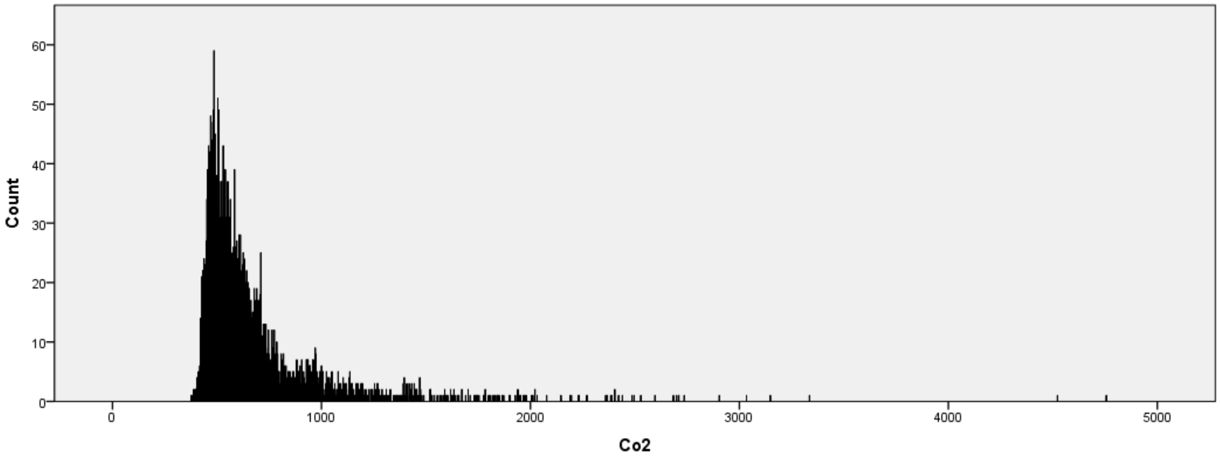


Figure 17: Cluster monthly CO_2 level throughout the Day

The data shows (Table 7) that across the entire building, 9.03% of temperature records (406 out of 4,494) fell outside the recommended range, while 90.97% (4,088 records) remained within ideal parameters.

Table 7: Out of range CO_2 data throughout the month

Whole building	**Total number of Records**	**Records outside of recommended range**	**Percentage of records outside the recommended range**	**Records within recommended range**	**Percentage of records within the recommended range**
Overall	4494	406	9.03%	4088	90.97%

- **Mean difference analysis of the whole complex on different weekdays**

First, the daily mean of IEQ variables of each sensor was calculated. Subsequently, the normality test was conducted to identify the type of distribution of IEQ data. The Table 08 shows the result of the normality test. The p-value above 0.05 indicates normal distribution and below 0.05 indicates distribution is not normal (Ghasemi & Zahediasl., 2012)

The p-value for temperature is above 0.05, which means that the data for this variable is normally distributed, but the p-values for humidity and CO_2 are below 0.05, indicating that the data is not normally distributed for these two variables. Considering that we have eight sensors/areas to compare with each other, the suitable test for comparing temperature data is ANOVA, and for comparing humidity data and CO_2 data for each space is Kruskal-Wallis.

Table 8: Result of the normality test for each IEQ parameter

Test of Normality (Kolmogorov-Smirnov)		
	p-value	Interpretation
Daily Temperature Mean of Each Sensor	0.2	Data is normally distributed.
Daily Humidity Mean of Each Sensor	0.005	Data is not normally distributed.
Daily CO_2 Mean of Each Sensor	0.000	Data is not normally distributed.

Temperature

One-way ANOVA was conducted to investigate differences in the mean temperature of different weekdays. The result of the ANOVA test is shown in Table 9, the F (5.836), p-value of 0.00, which means that there is a statistically significant difference between at least two of the spaces.

Table 9: One-way ANOVA test for mean temperature on different weekdays

ANOVA

Temperature_mean

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	32.163	6	5.360	5.836	.000
Within Groups	221.360	241	.919		
Total	253.522	247			

To identify where those differences lie, we looked into the Post Hoc test (Tukey). Looking at the p-values presented in the multiple comparisons table 10, we observed that the mean temperature on Sunday was significantly lower than Thursday and Friday, and Monday was significantly lower than Thursday and Friday. Further, it was found that, Thursday with all days Sunday, Monday and Saturday, Friday with all days except Wednesday and Thursday, Saturday with Thursday significantly lower values.

Table 10: Multiple comparison of mean temperature in different of weekdays

Multiple Comparisons

Dependent Variable: Temperature_mean

Tukey HSD

(I) Weekday	**(J) Weekday**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Sunday	Monday	-.07111	.23960	1.000	-.7835	.6413
	Tuesday	.12028	.22730	.998	-.5556	.7961
	Wednesday	.22576	.22730	.955	-.4501	.9016
	Thursday	.84503*	.22730	.005	.1692	1.5209
	Friday	.77529*	.23960	.023	.0629	1.4877
	Saturday	-.07179	.23960	1.000	-.7842	.6406
Monday	Sunday	.07111	.23960	1.000	-.6413	.7835
	Tuesday	.19139	.22730	.980	-.4845	.8673
	Wednesday	.29688	.22730	.849	-.3790	.9727
	Thursday	.91614*	.22730	.001	.2403	1.5920
	Friday	.84641*	.23960	.009	.1340	1.5588
	Saturday	-.00068	.23960	1.000	-.7131	.7117
Tuesday	Sunday	-.12028	.22730	.998	-.7961	.5556
	Monday	-.19139	.22730	.980	-.8673	.4845
	Wednesday	.10549	.21430	.999	-.5317	.7427
	Thursday	.72475*	.21430	.015	.0875	1.3620
	Friday	.65502	.22730	.064	-.0208	1.3309
	Saturday	-.19207	.22730	.980	-.8679	.4838
Wednesday	Sunday	-.22576	.22730	.955	-.9016	.4501
	Monday	-.29688	.22730	.849	-.9727	.3790
	Tuesday	-.10549	.21430	.999	-.7427	.5317
	Thursday	.61926	.21430	.063	-.0179	1.2565
	Friday	.54953	.22730	.196	-.1263	1.2254
	Saturday	-.29756	.22730	.847	-.9734	.3783
Thursday	Sunday	-.84503*	.22730	.005	-1.5209	-.1692
	Monday	-.91614*	.22730	.001	-1.5920	-.2403

	Tuesday	-.72475*	.21430	.015	-1.3620	-.0875
	Wednesday	-.61926	.21430	.063	-1.2565	.0179
	Friday	-.06973	.22730	1.000	-.7456	.6061
	Saturday	-.91682*	.22730	.001	-1.5927	-.2410
Friday	Sunday	-.77529*	.23960	.023	-1.4877	-.0629
	Monday	-.84641*	.23960	.009	-1.5588	-.1340
	Tuesday	-.65502	.22730	.064	-1.3309	.0208
	Wednesday	-.54953	.22730	.196	-1.2254	.1263
	Thursday	.06973	.22730	1.000	-.6061	.7456
	Saturday	-.84709*	.23960	.009	-1.5595	-.1347
Saturday	Sunday	.07179	.23960	1.000	-.6406	.7842
	Monday	.00068	.23960	1.000	-.7117	.7131
	Tuesday	.19207	.22730	.980	-.4838	.8679
	Wednesday	.29756	.22730	.847	-.3783	.9734
	Thursday	.91682*	.22730	.001	.2410	1.5927
	Friday	.84709*	.23960	.009	.1347	1.5595

*. The mean difference is significant at the 0.05 level.

Humidity

To find out if there were statistically significant variations in mean humidity between weekdays, a non-parametric Independent-Samples Kruskal-Wallis Test was used. The distribution of humidity means across weekdays did not differ significantly, according to the results Table 11 and 12 (H (6) = 7.386, p =.287). The null hypothesis was upheld because the significance value exceeded the alpha level of.050, indicating that there is no statistically significant difference in humidity levels between weekdays.

Table 11: Kruskal-Wallis test, differences among the humidity of different weekdays

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.^{a,b}	Decision
1	The distribution of Humidity_mean is the same across categories of Weekday.	Independent-Samples Kruskal-Wallis Test	.287	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 12:Kruskal-Wallis test, differences among the mean humidity different weekdays

Independent-Samples Kruskal-Wallis Test Summary

Total N	248
Test Statistic	7.386[a]
Degree Of Freedom	6
Asymptotic Sig.(2-sided test)	.287

a. The test statistic is adjusted for ties.

Carbon Dioxide (CO_2)

To find out if there were statistically significant variations in mean CO_2 between weekdays, a non-parametric Independent-Samples Kruskal-Wallis Test was used. The distribution of CO_2 means across weekdays did not differ significantly, according to the results Table 13 and 14 (H (6) = 9.666, p =.139). The null hypothesis was upheld because the significance value exceeded the alpha level of.050, indicating that there is no statistically significant difference in CO_2 levels between weekdays.

Table 13: Kruskal-Wallis test, differences among the mean CO_2 different weekdays

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of CO_2 _mean_1 is the same across categories of Weekday.	Independent-Samples Kruskal-Wallis Test	.139	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 14:Kruskal-Wallis test, differences among the mean CO_2 different weekdays

Independent-Samples Kruskal-Wallis Test Summary

Total N	217
Test Statistic	9.666[a]
Degree Of Freedom	6

Asymptotic Sig.(2-sided test)	.139

a. The test statistic is adjusted for ties.

4.2.3 Objective 2: Compare IEQ performance across different rooms within the temple.

- **Comparison of Temperature in each interior space**

Based on over 5,600 hourly measurements taken during the survey period, Table 15 shows the descriptive statistics of temperature across eight major indoor spaces in the Sri Lankarama Temple. With a minimum temperature of 16°C, a maximum temperature of 26°C, and a standard deviation of 1.452°C, the kitchen had the highest mean temperature, measuring 21.10°C. The library came next, with a mean temperature of 20.88°C, with a standard deviation of 1.063°C and a range of 18°C to 25°C. The mean temperature in Prayer Room 2 was 20.86°C, with a range of 16°C to 24°C and a standard deviation of 1.346°C.

While Prayer Room 1 had a mean of 20.75°C, with temperatures ranging from 16°C to 24°C and a standard deviation of 1.281°C, Meditation Hall 1 recorded a mean of 20.80°C (min: 18°C, max: 26°C, SD: 1.332°C). The temperature in the break room ranged from 16°C to 25°C, with a mean of 20.69°C and a standard deviation of 1.324°C. The average temperature recorded in Meditation Hall 2 was 20.40°C, with a standard deviation of 1.498°C and a range of 17°C to 26°C.

With a standard deviation of 2.332°C, the Open Living Room had the highest variability of any room and the lowest mean temperature of 19.75°C, with the widest range of 13°C to 27°C. The mean temperature across all areas was 19.75°C to 21.10°C, with standard deviations varying from 1.063°C to 2.332°C..

Table 15: Descriptive analysis temperature data of each space

Location	**N**	**Mean**	**Min**	**Max**	**Std. Deviation**
Library	712	20.88	18	25	1.063

Kitchen	716	21.10	16	26	1.452
Open Living Room	722	19.75	13	27	2.332
Meditation hall 1	687	20.80	18	26	1.332
Meditation hall 2	722	20.40	17	26	1.498
Prayer room 1	720	20.75	16	24	1.281
Prayer room 2	721	20.86	16	24	1.346
Break room	619	20.69	16	25	1.324

Furthermore, Figure 18, depicts the variation of mean temperature per day in eight indoor areas observed in a month i.e. 30 days. The majority of temperature values were not higher than the specified indoor thermal comfort rate of 20 \°C 24 °C.

The mean temperature in each space varies between 17.0°C and 23.8°C. April 19, 2025, the kitchen recorded the highest mean temperature, which was almost 23.5°C. On the other hand, the Open living room experiences the lowest mean temperature, which drops to roughly 17.0°C April 10. Between April 11 and 13, there is a discernible drop in temperature in all zones, with the majority of places experiencing temperatures below 20.0°C. After that, temperatures progressively increase and peak once more between April 18 and April 21, including the Kitchen, Prayer Room, and Meditation Hall 1, reach or surpass 23.0°C. Temperatures drop to about 19.0°C in most zones and 18.0°C in the Break Room after April 22. This decline reaches a local minimum around April 26. Areas like the Kitchen, Library, and Meditation Hall 1 continue to be on the higher end of the temperature spectrum, varying between 20.0°C and 23.5°C, while Prayer Room 2 and the Break Room continuously record lower mean temperatures throughout the month, typically ranging between 17.0°C and 21.0°C.

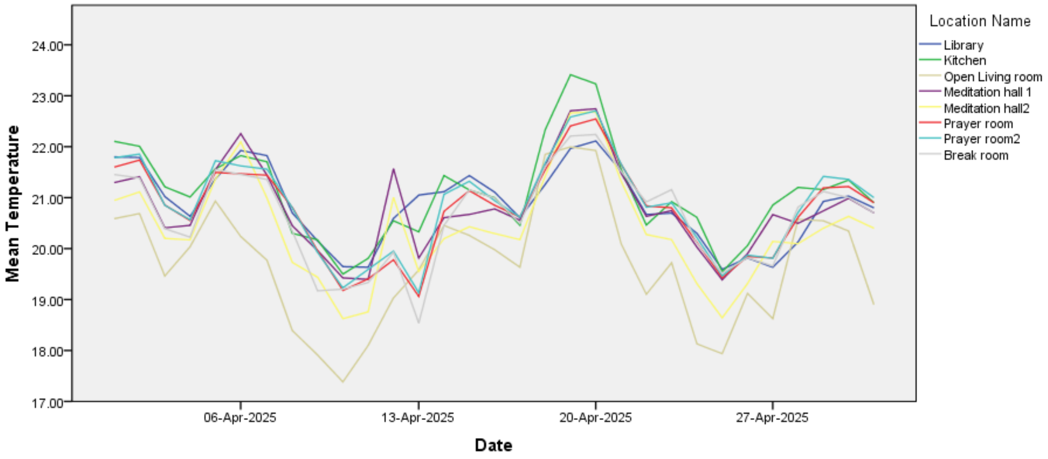


Figure 18: Daily mean temperature variations across indoor zones

Eight areas inside the complex exhibit an overall similar weekday temperature trend, according to the figure 19. The Open Living Room and Meditation Hall 2 exhibit the most fluctuation, with Thursday being the lowest (19°C) midweek day in the open living room and Saturday and Sunday being 1-2°C warmer. Temperatures in the Library and Break Room, Meditation Hall 1, and Prayer Room varied slightly (by ±1°C) every day and rose slightly on weekends. Interestingly, the same space temperature in Meditation Hall sensor 2 is 0.8°C higher than in sensor 1 record.

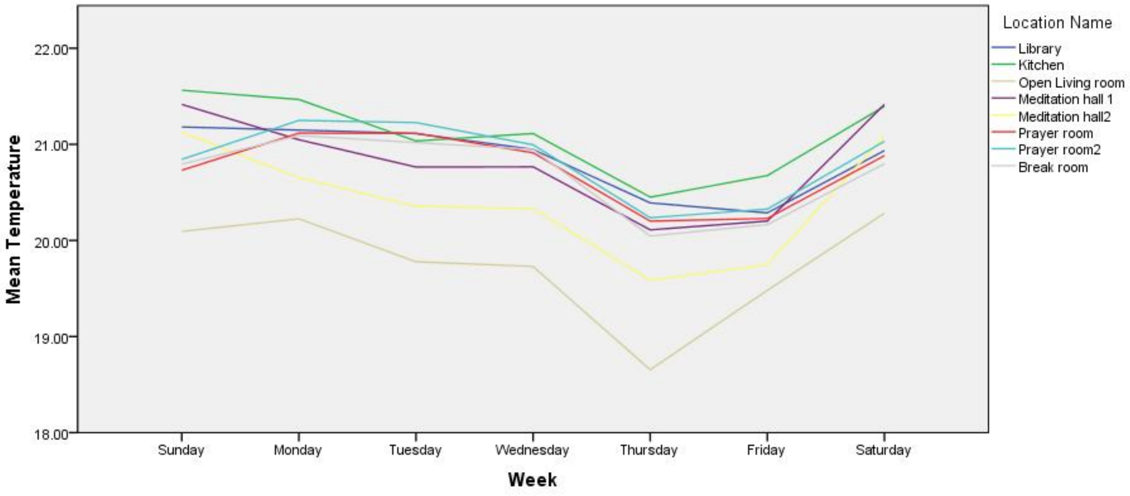


Figure 19: Mean temperature of different spaces in different weekdays

Additionally, the hourly mean temperature changes in eight areas within a complex were shown in Figure 20. All zones have temperatures between 17.5°C and 22.5°C.

The early morning hours (00:00–06:00) had the lowest mean temperatures, with open living room reaching a low of 17.8°C at 6:00 and other areas such as the Meditation hall 2 and Break Room recording temperatures between 18.5°C and 19.5°C. The majority of other spaces stay near 20.0°C during this period. After 8:00, the temperature starts to rise gradually and peaks between 14:00 and 16:00. At 22.5°C, the open living room had the highest mean temperature, followed closely by Kitchen and break room, both of which reach between 22.0°C and 22.5°C. Peak temperatures in other locations, like the Library, Break Room, and Prayer Room 2, are somewhat lower, ranging from 21.5°C to 22.0°C.

After the peak, there is a slight drop starting at 17:00, and by 24:00, all spaces had gradually decreased between 20.5°C and 21.5°C. While the open living room maintained the highest daytime peak, Meditation Hall 2 continuously displays the lowest temperature profile throughout the day.

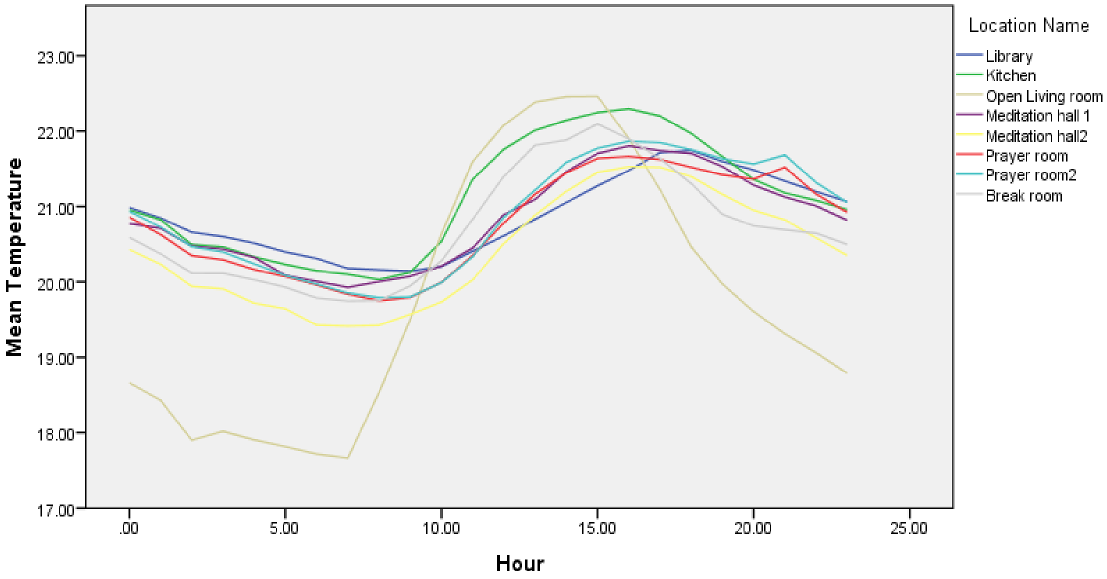


Figure 20: Mean temperature of each space throughout the day

The data was further analysed to examine the number of times the temperature fell outside of the recommended range (20-24°C) for each space. The result is shown in

Figure 21. The Kitchen open living room has the most out-of-range recordings (415), Meditation Hall 2 (168), closely followed by Prayer Room 1 (166), and Prayer Room 2 (166). The Meditation Hall 1 (160), library (144), and Break Room (162), and the kitchen (151) had the fewest number of records out of range.

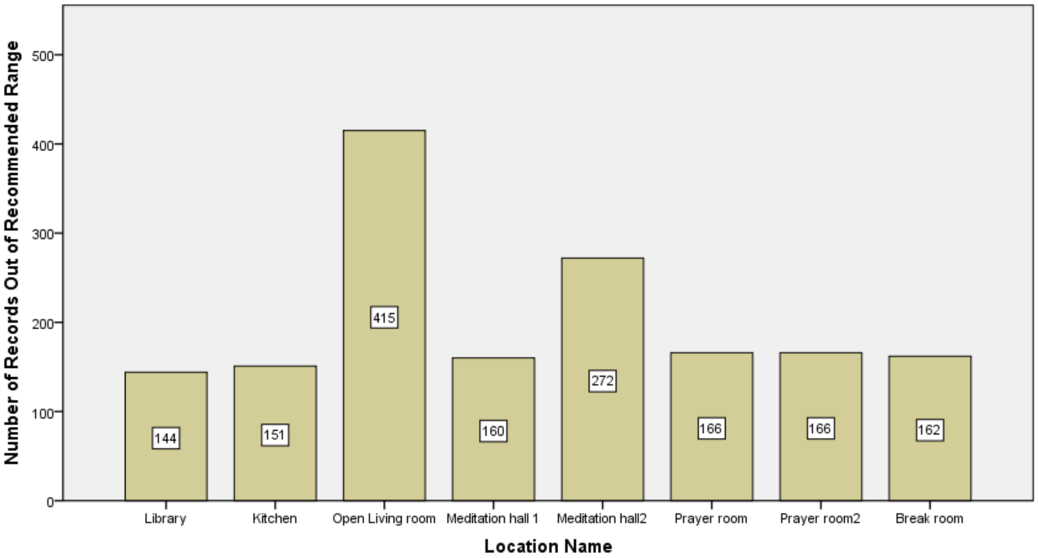


Figure 21: Cluster of out of the range level for each sensor

As presented in table 16, the out-of-range temperature data readings were most frequently observed in the Open Living Room (57.56%), followed by the Kitchen 21.09% (count 151) and Break Room 26.17% (count 162). On the other hand, Prayer Rooms 1 and 2 23.06% (count 166) and Meditation Hall 1 23.29% (count160) also displayed significant deviations. The library's out-of-range temperature data was the best at 20.22% (count 144). Despite being in the same space, Meditation Hall 2 37.67% (count 272) had a drastically different percentage than Hall 1.

Table 16: Out of the range temperature for different spaces

Location	**Total number of Records**	**Records outside of recommended range**	**Percentage of records outside the recommended range**	**Records within recommended range**	**Percentage of records within the recommended range**
Library	712	144	20.22	568	79.78
Kitchen	716	151	21.09	565	78.91

Open Living Room	721	415	57.56	306	42.44
Meditation hall 1	687	160	23.29	527	76.71
Meditation hall 2	722	272	37.67	450	62.33
Prayer room 1	720	166	23.06	554	76.94
Prayer room 2	721	166	23.02	555	76.98
Break room	619	162	26.17	457	73.83

- **Comparison of Humidity in each interior space**

Based on several hundred hourly measurements per location, Table 17 displays the descriptive statistics of relative humidity across eight monitored spaces in the Sri Lankarama Temple. With a mean humidity of 80.34%, the Open Living Room had the highest variability, with a standard deviation of 11.984, and a minimum of 44% and a maximum of 100%. With a standard deviation of 9.004% and a mean of 79.98%, which ranged from 58% to 99%, Prayer Room 1 came next. The humidity in Prayer Room 2 ranged from 56% to 95%, with a mean of 78.21% and a standard deviation of 8.565%.

The mean humidity in the break room was 77.51%, with a standard deviation of 10.986% and a range of 49% to 100%. While Meditation Hall 1 had a mean of 74.87%, with a range of 53% to 97%, and a standard deviation of 8.565%, Meditation Hall 2 recorded a mean of 75.5%, minimum of 44%, maximum of 97%, and standard deviation of 9.227%. The humidity in the kitchen ranged from 45% to 94%, with a mean of 74.7% and a standard deviation of 9.312%.

Out of all the spaces, the Library had the most consistent humidity levels, with the lowest mean humidity of 67.44%, the lowest standard deviation of 2.774%, and a minimum of 58% to 79%. With standard deviations ranging from 2.774% to 11.984% and mean humidity values ranging from 67.44% to 80.34% across all locations, all observed values are higher than the 30% to 60% recommended indoor range

Table 17: Descriptive analysis humidity data each space

Location	**N**	**Mean**	**Min**	**Max**	**Std. Deviation**
Library	712	67.44	58	79	2.774
Kitchen	716	74.7	45	94	9.312
Open Living Room	722	80.34	44	100	11.984
Meditation hall 1	687	74.87	53	97	8.565
Meditation hall 2	722	75.5	0	97	9.227
Prayer room 1	720	79.98	58	99	9.004
Prayer room 2	721	78.21	56	95	8.565
Break room	619	77.51	49	100	10.986

The graph (Figure 22) shows how humidity changes overtime in various places in the temple in the month of April 2025. Humidity is continuously high (ranging between 75 and 100 percent) in all areas and it reaches especially high value in meditation rooms, prayer rooms and kitchen at multiple points on roughly the same data points between April 5-10 and April 19- 24. Most probably, these surges are associated with high occupancy, or poor ventilation. Contrarily, the humidity level in the Library and Break Room is quite similar and lower compared to the other locations (about 6070%) and shows the good control over the environment. Remarkably, the data in the Kitchen column shows slight sharp and brief vertical tumbles that are intermittent and could indicate sensor malfunction or spurt of forced menace. High humidity is likely to persist with time especially when it comes to zones of the spiritual aspect hence the need to introduce better dehumidification methods especially at crowded functions.

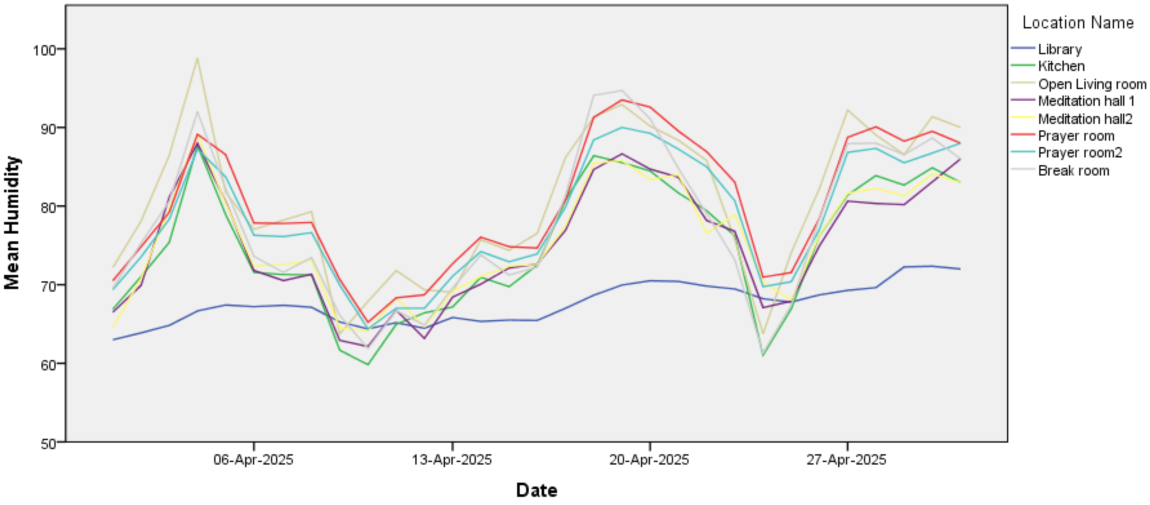


Figure 22: Daily mean humidity variations across indoor zones

Figure 23 displays the mean humidity levels throughout the duration of the week in each of the complex's spaces. Humidity levels are regularly greatest in the prayer room 1, peaking on Monday (83%) and Saturday (~83%). The library, on the other hand, consistently has the lowest humidity levels, showing no much variation and Thursday noted lowest value ~62%. Notably, the humidity in the majority of spaces, such as the kitchen, meditation hall 1 & 2, and break room, decreases in the middle of the week, reaching its lowest point on Thursday. On Friday and Saturday, however, there is a noticeable increase in humidity in every region. Furthermore, the humidity in the open living room increases significantly on Friday to highest mean value of all spaces 85%.

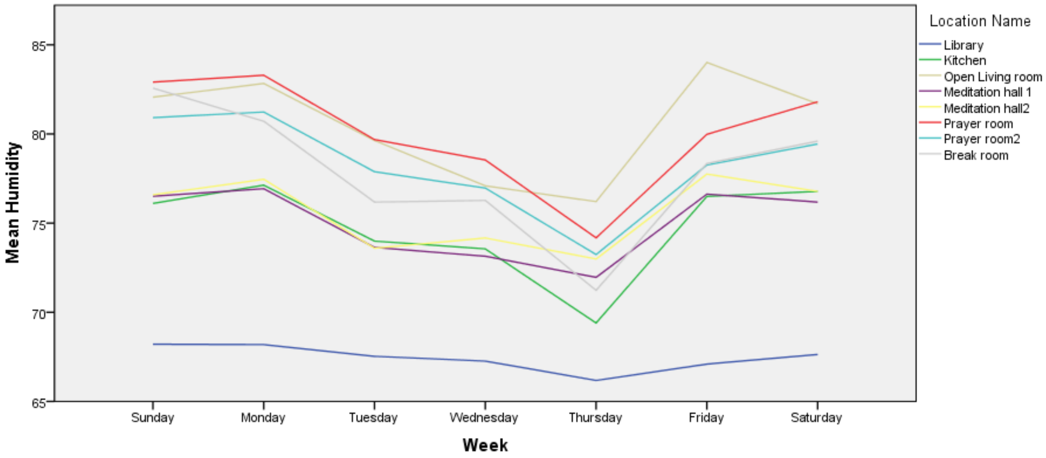


Figure 23: Mean humidity of different spaces in different weekdays

Figure 24 below illustrates the average humidity levels of each location during the day. The humidity pattern in the open living room exhibits significant fluctuations, reaching a high of 87% at 9 AM. It then drops by up to 72% at 3 PM in the evening. All other areas have a consistent variation pattern throughout the day, with little fluctuations, whereas the stated peak values occur around 11 AM and subsequently decline. Conversely, the library had the lowest values 68% with few observed changes.

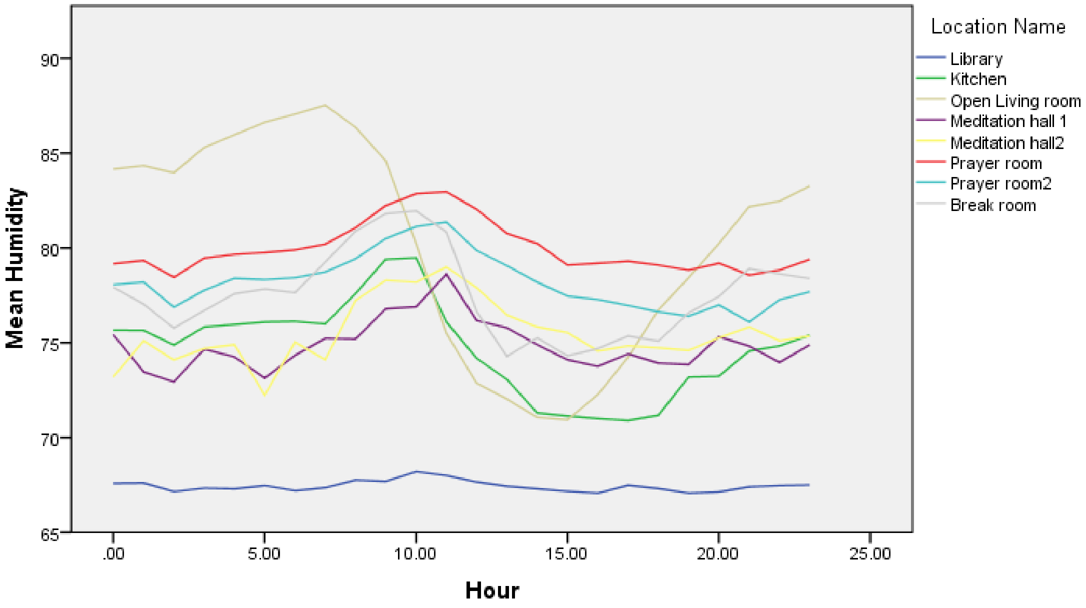


Figure 24: Mean humidity of each space throughout the day

The humidity levels in all spaces are not within the acceptable range, as illustrated in Figure 25. This indicated that the preponderance of records has fallen outside the range, while a small number were within the 30-60% range. The counts in each room were nearly identical: 707 in the library, 661 in the kitchen, 672 in the open living room, and 659 and 704 in the meditation halls 1 and 2. Additionally, there are 714 and 708 counts in Payer rooms 1 and 2. The Break room had the lowest count of 586 counts, which was outside the range.

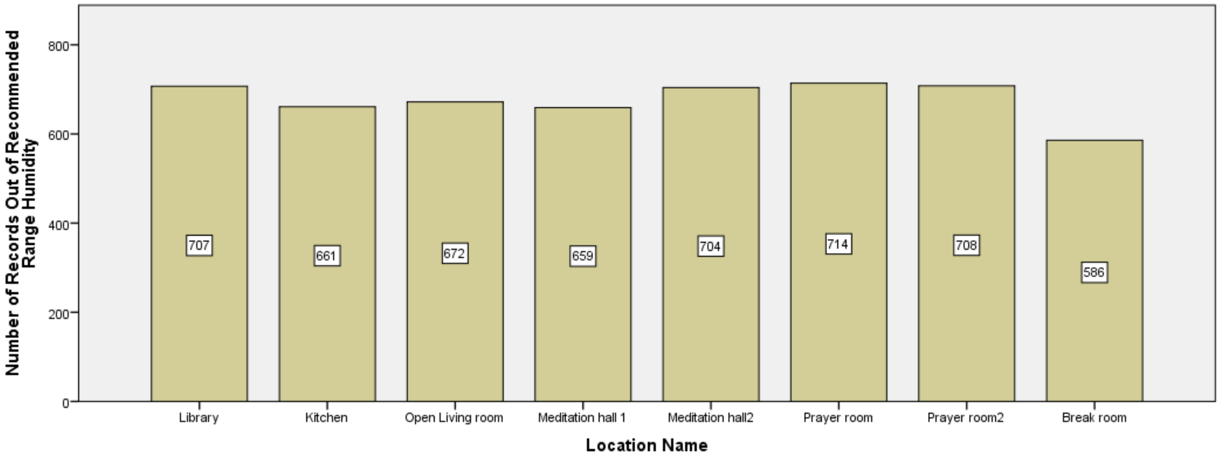


Figure 25: Cluster of out of the range level for each sensor

Refer to the Table 18, The library had the highest percentage of readings outside the recommended range at 99.30%, with 707 out of 712 records exceeding safe levels, as indicated by table 17, which shows the out-of-range counts of humidity levels in various temple spaces. In the same vein, Prayer Room 1 and Meditation Hall 2 recorded 99.17% and 97.51% of readings that were outside the recommended threshold, respectively. The values in the Open Living Room and Kitchen were also alarming, with more than 92% of their records exceeding the recommended limits. Meditation Hall 1 and the Break Room had records that were 95.92% and 94.67% outside the safe range, respectively. The Kitchen had the maximum percentage of measurements within the recommended CO_2 thresholds at 7.68%, while the library had the lowest at 0.70%.

Table 18:Out of the range humidity for different spaces

Location	**Total number of Records**	**Records outside of recommended range**	**Percentage of records outside the recommended range**	**Records within recommended range**	**Percentage of records within the recommended range**
Library	712	707	99.30	5	0.70
Kitchen	716	661	92.32	55	7.68
Open Living Room	721	672	93.20	49	6.80
Meditation hall 1	687	659	95.92	28	4.08
Meditation hall 2	722	704	97.51	18	2.49
Prayer room 1	720	714	99.17	6	0.83
Prayer room 2	721	708	98.20	13	1.80
Break room	619	586	94.67	33	5.33

- **Comparison of CO_2 in each interior space**

Based on 5600 hourly measurements per space, Table 19 shows the descriptive statistics of CO_2 concentrations in the Sri Lankarama Temple's various indoor spaces. With a minimum of 556 ppm, a maximum of 2,422 ppm, and a standard deviation of 319.540

ppm, Prayer Room 2 had the highest mean CO_2 level, measuring 979.48 ppm. With a mean of 721.35 ppm, a standard deviation of 231.952 ppm, and a range of 418 ppm to 1,872 ppm, Prayer Room 1 came next.

With a minimum of 384 ppm, a maximum of 4,522 ppm, and a standard deviation of 362.181 ppm, the mean CO_2 level recorded in Meditation Hall 1 was 655.81 ppm. The mean for Meditation Hall 2 was 634.23 ppm, with a standard deviation of 357.517 ppm and a range of 394 ppm to 4,756 ppm. Each of these two halls had a standard deviation above 350 ppm, making them the most variable spaces.

Kitchen's CO_2 level ranged from 376 ppm to 936 ppm, with a mean of 558.22 ppm and a standard deviation of 73.324 ppm. The Open Living Room had the most consistent CO_2 readings, with a mean of 494.84 ppm, the lowest of all the spaces measured, a minimum of 388 ppm, a maximum of 1,166 ppm, and a standard deviation of 48.889 ppm.

Values in the Break Room ranged from 394 ppm to 1,004 ppm, with a mean of 551.88 ppm and a standard deviation of 75.810 ppm. The table did not include data for the library as device not indicated during the period. Overall, the standard deviations varied greatly, from 48.889 ppm to 362.181 ppm, and the mean CO_2 levels varied from 494.84 ppm to 979.48 ppm, reflecting variations in air quality and room-to-room variability.

Table 19: Descriptive analysis data of CO_2 in each space

Location	**N**	**Mean**	**Min**	**Max**	**Std. Deviation**
Library	712				
Kitchen	716	558.22	376	936	73.324
Open Living Room	722	494.84	388	1166	48.889
Meditation hall 1	687	655.81	384	4522	362.181
Meditation hall 2	722	634.23	394	4756	357.517
Prayer room 1	720	721.35	418	1872	231.952
Prayer room 2	721	979.48	556	2422	319.54
Break room	619	551.88	394	1004	75.81

Figure 26 shows the daily mean CO_2 concentrations in different indoor areas in April 2025. The greatest CO_2 levels were found in prayer room 2, which peaked on April 19, 2025, at around 1,500 ppm, while prayer room 1 peak fallen to 1000ppm in the same day. Also, excessive amounts were observed in Meditation Hall 1 and 2, reaching about 1,300 ppm before declining after April 23, 2025. Other spaces, such as the open living room, library and the kitchen, often maintained Co_2 mean levels between 500 and 800 ppm.

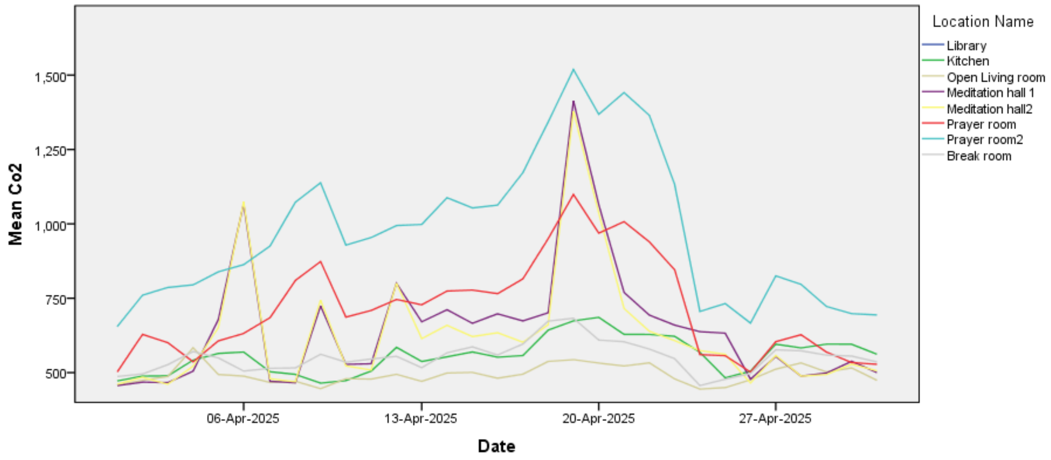


Figure 26: Daily mean CO_2 variations across indoor zones

The figure 27 shows the mean CO_2 levels across different spaces in the complex throughout the weekdays. The mean CO_2 levels in prayer room 2 are consistently the highest, ranging from 950 ppm on Thursday to 1,080 ppm on Monday. Elevated levels are also seen in Meditation hall 1, peaking on Saturday and ranging between 700 and 780 parts per million. With readings ranging from 580 ppm on Thursday to 860 ppm on Sunday and Saturday, Meditation Hall 1 and prayer room 1 exhibit a comparable pattern. With only slight variations throughout the week, the mean CO_2 concentrations in the kitchen, library, and break room remain lower, typically ranging from 500 to 600 ppm. The Open Living Room consistently maintains values near 500 ppm, which is the lowest and most consistent value.

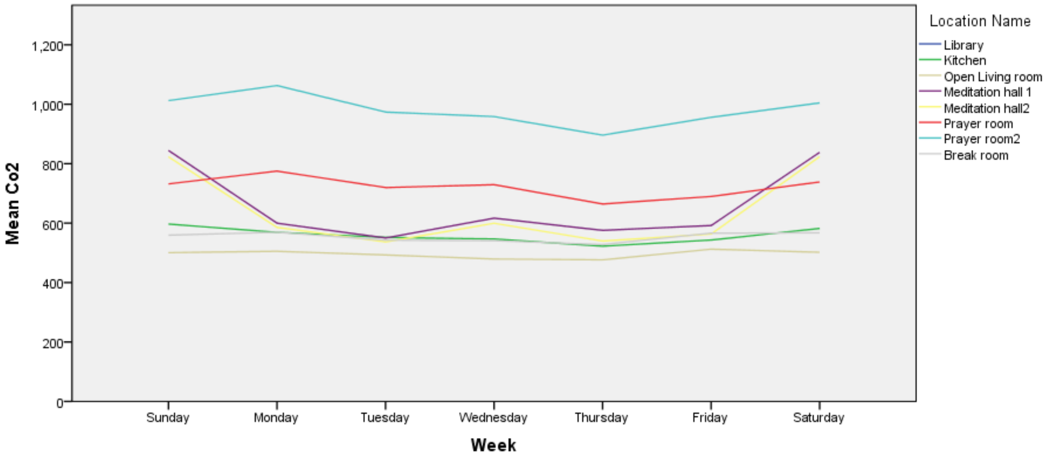


Figure 27: Mean CO_2 of different spaces in different weekdays

Figure 28 below illustrates the average humidity levels of each location during the day. The humidity pattern in the open living room exhibits significant fluctuations, reaching a high of 87% at 9 AM. It then drops by up to 72% at 3 PM in the evening. All other areas have a consistent variation pattern throughout the day, with little fluctuations, whereas the stated peak values occur around 11 AM and subsequently decline. Conversely, the library had the lowest values 68% with few observed changes.

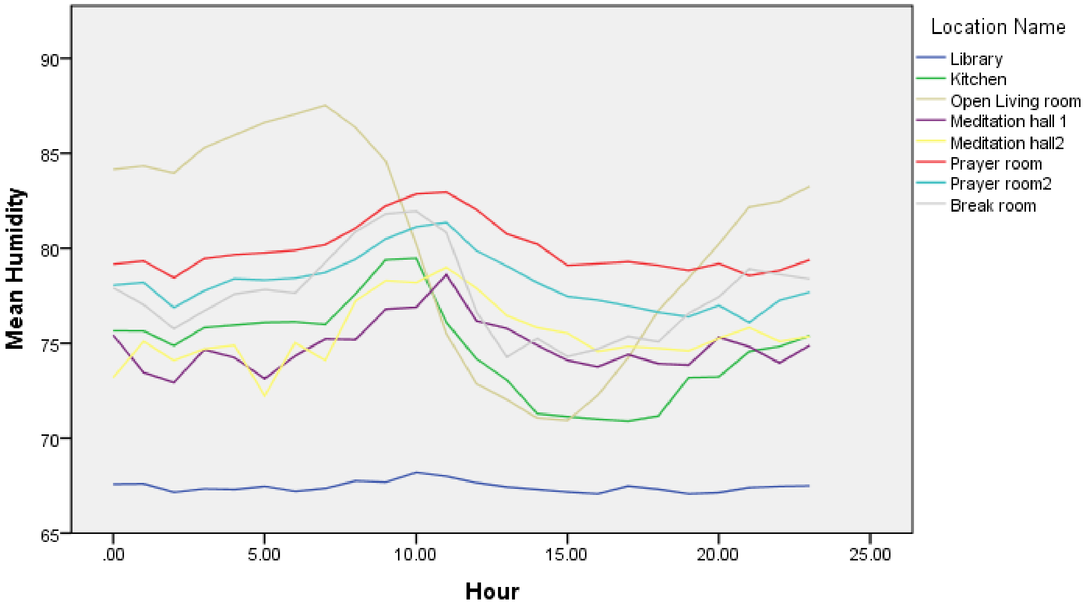


Figure 28: Mean humidity of each space throughout the day

The number of CO_2 readings that exceeded the recommended range across different indoor spaces is shown in Figure 29. With 253 occurrences, Prayer Room 2 had the most out-of-range CO_2 readings. Prayer Room 1 came next, with 82 cases of CO_2 levels above the advised threshold.

There were 35 out-of-range occurrences in Meditation Hall 2 and 34 in Meditation Hall 1. There was only one reading above the permissible CO_2 level in each of the open living room and break room. There were no out-of-range CO_2 readings for the kitchen or library. The distribution of out-of-range CO_2 values varies significantly across the data, with 0 to 253 occurrences per location.

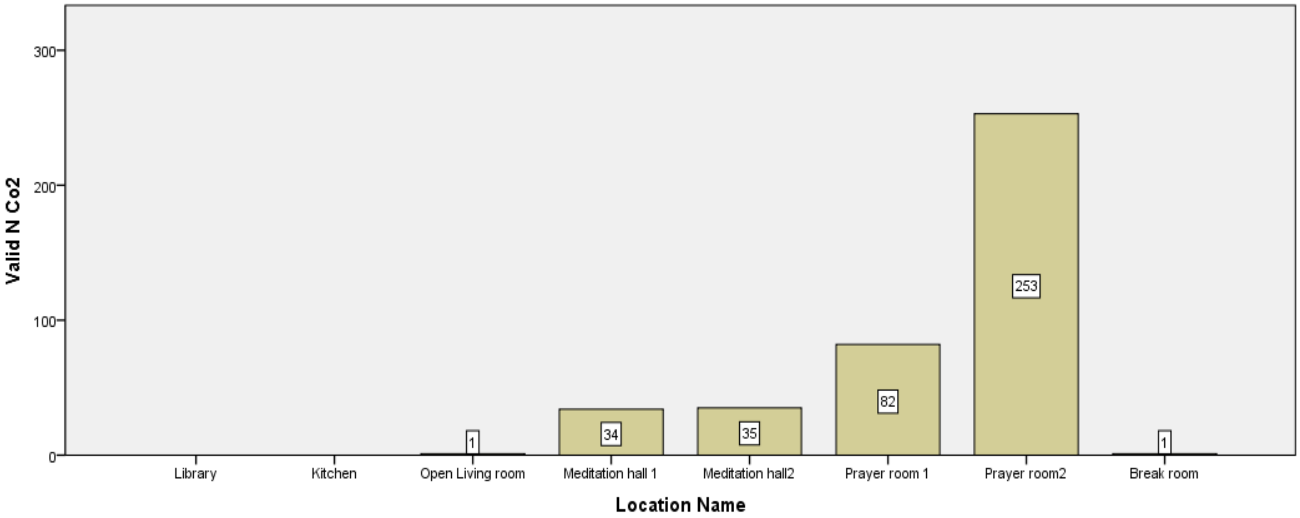


Figure 29: Cluster of out of the range CO_2 level for each sensor

The quantity and proportion of CO_2 readings outside and within the advised range (<1000ppm) for various indoor spaces are shown in Table 20. Prayer room 2 with 253 out of 464 records, or 54.53% of the data, had the most out-of-range values. prayer room 1, With 82 out of 637 records (or 12.87%) outside the suggested range, There were 34 (5.21%) and 35 (5.09%) records outside the range in Meditation Hall 1 and Meditation Hall 2, respectively. Only one record, or 0.14% and 0.16%, respectively, was out of range in the Open Living Room and Break Room. With 100% of its 716 records falling within the acceptable range, the Kitchen had no records outside the range.

Table 20: Out of the range CO_2 for different spaces

Location	**Total number of Records**	**Records outside of recommended range**	**Percentage of records outside the recommended range**	**Records within recommended range**	**Percentage of records within the recommended range**
Kitchen	716	0	0.00	716	100.00
Open Living Room	720	1	0.14	719	99.86
Meditation hall 1	652	34	5.21	618	94.79
Meditation hall 2	687	35	5.09	652	94.91
Prayer room 1	637	82	12.87	555	87.13
Prayer room 2	464	253	54.53	211	45.47
Break room	618	1	0.16	617	99.84

Mean difference analysis of different spaces

The data was analysed in order to investigate whether there are statistically significant differences in the daily mean value of IEQ variables in different rooms/sensors during the experiment period.

Investigating the mean differences of temperature in interior spaces

One-way ANOVA was conducted to investigate differences in the mean temperature of different spaces. The result of ANOVA test shows in Table 21, the F (6.151), p-value of 0.00 which mean that there is a statistically significant difference between at least two of the space.

Table 21: One-way ANOVA differences in the mean temperature of different spaces

ANOVA
Temperature means

	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	38.566	7	5.509	6.151	.000
Within Groups	214.956	240	.896		
Total	253.522	247			

To identify where those differences lie, we looked into Post Hoc test (Tukey).

Looking at the p-values presented in the multiple comparisons table 22, we observed that the mean temperature in the open living room was significantly lower that six other spaces, namely the library, kitchen, meditation hall 1, prayer room 1, prayer room 2, and break room. Figure 30 below visualise these differences. Even though the figure shows slight differences among other spaces, those are not statistically significant.

Table 22: Multiple comparisons mean temperature in different spaces

Multiple Comparisons

Dependent Variable: Temperature_mean
Tukey HSD

(I) Location Name		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Library	Kitchen	-.22182	.24038	.984	-.9569	.5132
	Open Living room	1.14621*	.24038	.000	.4111	1.8813
	Meditation hall 1	.06317	.24038	1.000	-.6719	.7982
	Meditation hall2	.46098	.24038	.540	-.2741	1.1960
	Prayer room	.10467	.24038	1.000	-.6304	.8397
	Prayer room2	.00398	.24038	1.000	-.7311	.7390
	Break room	.22677	.24038	.981	-.5083	.9618
Kitchen	Library	.22182	.24038	.984	-.5132	.9569
	Open Living room	1.36803*	.24038	.000	.6330	2.1031
	Meditation hall 1	.28499	.24038	.935	-.4501	1.0200
	Meditation hall2	.68280	.24038	.090	-.0523	1.4179
	Prayer room	.32649	.24038	.875	-.4086	1.0615
	Prayer room2	.22580	.24038	.982	-.5093	.9609
	Break room	.44859	.24038	.576	-.2865	1.1836
Open Living room	Library	-1.14621*	.24038	.000	-1.8813	-.4111
	Kitchen	-1.36803*	.24038	.000	-2.1031	-.6330
	Meditation hall 1	-1.08304*	.24038	.000	-1.8181	-.3480
	Meditation hall2	-.68523	.24038	.088	-1.4203	.0498
	Prayer room	-1.04154*	.24038	.001	-1.7766	-.3065

	Prayer room2	-1.14223*	.24038	.000	-1.8773	-.4072
	Break room	-.91944*	.24038	.004	-1.6545	-.1844
Meditation hall 1	Library	-.06317	.24038	1.000	-.7982	.6719
	Kitchen	-.28499	.24038	.935	-1.0200	.4501
	Open Living room	1.08304*	.24038	.000	.3480	1.8181
	Meditation hall2	.39781	.24038	.716	-.3373	1.1329
	Prayer room	.04150	.24038	1.000	-.6936	.7766
	Prayer room2	-.05919	.24038	1.000	-.7943	.6759
	Break room	.16360	.24038	.997	-.5715	.8987
Meditation hall2	Library	-.46098	.24038	.540	-1.1960	.2741
	Kitchen	-.68280	.24038	.090	-1.4179	.0523
	Open Living room	.68523	.24038	.088	-.0498	1.4203
	Meditation hall 1	-.39781	.24038	.716	-1.1329	.3373
	Prayer room	-.35631	.24038	.816	-1.0914	.3788
	Prayer room2	-.45700	.24038	.552	-1.1921	.2781
	Break room	-.23421	.24038	.978	-.9693	.5009
Prayer room	Library	-.10467	.24038	1.000	-.8397	.6304
	Kitchen	-.32649	.24038	.875	-1.0615	.4086
	Open Living room	1.04154*	.24038	.001	.3065	1.7766
	Meditation hall 1	-.04150	.24038	1.000	-.7766	.6936
	Meditation hall2	.35631	.24038	.816	-.3788	1.0914
	Prayer room2	-.10069	.24038	1.000	-.8358	.6344
	Break room	.12210	.24038	1.000	-.6130	.8572
Prayer room2	Library	-.00398	.24038	1.000	-.7390	.7311
	Kitchen	-.22580	.24038	.982	-.9609	.5093
	Open Living room	1.14223*	.24038	.000	.4072	1.8773
	Meditation hall 1	.05919	.24038	1.000	-.6759	.7943
	Meditation hall2	.45700	.24038	.552	-.2781	1.1921
	Prayer room	.10069	.24038	1.000	-.6344	.8358
	Break room	.22279	.24038	.983	-.5123	.9578
Break room	Library	-.22677	.24038	.981	-.9618	.5083
	Kitchen	-.44859	.24038	.576	-1.1836	.2865
	Open Living room	.91944*	.24038	.004	.1844	1.6545
	Meditation hall 1	-.16360	.24038	.997	-.8987	.5715
	Meditation hall2	.23421	.24038	.978	-.5009	.9693
	Prayer room	-.12210	.24038	1.000	-.8572	.6130
	Prayer room2	-.22279	.24038	.983	-.9578	.5123

*. The mean difference is significant at the 0.05 level.

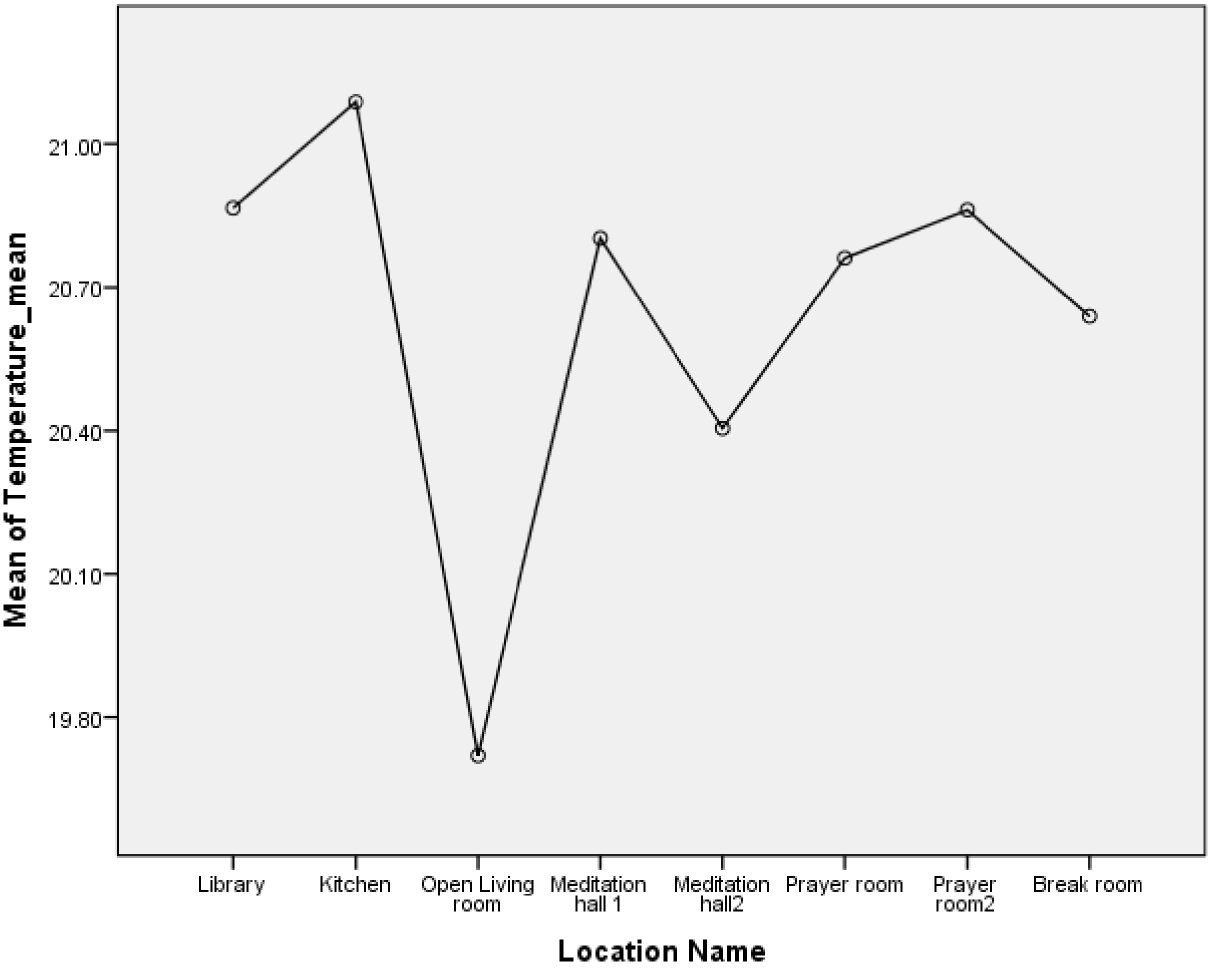


Figure 30: Mean temperature differences in different room

Investigating the mean differences of humidity in interior spaces:

A Kruskal-Wallis test was conducted to examine whether there are statistically significant differences among the mean of humidity in different spaces. The result as shown in table 23 and 24 indicates H = 53.20, df = 7, p <0.001 which means that the null hypothesis of the test is rejected, and we conclude that there are statistically significant differences among the humidity of two or more spaces.

Table 23: Kruskal-Wallis test: statistically significant differences among the mean humidity of different spaces

Hypothesis Test Summary				
	Null Hypothesis	**Test**	**Sig.^{a,b}**	**Decision**

1	The distribution of Humidity_mean is the same across categories of Location Name.	Independent-Samples Kruskal-Wallis Test	<.001	Reject the null hypothesis.
a. The significance level is .050.				
b. Asymptotic significance is displayed.				

Table 24: Independent-Samples Kruskal-Wallis Test Summary

Independent-Samples Kruskal-Wallis Test Summary	
Total N	248
Test Statistic	53.204[a]
Degree Of Freedom	7
Asymptotic Sig.(2-sided test)	<.001
a. The test statistic is adjusted for ties.	

To understand where those differences lie, we looked into the pairwise comparisons table 25 and box plot (figure 31). The humidity in the library was significantly lower than in all other spaces (Adj. Sig .< 0.05 for all these pairs). No significant differences between the humidity of other spaces were found. This has been visualized in the figure 32.

Table 25: Pairwise comparisons of the humidity in the library

Pairwise Comparisons of Location Name					
Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Library-Kitchen	-66.790	18.221	-3.666	<.001	.007
Library-Meditation hall 1	-68.339	18.221	-3.751	<.001	.005
Library-Meditation hall2	-73.968	18.221	-4.060	<.001	.001
Library-Break room	-87.145	18.221	-4.783	<.001	.000
Library-Prayer room2	-96.806	18.221	-5.313	<.001	.000
Library-Prayer room	-110.274	18.221	-6.052	<.001	.000
Library-Open Living room	-110.355	18.221	-6.057	<.001	.000
Kitchen-Meditation hall 1	-1.548	18.221	-.085	.932	1.000
Kitchen-Meditation hall2	-7.177	18.221	-.394	.694	1.000
Kitchen-Break room	-20.355	18.221	-1.117	.264	1.000
Kitchen-Prayer room2	-30.016	18.221	-1.647	.099	1.000
Kitchen-Prayer room	-43.484	18.221	-2.387	.017	.476
Kitchen-Open Living room	-43.565	18.221	-2.391	.017	.471

Meditation hall 1-Meditation hall2	-5.629	18.221	-.309	.757	1.000
Meditation hall 1-Break room	-18.806	18.221	-1.032	.302	1.000
Meditation hall 1-Prayer room2	-28.468	18.221	-1.562	.118	1.000
Meditation hall 1-Prayer room	-41.935	18.221	-2.302	.021	.598
Meditation hall 1-Open Living room	42.016	18.221	2.306	.021	.591
Meditation hall2-Break room	-13.177	18.221	-.723	.470	1.000
Meditation hall2-Prayer room2	-22.839	18.221	-1.253	.210	1.000
Meditation hall2-Prayer room	-36.306	18.221	-1.993	.046	1.000
Meditation hall2-Open Living room	36.387	18.221	1.997	.046	1.000
Break room-Prayer room2	9.661	18.221	.530	.596	1.000
Break room-Prayer room	23.129	18.221	1.269	.204	1.000
Break room-Open Living room	23.210	18.221	1.274	.203	1.000
Prayer room2-Prayer room	13.468	18.221	.739	.460	1.000
Prayer room2-Open Living room	13.548	18.221	.744	.457	1.000
Prayer room-Open Living room	.081	18.221	.004	.996	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

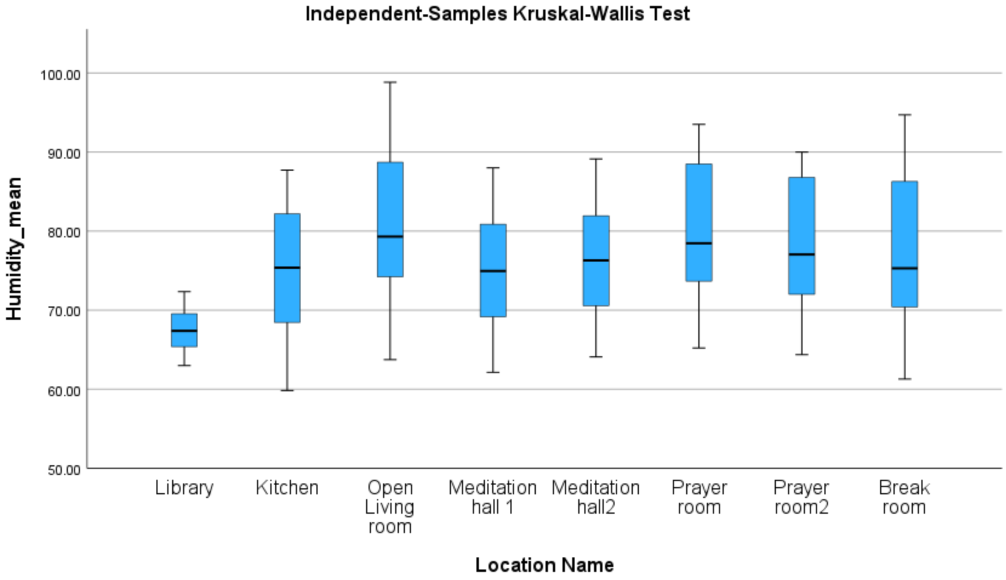


Figure 31: Humidity means with respect each space

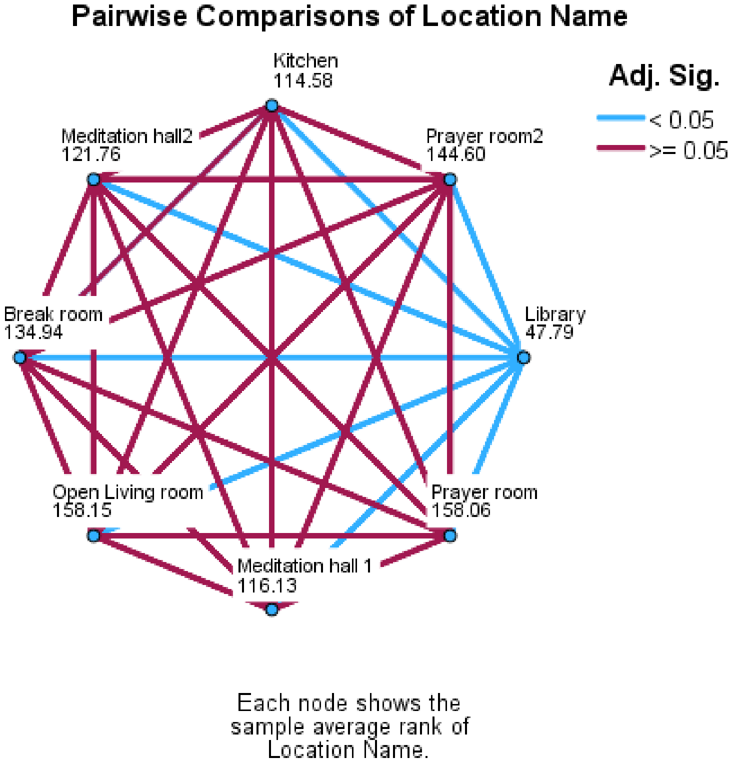


Figure 32: Visualization of link in different spaces

Investigating the mean differences of CO_2 in interior spaces:

A Kruskal-Wallis test was conducted to examine whether there are statistically significant differences among the mean CO_2 of different spaces. The result as shown in table 26 below indicates the (H = 103.163, df = 6, p =0.000) and which means that the null hypothesis of the test is rejected, and we conclude that there are statistically significant differences among the humidity of two or more spaces. This has been visualized in the Figure 33.

Table 26: Kruskal-Wallis test, differences among the mean CO_2 of different spaces

Independent-Samples Kruskal-Wallis Test Summary

Total N	217
Test Statistic	103.163[a]
Degree Of Freedom	6
Asymptotic Sig.(2-sided test)	.000

a. The test statistic is adjusted for ties.

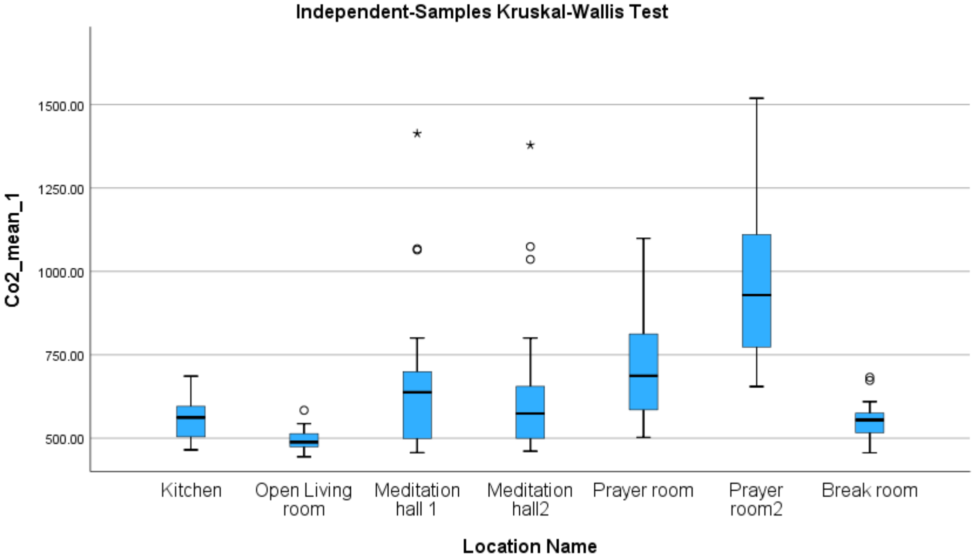


Figure 33: CO_2 means with respect to all spaces

To understand where those differences lie, we looked into the pairwise comparisons table 27 and box plot. The CO_2 in the Open living room significantly different (lower) than the CO2 level of Meditation hall 1 & 2 as well as Prayer room 1 &2, The co2 level in prayer room 2 significantly higher that meditation hall 1 &2, kitchen and break room.The co2 level in prayer room 1 significantly higher than the break room. (Adj. Sig .< 0.05 for all these pairs). No significant differences between the CO_2 of other spaces were found. This has been visualized in the Figure 34

Table 27: Pairwise comparisons of the CO_2 in each place

Pairwise Comparisons of Location Name

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Open Living room-Break room	-46.081	15.948	-2.889	.004	.081
Open Living room-Kitchen	47.694	15.948	2.991	.003	.058
Open Living room-Meditation hall2	-60.677	15.948	-3.805	.000	.003
Open Living room-Meditation hall 1	-68.258	15.948	-4.280	.000	.000
Open Living room-Prayer room	-103.097	15.948	-6.465	.000	.000
Open Living room-Prayer room2	-147.484	15.948	-9.248	.000	.000
Break room-Kitchen	1.613	15.948	.101	.919	1.000
Break room-Meditation hall2	14.597	15.948	.915	.360	1.000
Break room-Meditation hall 1	22.177	15.948	1.391	.164	1.000
Break room-Prayer room	57.016	15.948	3.575	.000	.007
Break room-Prayer room2	101.403	15.948	6.358	.000	.000
Kitchen-Meditation hall2	-12.984	15.948	-.814	.416	1.000
Kitchen-Meditation hall 1	-20.565	15.948	-1.289	.197	1.000
Kitchen-Prayer room	-55.403	15.948	-3.474	.001	.011
Kitchen-Prayer room2	-99.790	15.948	-6.257	.000	.000
Meditation hall2-Meditation hall 1	7.581	15.948	.475	.635	1.000

Meditation hall2-Prayer room	-42.419	15.948	-2.660	.008	.164
Meditation hall2-Prayer room2	-86.806	15.948	-5.443	.000	.000
Meditation hall 1-Prayer room	-34.839	15.948	-2.185	.029	.607
Meditation hall 1-Prayer room2	-79.226	15.948	-4.968	.000	.000
Prayer room-Prayer room2	-44.387	15.948	-2.783	.005	.113

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

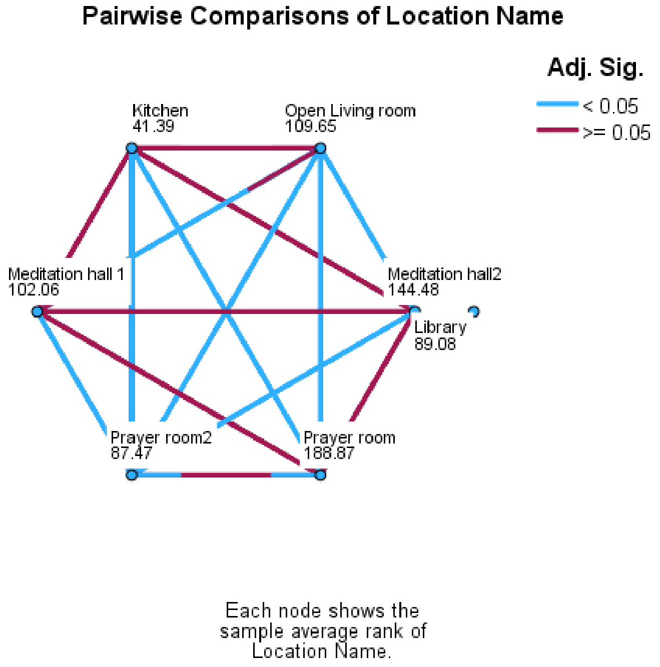


Figure 34: Box plot Mean CO_2 in all spaces

4.2.4 Objective 3: Analyse energy building consumption and the contribution of IEQ appliances.

Overview of Energy Consumption

The overall amount of power used in the April month in the facility was 633 kWh, which is equal to energy expenditure of NZD 160. The consumption of energy is distributed over several zones including library, the Kitchen, Meditation Hall, and Prayer Room with systems identified as the major consumers being the HVAC systems. List key appliances and estimated monthly consumption indicates in Table 28. If we assume the average monthly consumption is about 23.73 kW/m^2/year. This is way below mean and median of the energy consumption of the service buildings, which are 196 and 66 kW/m^2/year respectively. (BRANZ, 2014).

Table 28: Summary of overall amount of power used

Zone	Estimated Monthly Consumption (kWh)	Key Equipment
Library	80	LG HVAC System (Cooling: 3.46 kW / Heating: 3.93 kW)
Meditation Hall	160	2 × Daikin Units (Total Heating/Cooling ~3.2 kW)
Prayer Room	93	Mitsubishi HVAC (1.55–1.59 kW)
Kitchen	300	Water Heater, Washing Machine, Microwave, Oven
Total	633	

HVAC System Impact

Close to half of energy is used in HVAC systems, located in prayer room, library and Meditation Hall, which estimated 300 kWh/month. Final consumption is quite large when used continuously every day when there is a high demand for heating or cooling. Looking into the list of appliances and their operation time throughout the months it is evident that the active method of improving IEQ not have been used extensively. Moreover, the existing HVAC systems are primarily used temperature regulations and some extend can reduce humidity as well. However, when it comes to air circulation, they do not fresh air to the internal environment and therefore they do not contribute to a reduction of CO_2. The table 29 provides the list of HVAV systems, usage and monthly consumption.

Table 29: HVAC system usage

Location	HVAC Type	Monthly Usage (hrs)	Monthly Consumption (Est.)
Library	LG Inverter System	20	70 kWh
Meditation Hall	2 × Daikin Units	26*2	150 kWh
Prayer Room	Mitsubishi Unit	50	80 kWh

Kitchen Energy Use

The total comes to 180 kWh-per-month by the kitchen appliances with 3-kW electric water heater contributing considerably to this amount (up to 180-kWh-per-month) should it be left running 2-hours per day. The system is also aided by other machines like the washing machine, refrigerator and the oven etc. (Table 30)

Table 30: Kitchen energy use

Appliance	Power Rating	Usage Pattern	Monthly Consumption (Est.)
Water Heater (Rheem)	3.0 kW	2 hrs/day	180 kWh
Washing Machine	1.66 kW	5 hrs/week	30 kWh
Microwave, Oven, Fridge	~1.5 kW total	Regular daily use	50 kWh

High-Consumption Periods

Peaks of energy are in tandem with:

a) HVAC load (extreme temperature morning & evening).
b) The times of meals preparation (heating of water, cooking appliances).

Such peaks indicate the possibility of load reducing or shifting by means of timers and optimal operation time planning.

4.2.5 Objective 4: What current practices influence the temple's energy efficiency and IEQ?

The extracted responses to the interview transcribed were evaluated through the six steps of analysis developed by Braun and Clarke(2006)

- **Emerging Themes**

The factors and practices that influence temple energy efficiency

- Use of natural lights
- Passive ventilation (Window opening and closing)

The factors and practices that influence temple IEQ

Challenges

- Varied number of people: while average weekly visitors is about 210, it is difficult to estimate the number of people for events as visitors come voluntarily as their choice. This number can sometimes be very high.

Current practices:

- The use Passive method such as opening Windows manually
- The use of active methods of heating and ventilation (HVAC, Fans) which are operated manually
- Use of cooking equipment (Electric) in the temple which influence IEQ

Upgrade plans: Solar system

Upgrade Barriers

- Smart appliances seem to be a generally positive thing, but they also came with a few hiccups; perhaps in terms of installing complications or educational deficiency.

- **Data Triangulation**

The analysis discovers an active or favorable approach to the use of smart technology, in particular, energy efficiency and comfort. Nevertheless, the issues of peak occupancy control and the effectiveness of these systems in reality according to the environmental records peaks are causing problems. This ambiguous outcome leads to the realization that the full potential of smart building technologies cannot be achieved without the regular practice of training, system upgrades, and feedback interventions.

4.2.6 Objective 5: Recommend strategies to enhance IEQ while maintaining efficiency through synthesis of qualitative and quantitative data

In this section, the main findings of IEQ monitoring, energy consumption analysis, and the results of semi-structured interviews are combined to provide a comprehensive understanding of the Sri Lankarama Temple management in the way it operated its indoor environment and consumed energy throughout the month of April 2025.

1. Overall building IEQ Performance, Energy consumption and management practices summery

The Indoor Environmental Quality (IEQ) performance of the Sri Lankarama Temple revealed mixed results, The temperature 29.12% out of the range and 71% of temperature readings fell within the recommended comfort zone (20–24°C), CO_2 9.03% out of the range and Over 90% of CO_2 measurements remained below 1000 ppm, However, 96.32% of humidity readings were above the 60% upper threshold, highlighting the inadequacy of ventilation in high-occupancy, enclosed areas. Moreover, the persistent high humidity suggests the potential benefit of installing smart dehumidifiers in humidity-affected rooms to help maintain optimal indoor conditions (ASHRAE, 2025).

Significant differences in the mean temperature of the complex on different weekdays were observed, indicating insufficiency of IEQ practice to maintain the stable environment conditions in different days. No significant different at the humidity and CO_2 level of the building on different weekdays.

Comparing the mean temperature of different spaces, It was observed significant difference between the mean temperature of the open living room and other spaces observed. With regards differences in humidity level of different spaces significant difference between library and other spaces observed. (Library lower humidity).

Comparing CO_2 level of different spaces, it was observed sensor 2 at prayer room recorded the highest level of CO2 concentration followed by sensor1 in the prayer room. Looking at the layout and function of the room the occupant density near Sensor 2 was higher than in the area around Sensor 1. Notably, Sensor 2 was positioned closest to the monks' seating area, which typically accommodates multiple individuals during prayer sessions and rituals. This spatial arrangement likely contributed to the elevated CO_2 levels recorded at Sensor 2, as higher occupancy and reduced air circulation can significantly impact indoor air quality.

The building's electricity consumption was unevenly distributed, with the kitchen, prayer rooms, and meditation halls consuming the most energy because of their fans, lighting, and equipment. High energy use, however, did not always translate into improved IEQ; for example, Prayer Room 2 used a lot of energy but had low CO_2 and humidity readings. On the other hand, areas like the library and break rooms typically had better CO_2 and temperature levels while using less energy. Upgrade energy management with smart plug controls, occupancy sensors, and scheduled usage systems. (Niemelä et al., 2022; Bluyssen, 2021)

There are no real-time monitoring systems in place, energy use is not zoned, and volunteers are not well-informed about energy efficiency or IEQ standards. There is no regular assessment of indoor conditions or energy consumption by space, and the majority of ventilation is manually controlled. Implement real-time IEQ dashboards in key areas to support proactive decision-making. Train staff in energy-efficient equipment use and environmental monitoring basics. (Delzendeh et al., 2017)

2. IEQ Performance summary, Energy consumption and management practices of each space

The Library at Sri Lankarama Temple demonstrated the best overall Indoor Environmental Quality (IEQ) performance among all the monitored spaces. The environment was continuously kept steady, especially in terms of temperature. With only 20.22% of readings out of the range, the advised 20–24°C threshold, the mean temperature 20.88°C in the library was within the comfortable range. With a mean relative humidity of 67.44%, just above the suggested upper limit of 60%, and out of the range recorded 99.30%, the library performed better than any other room in terms of humidity. It was also the least variable of all the rooms. During the monitoring period, the library did not have access to CO_2 data. The library was among the areas of the building with the lowest energy consumption (80 kW/h). The appliance used in space only HVAC and lighting. The library benefits from being a low-maintenance, low-traffic area that requires little intervention in terms of management practices. According to the building manager, there are no installed energy-saving or IEQ-enhancing technologies, and ventilation is primarily natural. However, this straightforward method has worked well because space is used less frequently and creates little internal load. To overcome above maintain the current setup effectively to improve performance, while introducing humidity-absorbing materials to passively manage moisture levels. In addition to installing occupancy-based lighting controls to maximise energy use without affecting comfort, a low-cost CO_2 indicator should be installed as a preventive measure to further improve environmental monitoring and energy efficiency. (Al Horr and others, 2016)

Sri Lankarama Temple's kitchen had a mixed Indoor Environmental Quality (IEQ) performance. With a mean temperature of 21.10°C, which indicate the highest mean temperature among other spaces and only 21.09% of readings falling outside the advised comfort range of 20–24°C, the kitchen's temperature remained comparatively constant. As a result of the regular use of kitchen hood and ventilation during the hours when food was being prepared, this suggests that the temperature was generally acceptable. The humidity levels were consistently high, though, with a mean relative humidity of 74.7% and 92.32% of readings surpassing the advised upper limit of 60%, even with this energy consumption. Since 100 % of readings in the kitchen were below 1000 ppm, the CO_2 levels stayed within safe bounds and mean CO_2, level was 494.84% indicating that natural ventilation is adequate to avoid air stagnation, which is probably caused by open windows during peak hours.The kitchen was one of the areas of the building with the highest energy consumption (300 kW/h). The main cause of this is the regular use of several appliances, such as lighting, kitchen hood, microwaves, rice cookers, and refrigerators. Every day, these appliances help prepare meals for monks and special guests during temple events. In terms of management procedures, the kitchen follows a regular usage schedule and lacks any specific energy-saving techniques or IEQ controls. Although kitchen hood and appliances are frequently used, the building manager attested that there is no system in place to regulate humidity (such as dehumidifiers), and ventilation is dependent on manually operated windows or kitchen hood, which are only used during periods of high cooking demand. Furthermore, no energy monitoring is done for individual rooms. The installation of a high-capacity dehumidifier is advised in order to efficiently manage the moisture produced during cooking activities, minimise the ongoing humidity problems, and maximise energy efficiency in the kitchen. Additionally, switching to energy-efficient appliances would help lower the demand for electricity overall. By automating appliance usage and reducing inefficient energy use during off-peak hours, smart plug scheduling could further improve operational efficiency. (Da Costa et al., 2024; Freeman et al., 2022).

The Indoor Environmental Quality (IEQ) performance of the Meditation Hall revealed a complex picture of moderate success in temperature control as meditation hall 1 & 2 are two sensors fixed in one room two locations, but persistent issues with humidity and intermittent CO_2 management. With a mean temperature of 20.80°C and 76.71% of readings falling between 20 and 24°C, Meditation Hall 1's thermal conditions were comparatively stable. Meditation Hall 2 performed marginally worse, 62.33% of its temperature readings falling within range and mean temperature 20.40°C. The humidity levels in both, however, were constantly problematic: the mean humidity was between 74. 77% in Meditation Hall 1, with 95.92% and the mean humidity of sensor 2 was 75.5% and 97.51% of the readings surpassing the advised 60% threshold, respectively, in Hall 2. Although CO_2 levels were generally within acceptable limits (Sensor 1 was 655.81 ppm and Sensor 2 was 634.23 ppm) , they were elevated during periods of high occupancy, with over 5% of measurements in both locations showing out-of-range readings. The mean values for each of the IEQ parameters in the two locations were comparable.The Meditation Hall had moderate to high energy consumption (160kW/h), especially during scheduled meditation programs. HVAC, lighting, and sporadic portable purifiers and audio equipment were among the electrical appliances in use. Regarding management procedures, the building manager attested that mechanical systems are only occasionally turned on during major events, with the halls primarily depending on natural ventilation (through windows and doors). No real-time monitoring or control system is in place to track energy consumption at the room level or regulate IEQ parameters. Maintenance is also ongoing and taking care of problems. Equipment operation typically follows set routines rather than flexible, data-driven strategies, and volunteers are not trained in IEQ or energy efficiency practices. To improve environmental conditions in the Meditation Halls, it is advisable to introduce smart dehumidifiers capable of adjusting operations based on real-time humidity levels, alongside CO_2 indicators to prompt timely ventilation during high-occupancy periods. Additionally, replacing existing fans with energy-efficient models integrated with scheduled control systems would enhance thermal comfort while minimizing energy waste. These interventions should be complemented by efforts to enhance natural cross-ventilation, optimizing airflow and reducing reliance on mechanical systems. (Sakhare & Ralegaonkar, 2014; Lee et al., 2021)

Despite being a relatively low-energy-use space, the Sri Lankarama Temple's Open Living Room had some of the worst Indoor Environmental Quality (IEQ) performance of any monitored space. The mean temperature in this area was 19.75°C, which is marginally colder than the 20–24°C comfort range. It also had the highest percentage of temperature readings that were out of range, with 57.56% of the data falling outside the ideal range. This is probably because of the high exposure to outdoor elements, the lack of insulation, and the partially controlled air movement. With a mean relative humidity of 80.34%, the highest of all the rooms, and 93.2% of readings surpassing the 60% upper limit, humidity performance was likewise subpar. With a mean CO_2 level of 494.84 ppm and 99.86% of readings falling within the acceptable range, the Open Living Room had some of the best levels. This implies that because of cross-ventilation and open walls that permit constant air exchange, ventilation and airflow in this semi-open or naturally ventilated space are efficient at dispersing CO_2. Regarding energy use, the Open Living Room used very little electricity. Only simple lighting and sporadic fans consume energy in this space occasionally. Regarding management procedures, the Open Living Room functions without the use of any specialised machinery or control systems. Although there is no targeted environmental control, zoning, or monitoring, its open design promotes natural ventilation. Furthermore, the area is typically allowed to self-regulate and neither thermal comfort nor humidity are regularly evaluated. It is advised to use thermal curtains and moisture-absorbing ceiling materials to improve indoor comfort and reduce heat exchange in order to address the Open Living Room's thermal instability and excessive humidity. Air movement can be supported by low-energy fans without raising energy consumption. Furthermore, adding screened openings to improve passive ventilation would enable steady airflow while maintaining shielding against insects or pollutants from the outdoors. These low-energy and passive techniques provide a long-term solution for raising IEQ in public spaces. (Ginks & Painter, 2017; Martani et al., 2012)

One of the Sri Lankarama Temple's most used and energy-intensive areas was the Prayer Room, where two sensors were installed (Prayer Room 1 and Prayer Room 2). With a mean temperature of 20.75°C in Prayer Room 1 and a slightly higher mean temperature of 20.86°C in Prayer Room 2, both rooms maintained a moderate level of thermal comfort. In each location, about 23% of temperature readings were outside the advised 20–24°C range. But in this space, humidity was a major problem. The average relative humidity in Prayer Rooms 1 and 2 was 79.98% and 78.21%, respectively. Over 98% of the measured humidity levels in both situations were higher than the 60% upper limit advised for indoor comfort and health. The most worrisome was the CO_2 performance (Prayer room sensor 1-721.31 ppm and Prayer room sensor 2-979.48 ppm), especially in location (Prayer Room 2). More than 54.53% of CO_2 measurements were higher than the permissible 1000 ppm limit. Though still above ideal levels, location (Prayer Room 1) fared better, with only 12.82% of readings out of range. The continuous operation of the HVAC system, lighting systems, and perhaps sound or audio-visual equipment used during rituals is the main reason why the prayer room had high electricity consumption from an energy standpoint. In terms of management procedures, the building manager attested that there is no automated control or real-time monitoring for IEQ parameters, and that HVAC only activates in response to events or needs. The majority of ventilation occurs naturally through windows or door openings and is not deliberately controlled by occupancy or air quality. Furthermore, volunteers are not given any particular training in IEQ or energy-efficient operations, and neither routine air quality checks nor room-specific energy monitoring are carried out. Install demand-controlled exhaust systems, CO_2 sensors, and dehumidifiers; automate fan/lights using smart timers. (Seppänen et al., 1999; Hope & Simon, 2007)

The Sri Lankarama Temple's Break Room provides visitors with a simple place to arrange pilgrims. When it came to controlling humidity and temperature, the Break Room did fairly well in terms of Indoor Environmental Quality (IEQ). With only 24.64% of readings falling outside of the recommended comfort range of 20 to 24°C, the mean temperature was 20.60°C. With a mean relative humidity of 75.80% and 96.99% of readings above the permissible limit of 60%, humidity was a major concern. With only 4.31% of readings surpassing the 1000 ppm threshold, the Break Rooms fared reasonably well in terms of CO_2 levels. From an energy usage perspective, the Break Rooms exhibited low electricity consumption, due to the use of lighting. Regarding management practices, natural ventilation is predominant, this area are not given priority for IEQ monitoring or focused interventions, the building manager admitted. Additionally, this room lacks ventilation devices, humidity sensors, and cleaning technologies intended to control moisture. To manage excess humidity and improve air circulation, the addition of a compact dehumidifier and trickle vents is recommended. Furthermore, signage encouraging users to keep doors open after use can promote passive ventilation and support healthier indoor conditions with minimal energy impact. (Janda, 2006; Sung & Hsiao, 2021)

5 Conclusion and Recommendations

5.1 Overview of the research

This study investigated the complex interaction between Indoor Environmental Quality (IEQ), energy consumption, and building management practices in the context of Sri Lankarama Temple—a sacred, community-centered religious building in New Zealand. The primary objectives of the research were to assess the environmental performance of the temple's indoor spaces, evaluate how energy is used in relation to environmental comfort, identify inefficiencies in building operations, and propose actionable, evidence-based strategies to improve both IEQ and energy efficiency. Each of these objectives was successfully addressed through a combination of quantitative data collection (over 15,000 sensor readings across temperature, humidity, and CO_2), energy audits based on appliance use and electricity bills, and qualitative insights gathered from management interviews.

Nearly all monitored areas had excessively high humidity levels, with over 96% of data points exceeding the internationally recommended threshold of 60%. In contrast, most spaces' temperature stayed within acceptable bounds. This trend was particularly important in enclosed, high-use areas like the kitchen, meditation halls and prayer rooms where building materials and occupant comfort may be at risk. With regards to CO2 level, some spaces were found to be problematic. In prayer room (sensor 2), more than 54% of CO2 measurements exceeded 1000 ppm, suggesting that ventilation techniques were inadequate during times of high occupancy. Additionally, meditation hall recorded that in short period of time CO2 level was above the limit (5% of the records). Other spaces had no issue with regards to CO2 concentration.

Comparing energy use of spaces with their IEQ, there was no corresponding improvement in IEQ despite the Kitchen and Prayer Rooms using a lot of energy, indicating a glaring discrepancy between energy input and environmental results. These results demonstrated that energy was being used reactively, frequently without automation, strategic control, or real-time monitoring, resulting in inefficiencies and less than ideal comfort.

Additionally, the study suggests installing real-time IEQ monitoring dashboards that show the current CO_2, humidity, and temperature in strategic areas. By using these tools, Visitors and temple monks, better equipped to react to indoor conditions, such as opening windows, turning on fans, or modifying schedules based on facts rather than conjecture. Training volunteers and monks in temple on sustainable operations and how their choices affect energy and environmental performance is equally crucial in promoting this. Ongoing behaviour change can be facilitated by straightforward checklists, signage, and clear operational guidelines.

5.2 Contribution

Despite its limitations, this study makes several significant contributions to the building operation of the temple, as well as to the literature and existing body of knowledge.

This study adds to the body of knowledge by providing a comprehensive, room-by-room examination of environmental performance in a temple setting, a building type that has received little attention in the literature on energy efficiency and IEQ. It shows how even traditionally run spaces can benefit from contemporary, data-informed environmental management, and it offers a scalable study for other religious and heritage buildings in New Zealand and countries where similar climatic conditions. These insights can be useful for researchers, designers in the cultural and religious sectors, as well as temple committees, facility managers, and sustainability consultants.

Moreover, the study benefits the temple committee and operator by providing insight on how to improve IEQ and maintain energy efficiency. First and foremost, it provides a thorough, data-driven evaluation of IEQ conditions in an operational temple creating by combining spatial energy use estimates, qualitative building management insights, and real-time sensor data on temperature, humidity, and CO_2, as well as how occupancy patterns, room functions, and operational behaviour affect these relationships. Second, the study creates performance profiles for each of the eight different areas of Sri Lankarama Temple, providing useful information about which areas function well, which ones do not, and why. Thirdly, in order to improve IEQ without increasing energy waste, it offers a set of practical, evidence-based suggestions that are specific to each space and range from inexpensive passive design techniques to intelligent control systems. Finally, by emphasising how religious and community buildings can embrace contemporary, effective, and health-focused practices while preserving their cultural and spiritual integrity, the study adds to the larger conversation on sustainable heritage management. As a result, the results apply not only to Sri Lankarama Temple but also to other places of worship that want to improve occupant comfort, safeguard their health, and run more sustainably.

5.3 Limitations:

The Sri Lankarama Temple's study on energy performance, management practices, and indoor environmental quality (IEQ) has a number of limitations that could compromise its breadth, accuracy, and generalisability. Seasonal variations, are not captured by the 30-day limit on the data collection period. The study's capacity to provide long-term environmental insights is limited by this important missing data.

In addition to being constrained by presumptions regarding usage patterns, the energy use analysis method ignores variances like standby power, erratic equipment use, or concurrent load spikes. The strength of correlation analyses between energy and IEQ may therefore be impacted by the energy consumption values allocated to each room, which should be regarded as indicative rather than exact. In order to assess the relationship between IEQ and energy consumption, the study mostly used an average estimation of appliance usage time, due to lack of energy consumption meter for each room and appliance.

Additionally, the study's focus on a single case study, the Sri Lankarama Temple—as well as a particular religious, cultural, and architectural context limits the findings' generalisability. Without additional validation, the insights cannot be applied directly to larger populations of buildings because the building's design, material characteristics, and usage patterns may differ greatly from those of other religious or heritage structures.

5.4 Future Study

A number of topics are noted for further study and development in the future. First, in order to capture the impact of weather and climate variation on indoor conditions, it is advised that monitoring be conducted over a number of seasons. Secondly, room-level energy metering ought to be put into place in order to gather accurate consumption data, which would allow for a more thorough examination of the connections between energy and environmental performance. Thirdly, in addition to the sensor-based results, incorporating occupant perception surveys may yield insightful qualitative information on environmental controls' usability, comfort, and satisfaction. Lastly, a more comprehensive framework for sustainable sacred space design and elsewhere would be created by conducting multi-site comparative studies across various temples or heritage structures to validate and improve the suggestions made here.

This study concludes that temples like Sri Lankarama can greatly improve indoor comfort and health while also improving energy performance by utilising useful technologies, focused interventions, and more knowledgeable management practices. By taking these actions, the building's sacred and communal purpose will be preserved and it will be in line with modern ideas of sustainability, resilience, and environmental stewardship.

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7 APPENDIX

7.1 Interview Questionnaire

Introduction

Thank you for taking the time to speak with us. This interview aims to understand the use of Building appliances in the temple, attendance patterns, and energy consumption. Your insights will help us improve the temple's operations and sustainability efforts.

Section 1: General information

Can you briefly describe the temple's daily operations and activities? (e.g., prayers, meditation, community events, etc.)

Morning and day Arms giving’s, Evening Poojas

What is average daily and weekly attendance of visitors?

-Daily: 30

-Weekly: 210

Are there specific days or events when attendance is significantly higher?

Yes (please specify)	No
Yes Weekdays-Tuesdays and Thursdays, Weekends- Saturday and Sunday	

Section 2: Building Appliances in the Temple

What types of appliances or technologies are currently used in the temple? (e.g., HVAC, smart thermostats, automated lighting, Smart Security systems, etc.)

- HVAC(Heat Pumps), Dishwasher, Washing Machine, Security camara system, Microwaves and LED lights

How long have these appliances been in use?

Less than 1 year	1-3 years	More than 3 years
LED		Others

What was the primary reason for adopting appliances in the temple?

Energy efficiency	Cost savings	Improved visitor comfort	Sustainability goals	Other(Please specify)
yes	yes	yes	yes	N/A

How have these appliances improved temple operations? (e.g., reduced energy costs, improved comfort, easier maintenance, etc.)

- HVAC: occupant comfort
- LED – Reduced energy cost,
- Dish washer: reduce water/energy
- Camera and security system: improved security
- Others – Not sure

Have you faced any challenges with the implementation or use of appliances?

Yes (please specify)	No
	No

Do visitors provide feedback about the appliances?

Yes (please summarize)	No
	No

Comments: ……………N/A………………………………………………..

Section 3: Energy use and Sustainability

How is energy currently used in the temple? (e.g., lighting, heating/cooling, appliances, etc.)

- Lighting, Heating/cooling, hot water, camara system, other appliances such as dishwashers, refrigerators and microwaves

Has the use of appliances impacted energy consumption?

Yes, energy use has decreased	Yes, energy use has increased	No significant change	Not measured
			Not Measured

Are there any renewable energy systems (e.g., solar panels) installed in the temple?

Yes (please specify)	No
	No

What measures are taken to ensure energy efficiency in the temple? (e.g., energy audits, LED lighting, timers, etc.)

LED lighting

How important is sustainability in the temple's operations?

Very important	Moderately important	Not a priority
Very important		

Section 4: Attendance and Visitor Experience

How do you track attendance (daily/weekly)? (e.g., manual counting, sensors, etc.)

- Rough estimation during functions

Do you notice any patterns in attendance related to weather or seasonal changes?

Yes (please specify)	No
Attendances changes depending on cultural and religious events – participation is more.	

How does the temple ensure a comfortable environment for visitors during peak attendance? (e.g., temperature control, ventilation, seating arrangements, etc.)

Heat pumps, more seating arrangements and shelters (covered tents).

Do you think building appliances have improved the visitor experience?

Yes, significantly	Yes, slightly	No difference	Not sure
			Not sure

Section 5: Future Plans and Suggestions

What are the temple's future plans for improving operations and visitor experience? (e.g., new technologies, infrastructure upgrades, etc.)

Currently looking into Solar energy system

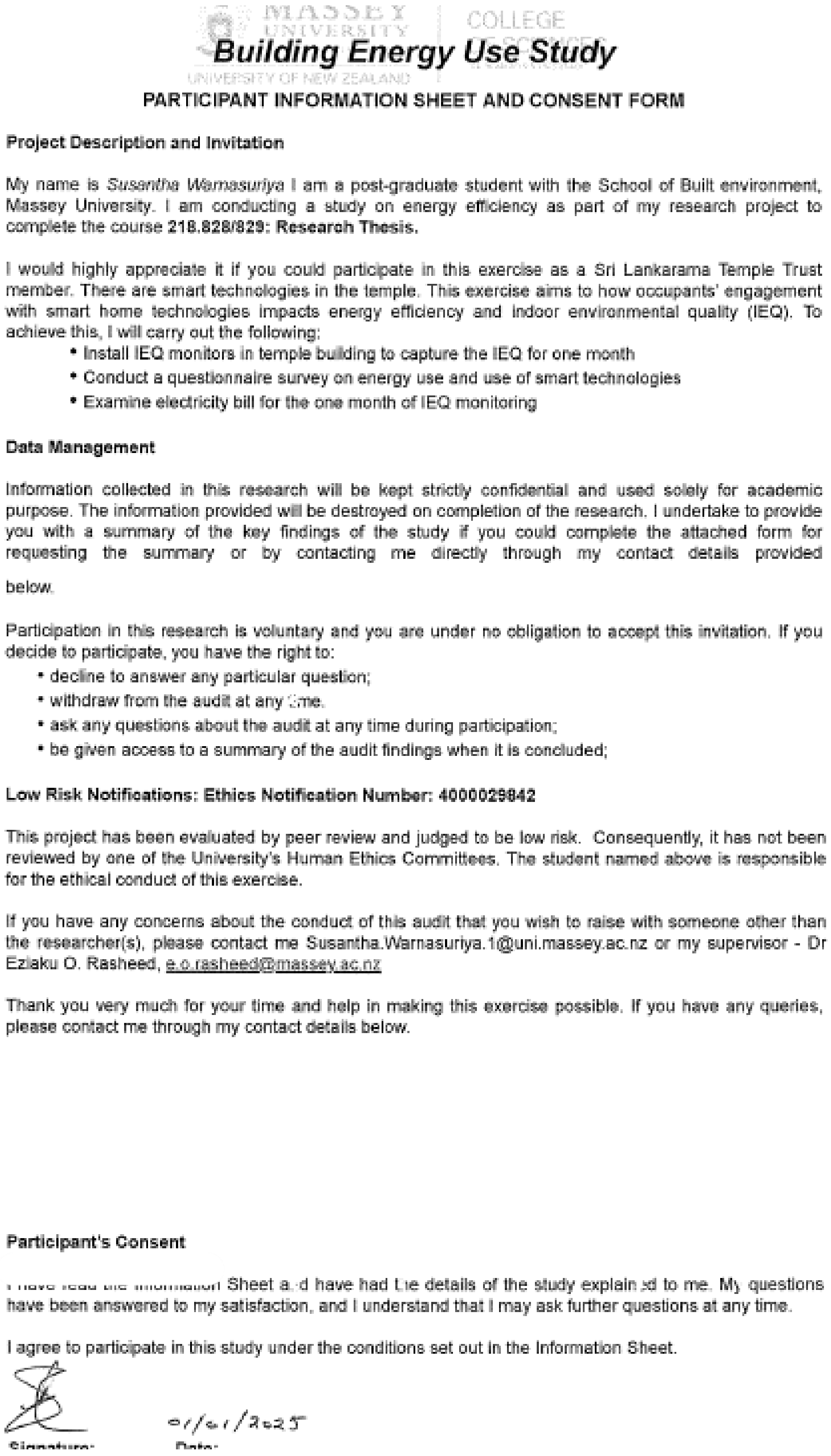
Do you have any suggestions for improving energy efficiency or sustainability in the temple?

Yes (please specify)	No
Currently looking into Solar energy system	

Is there anything else you would like to share about the temple's use of technology or operations?

No

7.2 Participant consent form



Building Energy Use Study

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

Project Description and Invitation

My name is *Susantha Warnasuriya* I am a post-graduate student with the School of Built environment, Massey University. I am conducting a study on energy efficiency as part of my research project to complete the course **218.828/829: Research Thesis.**

I would highly appreciate it if you could participate in this exercise as a Sri Lankarama Temple Trust member. There are smart technologies in the temple. This exercise aims to how occupants' engagement with smart home technologies impacts energy efficiency and indoor environmental quality (IEQ). To achieve this, I will carry out the following:

- Install IEQ monitors in temple building to capture the IEQ for one month
- Conduct a questionnaire survey on energy use and use of smart technologies
- Examine electricity bill for the one month of IEQ monitoring

Data Management

Information collected in this research will be kept strictly confidential and used solely for academic purpose. The information provided will be destroyed on completion of the research. I undertake to provide you with a summary of the key findings of the study if you could complete the attached form for requesting the summary or by contacting me directly through my contact details provided below.

Participation in this research is voluntary and you are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the audit at any time.
- ask any questions about the audit at any time during participation;
- be given access to a summary of the audit findings when it is concluded;

Low Risk Notifications: Ethics Notification Number: 4000029842

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The student named above is responsible for the ethical conduct of this exercise.

If you have any concerns about the conduct of this audit that you wish to raise with someone other than the researcher(s), please contact me Susantha.Warnasuriya.1@uni.massey.ac.nz or my supervisor - Dr Eziaku O. Rasheed, e.o.rasheed@massey.ac.nz

Thank you very much for your time and help in making this exercise possible. If you have any queries, please contact me through my contact details below.

Participant's Consent

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

01/01/2025

Signature: Date:

7.3 Appendix 3- Quantitative data-One month temperature, humidity and CO2 data, from 1st to 30th April 2025, Sri Lankarama Temple Otahuhu

No	Location Name	Temperature	Humidity	co2	Local Timestamp
1	**1**	20.8	72		1/5/2025 0:00
2	**2**	20.9	83	562	1/5/2025 0:00
3	**3**	18.9	90	474	1/5/2025 0:00
4	**4**	20.7	86	500	1/5/2025 0:00
5	**5**	20.4	83	506	1/5/2025 0:00
6	**6**	20.9	88	528	1/5/2025 0:00
7	**7**	21	88	694	1/5/2025 0:00
8	**8**	20.7	86	536	1/5/2025 0:00
9	**1**	20.9	73		30-04-2025 23:00:00
10	**2**	21	84	574	30-04-2025 23:00:00
11	**3**	18.8	90	504	30-04-2025 23:00:00
12	**4**	20.8	81	534	30-04-2025 23:00:00
13	**5**	20.5	84	490	30-04-2025 23:00:00
14	**6**	21	88	496	30-04-2025 23:00:00
15	**7**	21.1	84	690	30-04-2025 23:00:00
16	**8**	20.7	87	532	30-04-2025 23:00:00
17	**1**	21.1	73		30-04-2025 22:00:00
18	**2**	21	85	574	30-04-2025 22:00:00
19	**3**	18.9	92	506	30-04-2025 22:00:00
20	**4**	20.9	83	504	30-04-2025 22:00:00
21	**5**	20.7	84	512	30-04-2025 22:00:00
22	**6**	21.1	88	518	30-04-2025 22:00:00
23	**7**	21.2	88	682	30-04-2025 22:00:00
24	**8**	20.8	87	584	30-04-2025 22:00:00
25	**1**	21.2	74		30-04-2025 21:00:00
26	**2**	21	85	610	30-04-2025 21:00:00
27	**3**	19.4	94	540	30-04-2025 21:00:00
28	**4**	21.1	85	488	30-04-2025 21:00:00
29	**5**	20.8	85	520	30-04-2025 21:00:00
30	**6**	21.3	89	534	30-04-2025 21:00:00
31	**7**	21.4	86	688	30-04-2025 21:00:00
32	**8**	20.8	88	578	30-04-2025 21:00:00
33	**1**	21.2	74		30-04-2025 20:00:00
34	**2**	21.1	84	602	30-04-2025 20:00:00
35	**3**	19.8	93	518	30-04-2025 20:00:00
36	**4**	21.1	85	506	30-04-2025 20:00:00
37	**5**	20.9	85	502	30-04-2025 20:00:00
38	**6**	21.4	88	564	30-04-2025 20:00:00
39	**7**	21.6	86	694	30-04-2025 20:00:00
40	**8**	20.8	88	592	30-04-2025 20:00:00
41	**1**	21.2	73		30-04-2025 19:00:00
42	**2**	21.4	84	616	30-04-2025 19:00:00
43	**3**	20.3	91	454	30-04-2025 19:00:00
44	**4**	21.2	85	476	30-04-2025 19:00:00
45	**5**	21	85	480	30-04-2025 19:00:00
46	**6**	21.3	88	508	30-04-2025 19:00:00
47	**7**	21.5	85	640	30-04-2025 19:00:00
48	**8**	20.6	90	524	30-04-2025 19:00:00
49	**1**	21.3	73		30-04-2025 18:00:00
50	**2**	21.5	83	542	30-04-2025 18:00:00

2886	**2**	21.2	66	612	15-04-2025 21:00:00
2887	**3**	20	68	490	15-04-2025 21:00:00
2888	**5**	20.9	68	618	15-04-2025 21:00:00
2889	**6**	22.5	67	838	15-04-2025 21:00:00
2890	**7**	22.6	67	1136	15-04-2025 21:00:00
2891	**8**				15-04-2025 21:00:00
2892	**1**	22.2	64		15-04-2025 20:00:00
2893	**2**	21.4	63	546	15-04-2025 20:00:00
2894	**3**	20.4	68	454	15-04-2025 20:00:00
2895	**5**	21.1	69	588	15-04-2025 20:00:00
2896	**6**	21.8	70	1088	15-04-2025 20:00:00
2897	**7**	22.1	68	1456	15-04-2025 20:00:00
2898	**8**	21.6	66	654	15-04-2025 20:00:00
2899	**1**	22.3	64		15-04-2025 19:00:00
2900	**2**	21.8	63	540	15-04-2025 19:00:00
2901	**3**	20.7	68	480	15-04-2025 19:00:00
2902	**5**	21.4	71	572	15-04-2025 19:00:00
2903	**6**	21.8	69	694	15-04-2025 19:00:00
2904	**7**	22.2	65	954	15-04-2025 19:00:00
2905	**8**	21.7	65	532	15-04-2025 19:00:00
2906	**1**	22.4	64		15-04-2025 18:00:00
2907	**2**	22.2	63	504	15-04-2025 18:00:00
2908	**3**	21.4	66	432	15-04-2025 18:00:00
2909	**5**	21.7	72	596	15-04-2025 18:00:00
2910	**6**	21.9	69	704	15-04-2025 18:00:00
2911	**7**	22.2	67	896	15-04-2025 18:00:00
2912	**8**	22	66	576	15-04-2025 18:00:00
2913	**1**	22.3	65		15-04-2025 17:00:00
2914	**2**	22.5	62	506	15-04-2025 17:00:00
2915	**3**	22.2	64	488	15-04-2025 17:00:00
2916	**5**	21.8	72	614	15-04-2025 17:00:00
2917	**6**	22	68	714	15-04-2025 17:00:00
2918	**7**	22.3	66	898	15-04-2025 17:00:00
2919	**8**				15-04-2025 17:00:00
2920	**1**	22.2	65		15-04-2025 16:00:00
2921	**2**	22.7	63	558	15-04-2025 16:00:00
2922	**3**	23	62	490	15-04-2025 16:00:00
2923	**4**	22.2	71	642	15-04-2025 16:00:00
2924	**5**	21.9	72	604	15-04-2025 16:00:00
2925	**6**	22.1	70	712	15-04-2025 16:00:00
2926	**7**	22.4	66	910	15-04-2025 16:00:00
2927	**1**	21.9	65		15-04-2025 15:00:00
2928	**2**	22.8	61	522	15-04-2025 15:00:00
2929	**3**	23.8	60	492	15-04-2025 15:00:00
2930	**4**	21.9	72	648	15-04-2025 15:00:00
2931	**5**	21.8	73	598	15-04-2025 15:00:00
2932	**6**	22.2	71	774	15-04-2025 15:00:00
2933	**7**	22.4	67	948	15-04-2025 15:00:00
2934	**8**	22.7	63	548	15-04-2025 15:00:00
2935	**1**	21.6	65		15-04-2025 14:00:00
2936	**2**	22.7	61	570	15-04-2025 14:00:00
2937	**3**	24.6	58	466	15-04-2025 14:00:00
2938	**4**	21.4	73	652	15-04-2025 14:00:00
2939	**5**	21.5	74	614	15-04-2025 14:00:00
2940	**6**	21.9	74	748	15-04-2025 14:00:00
2941	**7**	22.1	73	984	15-04-2025 14:00:00
2942	**8**	23	62	504	15-04-2025 14:00:00
2943	**1**	21.2	66		15-04-2025 13:00:00
2944	**2**	22.1	67	600	15-04-2025 13:00:00
2945	**3**	24.6	60	434	15-04-2025 13:00:00
2946	**4**	21	74	628	15-04-2025 13:00:00
2947	**5**	20.8	75	598	15-04-2025 13:00:00
2948	**6**	21.4	77	710	15-04-2025 13:00:00
2949	**7**	21.4	78	992	15-04-2025 13:00:00
2950	**8**	22.4	66	530	15-04-2025 13:00:00
2951	**1**	20.9	66		15-04-2025 12:00:00
2952	**2**	21.4	71	564	15-04-2025 12:00:00
2953	**3**	23.3	66	474	15-04-2025 12:00:00
2954	**4**	20.7	75	654	15-04-2025 12:00:00
2955	**5**	20.2	77	614	15-04-2025 12:00:00
2956	**6**	20.9	79	708	15-04-2025 12:00:00
2957	**7**	21.2	77	1024	15-04-2025 12:00:00
2958	**8**				15-04-2025 12:00:00
2959	**1**	20.6	66		15-04-2025 11:00:00
2960	**2**	20.8	76	538	15-04-2025 11:00:00
2961	**3**	22.5	72	508	15-04-2025 11:00:00
2962	**4**	20.3	79	654	15-04-2025 11:00:00
2963	**5**	19.8	77	626	15-04-2025 11:00:00
2964	**6**	20.5	81	706	15-04-2025 11:00:00
2965	**7**	20.4	80	1064	15-04-2025 11:00:00
2966	**8**	21.3	77	560	15-04-2025 11:00:00

5544	**5**	22.4	68	460	1/4/2025 17:00
5545	**6**	22.7	70	444	1/4/2025 17:00
5546	**7**	23.2	68	594	1/4/2025 17:00
5547	**8**	23.2	67	452	1/4/2025 17:00
5548	**1**	22.4	63		1/4/2025 16:00
5549	**2**	23.9	62	448	1/4/2025 16:00
5550	**3**	24.2	63	454	1/4/2025 16:00
5551	**4**	22.9	66	454	1/4/2025 16:00
5552	**5**	22.2	69	422	1/4/2025 16:00
5553	**6**	22.7	70	458	1/4/2025 16:00
5554	**7**	23.1	67	598	1/4/2025 16:00
5555	**8**	23.3	65	434	1/4/2025 16:00
5556	**1**	22.1	63		1/4/2025 15:00
5557	**2**	23.7	59	508	1/4/2025 15:00
5558	**3**	25.1	57	460	1/4/2025 15:00
5559	**4**	22.5	67	450	1/4/2025 15:00
5560	**5**	21.8	68	460	1/4/2025 15:00
5561	**6**	22.4	72	446	1/4/2025 15:00
5562	**7**	22.7	70	638	1/4/2025 15:00
5563	**8**	23.1	66	466	1/4/2025 15:00
5564	**1**	21.8	63		1/4/2025 14:00
5565	**2**	23.2	65	510	1/4/2025 14:00
5566	**3**	24.7	61	460	1/4/2025 14:00
5567	**4**	21.8	66	448	1/4/2025 14:00
5568	**5**	21.2	70	462	1/4/2025 14:00
5569	**6**	22	73	488	1/4/2025 14:00
5570	**7**	22.2	71	598	1/4/2025 14:00
5571	**8**	22.5	69	488	1/4/2025 14:00
5572	**1**	21.5	62		1/4/2025 13:00
5573	**2**	22.9	64	460	1/4/2025 13:00
5574	**3**	24.3	61	460	1/4/2025 13:00
5575	**4**	21.3	69	460	1/4/2025 13:00
5576	**5**	20.7	70	452	1/4/2025 13:00
5577	**6**	21.7	75	498	1/4/2025 13:00
5578	**7**	21.7	73	660	1/4/2025 13:00
5579	**8**	22.2	70	506	1/4/2025 13:00
5580	**1**	21.1	62		1/4/2025 12:00
5581	**2**	22.4	68	476	1/4/2025 12:00
5582	**3**	23.9	64	440	1/4/2025 12:00
5583	**4**	20.4	68	448	1/4/2025 12:00
5584	**5**	20	70	448	1/4/2025 12:00
5585	**6**	21.1	77	510	1/4/2025 12:00
5586	**7**	21.2	75	678	1/4/2025 12:00
5587	**8**	21.7	72	464	1/4/2025 12:00
5588	**1**	20.8	62		1/4/2025 11:00
5589	**2**	21.9	71	424	1/4/2025 11:00
5590	**3**	23.4	67	420	1/4/2025 11:00
5591	**4**	19.9	69	474	1/4/2025 11:00
5592	**5**	19.4	68	482	1/4/2025 11:00
5593	**6**	20.5	79	514	1/4/2025 11:00
5594	**7**	20.5	76	710	1/4/2025 11:00
5595	**8**	20.8	77	456	1/4/2025 11:00
5596	**1**	20.6	63		1/4/2025 11:00
5597	**2**	20.9	78	434	1/4/2025 10:00
5598	**3**	21.5	77	436	1/4/2025 10:00
5599	**4**	19.6	67	470	1/4/2025 10:00
5600	**5**	19.1	66	452	1/4/2025 10:00
5601	**6**	20	74	500	1/4/2025 10:00
5602	**7**	20	77	650	1/4/2025 10:00
5603	**8**	19.9	79	450	1/4/2025 10:00
5604	**1**	20.5	63		1/4/2025 9:00
5605	**2**	20.4	71	460	1/4/2025 9:00
5606	**3**	19	81	478	1/4/2025 9:00
5607	**4**	19.6	65	446	1/4/2025 9:00
5608	**5**	19	67	442	1/4/2025 9:00
5609	**6**	19.9	71	512	1/4/2025 9:00
5610	**7**	19.9	74	682	1/4/2025 9:00
5611	**8**	19.6	72	498	1/4/2025 9:00
5612	**1**	20.7	63		1/4/2025 8:00
5613	**2**	20.3	67	488	1/4/2025 8:00
5614	**3**	16.4	80	504	1/4/2025 8:00
5615	**4**	19.6	66	456	1/4/2025 8:00
5616	**5**	19.1	66	426	1/4/2025 8:00
5617	**6**	20.1	69	456	1/4/2025 8:00
5618	**7**	20.1	66	606	1/4/2025 8:00
5619	**8**	19.7	68	504	1/4/2025 8:00
5620	**1**				1/4/2025 7:00
5621	**2**	20.4	67	482	1/4/2025 7:00
5622	**3**	16	81	480	1/4/2025 7:00
5623	**4**	19.8	66	450	1/4/2025 7:00
5624	**5**	19.3	67	438	1/4/2025 7:00
5625	**6**	20.3	68	452	1/4/2025 7:00
5626	**7**	20.3	68	610	1/4/2025 7:00
5627	**8**	19.9	68	468	1/4/2025 7:00
5628	**1**	21	63		1/4/2025 6:00
5629	**2**	20.6	67	436	1/4/2025 6:00
5630	**3**	16.3	79	460	1/4/2025 6:00

5631	**4**	19.8	66	442	1/4/2025 6:00
5632	**5**	19.6	66	426	1/4/2025 6:00
5633	**6**	20.5	68	436	1/4/2025 6:00
5634	**7**	20.4	68	630	1/4/2025 6:00
5635	**8**	20.1	69	482	1/4/2025 6:00
5636	**1**	21.1	63		1/4/2025 5:00
5637	**2**	20.8	68	434	1/4/2025 5:00
5638	**3**	16.7	78	474	1/4/2025 5:00
5639	**4**	20.1	67	388	1/4/2025 5:00
5640	**5**	19.8	66	452	1/4/2025 5:00
5641	**6**	20.7	68	450	1/4/2025 5:00
5642	**7**	20.7	66	644	1/4/2025 5:00
5643	**8**	20.3	68	478	1/4/2025 5:00
5644	**1**	21.3	64		1/4/2025 4:00
5645	**2**	21	68	504	1/4/2025 4:00
5646	**3**	16.8	79	436	1/4/2025 4:00
5647	**4**	20.3	66	446	1/4/2025 4:00
5648	**5**	20.1	66	450	1/4/2025 4:00
5649	**6**	20.9	68	464	1/4/2025 4:00
5650	**7**	21	68	624	1/4/2025 4:00
5651	**8**	20.4	68	470	1/4/2025 4:00
5652	**1**	21.5	63		1/4/2025 3:00
5653	**2**	21.2	68	464	1/4/2025 3:00
5654	**3**	17.2	76	470	1/4/2025 3:00
5655	**4**	20.7	67	442	1/4/2025 3:00
5656	**5**	20.3	66	430	1/4/2025 3:00
5657	**6**	21.1	68	438	1/4/2025 3:00
5658	**7**	21.3	66	614	1/4/2025 3:00
5659	**8**	20.7	68	466	1/4/2025 3:00
5660	**1**	21.7	63		1/4/2025 2:00
5661	**2**	21.4	68	486	1/4/2025 2:00
5662	**3**	17.6	78	448	1/4/2025 2:00
5663	**4**	20.9	65	446	1/4/2025 2:00
5664	**5**	20.6	66	404	1/4/2025 2:00
5665	**6**	21.2	67	464	1/4/2025 2:00
5666	**7**	21.3	68	608	1/4/2025 2:00
5667	**8**	20.9	68	466	1/4/2025 2:00
5668	**1**	21.9	63		1/4/2025 1:00
5669	**2**	21.6	67	376	1/4/2025 1:00
5670	**3**	18.4	77	456	1/4/2025 1:00
5671	**4**	21.2	63	470	1/4/2025 1:00
5672	**5**	20.8	66	436	1/4/2025 1:00
5673	**6**	21.5	68	458	1/4/2025 1:00
5674	**7**	21.5	66	584	1/4/2025 1:00
5675	**8**	21.1	68	448	1/4/2025 1:00
5676	**1**	22	63		1/4/2025 0:00
5677	**2**	21.8	67	466	1/4/2025 0:00
5678	**3**	19.2	75	432	1/4/2025 0:00
5679	**4**	21.4	64	418	1/4/2025 0:00
5680	**5**	24	0	414	1/4/2025 0:00
5681	**6**	21.5	66	452	1/4/2025 0:00
5682	**7**	21.7	65	596	1/4/2025 0:00
5683	**8**	21.2	67	454	1/4/2025 0:00