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Smart HVAC System for a Residential House in Kerala, India and Study of Green Building Regulations in Thrissur, Kerala, India and Dubai, UAE

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by

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Abstract

The objective is to analyze the green building regulations in Dubai, UAE and Thrissur, Kerala. By comparing these regulations. An understanding of the factors that impact the residents of the building built using these green building regulations and what can be learned from each regulation, and if there is a common factor connecting these two cities with different climates. The rising temperatures in fact have reduced similarities between the two, as Thrissur is a tropical wet climate and Dubai is hot however the temperatures and humidity levels during the summer are similar. The comparative analysis will allow for the determination of the most effective building regulations for each city, while the new measuring index will provide an objective way to evaluate the effectiveness of the building regulations in each city. The projects aim to develop a smart HVAC design for a residential two storey building in Kerala incorporating a sustainable design calculation and using sensors that are locally available in the region.

The state of Kerala has developed a vision plan to achieve its 2030 goals, which includes promoting entrepreneurship, environmental sustainability, and social sustainability. This study specifically focuses on the aspect of entrepreneurialism and environmental sustainability. (Kerala, 2014)

The residential house that's been constructed in Thrissur, Kerala is occupied by 2 adults and 2 teenagers. The House has a ground floor area of 1088.80 Sqft and a first floor of 399.23 Sqft.

Key Words:

Key Innovations

A smart framework

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Chapter 1: Introduction

1.1 Background information

The global shift towards sustainable development has resulted in many countries having instituted laws and regulations that are aimed at mitigating environmental impacts and promoting sustainable practices for the construction industry (Jian Zuo, 2014). The UAE's Dubai and India's Kerala, a southwestern state in the southwest, are two regions that are making significant strides in this area. Both locations have experienced considerable urban growth, so sustainability principles play an important role in building environments. An assessment of the similarities, differences, and overall effectiveness of Dubai and Kerala's green building regulations is provided. Based on regulatory approaches, measurement indexes, and key provisions in each region, this study will showcase their strengths and areas for improvement.

Thrissur, a city in Kerala, State of India, is known for its biodiversity and natural beauty. Green building regulations have been enacted by the state to promote energy efficiency, resource conservation, and sustainable construction practices. The regulations use local materials, integrate renewable energy, and manage water according to the local culture and environment. (Kerala, 2014)

In contrast, Dubai has become a global hub for sustainable urban development and ambitious architectural projects. As part of the city's green building regulations, buildings are evaluated for their energy efficiency, water conservation, air quality, and innovation. Despite its economic growth, Dubai's regulations prove its commitment to sustaining the environment.

The study compares and analyzes Kerala's and Dubai's green building regulations. It will also examine the effectiveness of measures of energy efficiency, water conservation, waste management, and renewable energy incentives. Policymakers, industry professionals, and researchers will gain valuable insight into green building regulations because of this comparative analysis. It aims to inform future developments in green building practices through learning from Kerala and Dubai.

A study between the comparison of Thrissur, Kerala and Dubai, UAE has not been done in depth before as the weather and climatic conditions are entirely different. There are nearly 4 million migrants in UAE, and most of them hail from Kerala indicating high share of the economic contribution to the city of Dubai by Keralites among the migrant Indians. (Business, 2023)

Green building systems

The term "green building" refers to the making and executing buildings and methods that are environmentally friendly and efficient throughout the entire life cycle of a building, from the initial stage to the final stage. Green building systems use sustainable materials and construction techniques to reduce construction's negative environmental impacts. The leading Green building Systems used around the world are Building Research Establishment Environmental Assessment Method (BREEAM) which was developed by the The building research Establishment Ltd in the UK, Leadership in Energy and Environmental Design (LEED) developed by US Green Building Council and Comprehensive Assessment System for Built Environment Efficiency created by the Japan Greenbuild Council/Japan Sustainable Building Consortium from Japan. (Jian Zuo, 2014). In India the national level green building codes are the Indian Green Building Council (IGBC) rating system and Green Rating Habitat Assessment (GRIHA). All of these The systems act as a framework to assess the level of sustainability of the building . There is an emphasis in the paper by Sunil Sharma on the need to consider green building principles not only for commercial or residential projects but for all types of development. According to studies, 40% of greenhouse gases are produced by buildings. Due to the efficiency of the building, green building regulations contribute to a reduction in greenhouse gases by reusing natural resources and using environmentally friendly materials. Green building principles mainly focus on efficient energy use and through renewable energy methods and other such processes. This helps to reduce the amount of energy consumed and can even lead to lower costs for the building owner in the long run. Additionally, they focus on reducing all types and pollution thus providing a comfortable and healthier quality to the people in living green regulations approved buildings (Dr.Sunil Sharma, 2023)

The green building systems also promote energy efficiency and water conservation, reducing buildings' carbon footprint. In a number of research studies, many of these green building systems have been compared and analyzed in conjunction with one another. The study shows how green building systems are evolving to better address climate change challenges. By considering the social, economic, and environmental phases of a building, these systems can aid in reduction of greenhouse gases, which helps in controlling global warming. One of the most crucial concepts that are often overlooked is that green building systems cannot be applied internationally due to the varying weather and climatic conditions from one place to another (Krajangsri, 2018). It is therefore necessary for a green building system to integrate sections that are tailored to take these variations in climate and weather into account and provide regulations comparable to those in a green building system.

1.2 Statement of the Problem

Currently, there is no comprehensive research systematically comparing the implementation, effectiveness, and outcomes of green building regulations in Dubai and Kerala, which hinders the identification of best practices and areas for improvement. There is limited literature on the adoption and integration of smart HVAC systems in green buildings, particularly in Kerala, which restricts our understanding of their potential benefits and challenges.

A detailed analysis of the impact of green building regulations on energy efficiency, environmental sustainability, and occupant comfort in Dubai and Kerala is required to evaluate their effectiveness and identify areas for improvement. Understanding the drivers and barriers for the adoption of smart HVAC systems in green buildings in both regions is crucial to promote their integration and maximize their potential for energy savings and indoor comfort.

As a result of the lack of standardized data and comprehensive evaluations of the energy and environmental performance of green buildings in Dubai and Kerala, it is difficult to assess their overall sustainability, energy efficiency, and environmental performance. Comparative analysis is necessary due to the differences in regulatory frameworks, certification processes, incentives, and penalties in Dubai and Kerala, which may influence the success of green building initiatives.

A thorough understanding of the strengths and weaknesses of the existing green building regulations and practices in Dubai and Kerala is crucial for developing strategies for improvement, harmonization, and policy refinement.

By bridging the knowledge gap and providing evidence-based recommendations, the research aims to contribute to sustainable development and address pressing environmental concerns by enhancing green building regulations in Dubai and Kerala and promoting the adoption of smart HVAC systems.

1.3 Project goals

In this project, recommendations will be provided aimed at improving the regulations governing green building in Dubai, including suggestions pertaining to improving existing regulations, addressing implementation gaps, encouraging innovation, and ensuring that regulations are aligned with international best practices in Dubai, UAE and Kerala, India. Throughout the paper, the impact of local cultures, climate conditions, resource availability, and societal attitudes towards sustainability will be explored and a smart HVAC system design is provided for a residential house in Thrissur, Kerala.

1.4 Aims and Objectives

The aims for the project is

1. To compare and analyze green building regulations and policies in Dubai and Kerala.
2. Analyze the similarities and differences between Dubai and Kerala in terms of green building regulations implementation and effectiveness.
3. To assess the impact of green building regulations on energy efficiency, environmental sustainability, and occupant
4. To assess the adoption and integration of smart HVAC systems in green buildings in Dubai and other regions.
5. Provide recommendations regarding the improvement of green building regulations and the promotion of smart HVAC systems in both regions.

The objectives are

1. Conduct a comprehensive literature review to understand green building regulations, policies, and practices in Dubai and Kerala.
2. Analyze and compare the key features, requirements, and standards of green building regulations in both regions.
3. Identify and evaluate the enforcement mechanisms of green building regulations in Dubai and Kerala, taking into account factors such as certification processes, incentives, and penalties.
4. Evaluate the energy efficiency and environmental performance of green buildings in Dubai and Kerala through data collection and analysis of case studies or building performance evaluations.
5. Assess the benefits and challenges associated with the adoption of smart HVAC systems in green buildings. This includes their impact on energy consumption, indoor air quality, and occupant comfort.
6. Consider factors such as technical feasibility, cost effectiveness, and regulatory support in identifying the barriers and drivers for the adoption of smart HVAC systems in Dubai and Kerala.

7. Identify recommendations and strategies to promote green building regulations in Dubai and Kerala, considering the specific socio-economic and environmental contexts of each region.

1.5 Research Methodology

1. Literature Review: A literature review was conducted to determine existing green building regulations, policies, and practices in Dubai and Kerala. The purpose of this is to provide a foundation for knowledge and identify gaps and areas for further study.
2. Comparative Analysis: A comparative analysis of Dubai and Kerala green building regulations was carried out. A study of the key features, requirements, standards, and implementation mechanisms of green building regulations in each region was conducted. Their similarities, differences, and effectiveness in promoting sustainability and energy efficiency were compared.
3. Case Studies: In order to evaluate the energy performance, environmental sustainability, and comfort of green buildings in Dubai and Kerala, case studies were conducted on representative green buildings. Collected data on energy consumption, indoor air quality, thermal comfort, and other relevant factors. An analysis of the performance of green buildings in both regions and the factors affecting their performance was conducted.
4. Data Collection and Analysis: Researched the adoption and integration of smart HVAC systems in green buildings. As part of this process, energy consumption, system efficiency, cost-effectiveness, and feedback from occupants are collected. The data was analyzed to determine the impact and benefits of smart HVAC systems in promoting indoor comfort and energy efficiency.
5. Policy Analysis: Identify the regulatory frameworks, certification processes, incentives, and penalties associated with green building regulations in both regions. Assess their effectiveness, strengths, and weaknesses in promoting sustainable building practices and the integration of smart HVAC systems.
6. Recommendations and Strategies: Develop recommendations and strategies designed to enhance green building regulations in Dubai and Kerala and promote the use of smart HVAC systems. Ensure that these recommendations are formulated taking into account the socioeconomic, cultural, and environmental context of each region.

1.6 Limitations of the Study

The limitations of the study are listed below -:

1. Data Reliability and Availability: There may be limited availability or access to data on green building regulations, building performance, and energy consumption in both Dubai and Kerala, which may limit the depth of analysis and comparison.
2. Generalizability: It is possible that the conclusions of this study are specific to Dubai and Kerala and cannot be easily extended to other regions or countries with different socio-economic, cultural, or regulatory contexts.
3. Time Constraints: Time constraints may limit the scope and depth of the analysis, such as insufficient time to collect data or an inability to analyze a large sample size of green buildings.
4. Challenges in Comparative Analysis: It may be difficult to conduct a comparative analysis between Dubai and Kerala due to differences in the availability of data, regulatory frameworks, cultural contexts, and levels of development.
5. Evolving Regulations and Policies: It is common for regulations and policies governing green building to be updated and revised over time. There is a possibility that the study may not capture the latest developments in the regulatory environment of Dubai and Kerala or future developments.
6. Technological Advancements: Due to the rapid advancement of technology, the study may limit its application to smart HVAC systems. Smart HVAC systems have not yet developed the latest advancements or trends, which could impact the findings.
7. Influence of Other Factors: In addition to green building regulations and smart HVAC systems, other factors, including occupant behavior, building design, and external environmental factors, may also shape building performance.
8. Language and Cultural Barriers: Differences in language and culture between Dubai and Kerala may present challenges when interpreting and comparing data, literature, or stakeholder perspectives.
9. Bias in Data Sources: Depending on which data sources and/or literature are used, there may be a potential bias if they are influenced by particular organizations, institutions, or stakeholders with their own interests.

Chapter 2 – Literature Review

Literature Review

1. Advanced sensing and structural monitoring

Advanced sensors are used to monitor structural health monitoring is an essential field due to the ageing of infrastructure. Though many types of sensors are being used, the significant problems faced by the industry is damage detection and validating them. It affects a lot of disciples like structures, mechanical systems, changes in the environment and human health. Due to environmental changes and boundary conditions, the primary challenge is to detect specific changes and their location. These damages happen suddenly. It is possible to understand these by using sensors such as impact-echo-based sensors. The structural deterioration can be monitored through a vibration-based energy harvester, which collects data continuously, and is not provided are interpolated. The drawbacks of traditional sensors were resolved using image processing techniques in computer-vision based methods. The phase-sensitive optical time-domain reflectometer used in healthcare also provides a different approach to retrieving data through vibrations. The emerging technology in damage detection involves deep learning-based procedures, where the damage features are automatically extracted for all types of damages. (Young-Jin Cha, 2022)

2. AI application in civil engineering

In recent times Artificial intelligence has played an essential role in civil engineering; AI is used to enhance machine elements to human thinking level and provide services in the same manner. In civil engineering, AI has been used for various fields such as structural engineering, transport engineering, construction management, environmental engineering etc. The AI techniques such as ANN (artificial neural network), fuzzy system (Fuzzy logic system creates human-like reasoning), expert system(A computer program that makes human-like expertise to solve problems in a different domain) and swarm intelligence (it shows the collective behaviour of decentralized and self-organized systems) has been used for the enhancement of technology in civil engineering fields. The papers by ET Lee and HC Eun created a prediction model for damage detection in building using the methods such as substructuring, damage detection, static based and dynamic-based substructuring. Another paper by S Golnaraghi et al used different Artificial neural networks methods such as backpropagation neural network, Radial basis network, generalized regression neural network and adaptive neuro-fuzzy interface system to understand which factors affect the labour productivity. The study concluded that temperature is the primary factor affecting labour productivity. A dynamic multicriteria decision-making method for low carbon supplier selection for standard carbon structure constructions, was created by X Cao. The model created had five main criteria and 17 subcriteria for selecting suppliers that provide low carbon items. It was done by using interval-valued triangular fuzzy numbers. (Tayfun Dede, 2019)

3. Moving to green building: Indoor environmental quality, thermal comfort and health.

The paper does a detailed study in Jordan to evaluate if there is any change in the employees' well-being after moving from conventional buildings to the green building following JGBG (Jordan green building guide). The argument is that green office buildings reduce energy consumption and improve green building quality, which will result in a better and more productive working environment for the employees. The study investigates indoor environment quality experienced by the employees in Green buildings against their experience in conventional buildings. It examines if there has been any positive impact for the employees after the transition. The study was done by using sensors and analysis instruments (Pi sensors and SWEMA instruments) and taking surveys of the employees in conventional and green buildings. The study indicated no improvement in employee satisfaction in the IEQ metrics, but there was an improvement in thermal comfort. There was no improvement in the sick building syndromes since 20% of employees still experienced around 5 SBS symptoms. (Rana Elnaklah, 2021)

4. Covid 19 pandemic and sick building syndrome

Coronavirus is an agent for severe acute respiratory syndrome and middle east respiratory syndrome. The Coronavirus that came in 2019, acute respiratory syndrome coronavirus -2, was found. It has become a pandemic that can cause pneumonia and can lead to death due to the acute myocardial injury, and chronic damage to the cardiovascular system. Sick building syndrome (SBS) can happen to the occupants of a poorly maintained building. The symptoms include headache, fatigue, and irritation in the throat and eyes. Due to the outbreak of Covid 19, people of all countries were asked to quarantine themselves to avoid getting infected. The policy of staying at home has made people expose themselves to SBS. Studies indicate that even though outdoor air pollution decreased due to reducing transportation and usage of machines, indoor pollution from cooking and telecommunication still exists. Also, disinfectant and chlorine-based cleaning materials to avoid CoV 2 add to indoor pollution if these are added in the absence of proper ventilation. Due to the high level of sound and odour pollution, SBS is supposed to increase in those buildings with poor ventilation. There will be an increase in individual Stress, anxiety and growth in smoking. Considering these issues, if individuals work accordingly, reducing SBS is relatively high. (Mohammad Reza Hosseini1, 2020)

5. Occupant health in buildings: Impact of the COVID-19 pandemic on the opinions of building professionals and implications on research.

This study investigated the experience, interest and knowledge of experienced professionals in occupant health in buildings. The introduction gives an idea of how many research methods are used to understand indoor environment quality. Mainly subjective assessments include surveys, interviews, and objects such as physiological measurements using sensors and tests. The paper did a mixed methodology of literature review, online survey and effect of covid. The research results indicated that the building professionals had given equal importance to their social, mental and physical well being during the periods covid-19; this was understood even after the research focused entirely on the psychological and physical well being. One of the notable results for physical well being was that the building professionals had mentioned fatigue, tiredness and muscle-skeletal disorders related symptoms which is a physical well-being issues that has affected many. The literature review focuses on signs such as eye throat, nose, skin-related signs which is also sick building syndrome symptoms. In mental well-being, stress, depression, moodswings and anxiety are the main symptoms. At the same time, professionals have the essential building attributes, ventilation and indoor air quality. The literature review shows indoor air quality, thermal conditions, lighting and daylighting. The future of directions can be including various other stakeholders for online surveys and interviews. Also, a lot of the indicators were week attributed to the Covid-19; hence the paper suggests taking a similar research work done once the pandemic is over to understand a different perspective

(Awada, Becerik-Gerber, White, b, & O’Neill, 2022)

6. A comprehensive review on indoor air quality monitoring systems for enhanced public health.

The paper has in-depth discussed Indoor Air Pollution (IAP) exposure in various developed and developing countries and associated risks. The use of wireless technologies for real-time monitoring by developing cyber-physical systems. A critical review in the field of system designing for microcontrollers and challenges in real-time monitoring systems has been indicated along with the future scope of the researchers' IAQ (Indoor air quality)monitoring. The paper depicts that nearly 90% of rural households use biomass for cooking. Even after improving the cooking environment measures nearly a billion people in Asia are still relying on biomass for cooking, which indicates that by 2030 cleaner indoor air target will not be achieved. The indoor air quality monitoring systems are an overview of the indoor air pollution systems which was developed before. As there is a rise based in wireless sensor network (WSN) and IoT (Internet of things), the papers review them in detail. A few of the interesting WSN based IAQM models are mentioned in the below tables. (Saini, Dutta, & Marques, 2020)

Table 3 Summary of IAQ monitoring systems based on IoT

Sr. No.	References	Year	Parameters considered	Architecture	Communication Interface	MCU	Data Access	Remarks
1.	Kang and Hwang [40]	2016	VOC, PM_{10}, CO, temperature and RH	IoT	Bluetooth, Wi-Fi and RF communication module	TI MSP430	Wb server	Comprehensive Real-Time Indoor Air-Quality Level Indicator was designed
2.	Idrees et al. [48]	2018	RH, temperature, O_3, SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10}	IoT	ZigBee and Wi-Fi ESP8266	ATmega328P	Web-based IBM Watson IoT platform, Mobile App	Automatic calibration system was developed fothe r sensor system, performed detailed power consumption and computational cost analysis
3.	Sivasankari et al. [49]	2018	RH, temperature, NO_2, CO and concentrations of smoke	IoT	UART	Raspberry Pi	IP Address on Web	Data can be monitored from anywhere by logging into IP address.

Figure 1. IAQ Monitoring systems based on IoT (Saini, Dutta, & Marques, 2020)

Table 2 Summary of IAQ monitoring systems based on WSN

Sr. No.	References	Year	Parameters Considered	Architecture	Communication Interface	MCU	Data Access	Remarks
1.	Alhmiedat and Samara [32]	2017	CO_2, benzene, NO_x and ammonia	WSN	ZigBee	ATtiny85 microcontroller	Simulation environment	A sleep state algorithm and interface circuit used to minimize power consumption
2.	Kim et al. [35]	2014	CO_2, VOCs, SO_2, NO_x, CO, PM and O_3	WSN	ZigBee	Raspberry Pi	Web server and Mobile	Experiments conducted in three different settings: big church, medium size classroom and small size living room; Real-time monitoring alert
3.	Yu and Lin [36]	2015	CO_2, RH, temperature	WSN	ZigBee	Not available	Web Pages and Mobile App	Use of ARIMA Model for prediction, System provided 55% reduction to the sensor network energy consumption with Fuzzy Log-c based decision model
4.	Abraham and Li [38]	2014	CO, VOC and CO_2, O_3, RH, temperature,	WSN	ZigBee module	Arduino Uno microcontroller	Web Server	Micro gas sensors were calibrated using least square estimation-based method
5.	Bhattacharya et al. [41]	2012	RH, temperature, gaseous pollutants and PM	WSN	ZigBee module	ATmega1281 (Waspmote)	HVAC control application, SMS and email-based alerts can be generated on subscription.	Context-Aware Framework was designed to connect sensors with applications.
6.	Ahn et al. [42]	2017	VOC, light quantity, RH, temperature, fine dust, CO_2	WSN	UART/I2C, ESP8266 Wi-Fi Module	ATmega328P	Linux Server	Comparative prediction models were designed using LSTM and GRU networks
7.	Pitarma et al. [43]	2016	Luminosity, CO_2, CO, RH and air temperature	WSN	ZigBee module	Arduino	Web portal	A dedicated web portal named as iAQ was designed using PHP to access system data
8.	Benammar et al. [44]	2018	RH, ambient temperature, Cl_2, O_3, NO_2, SO_2, CO, CO_2	WSN	ZigBee Pro radio module	ATmega 1281 (Waspmote), Raspberry Pi2 for core gateway	Open-source IoT web server platform	–
9.	Saad et al. [45]	2013	RH, temperature, PM and gaseous pollutants	WSN	AT86RF230 radio frequency front end IC for ZigBee standard	ATmega1281 low power MCU	Web InterfacThe s	Study was carried within the Lab environment.
10.	Tiele et al. [46]	2018	Sound levels, illuminance, CO, CO_2, total VOCs, PM_{10}, $PM_{2.5}$, RH and temperature	WSN	I2C/UART	Feather M0	OLED Display, MicroSD Card	Made use of eNose for data collection, Custom low-cost sensor module was designed using Altium Designer
11.	Arroyo et al. [50]	2019	Toluene, ethylbenzene, benzene, and xylene	WSN	ZigBee	Not available	Cloud server	Laboratoy based case study

Figure 2. Summary of IAQ monitoring system based on WSN (Saini, Dutta, & Marques, 2020)

The authors note a need for real-time IAQ monitoring systems, including prediction models. They were making use of deep learning models like LSTM and GRU.

7. Green building regulation in dubai and draw backs.

The green building regulation of Dubai provides regulations and specifications for building a efficient and less carbon foot print buildings in Dubai. Its sections include Ecology and planning, Building Validity, Resources Effectiveness in Energy, water and waste. This was done to create a healthy city with high standard of development in a sustainable way and have environmentally friendly materials and design tahta suits the city's climate being used to provide the buildings. The green building regulation was made in line with Dubai's action plan, to run a more sustainable metropolitan environment, 4 of the existing legislations were revoked to implement the present green building regulation. The building types chosen for this project 'Offices' belongs to residential and commercial typology. The indoor air quality monitoring is ' Demand controlled ventilation' which indicates that the CO2 levels should be kept below 800 parts per million and an alarm should be triggered in case these levels go up. It also indicates that the sensors kept should be checked every year by an authorized person.

The regulation does not have any other indoor air quality monitoring regulation where the concentration of other indoor gases are checked such as Benzene, Nitrogen and VOCs. This remains a drawback. In older buildings, the level of other gases can be higher due to the deterioration of MEP installations. (Municipality, 2015)

8. Development of an indoor air purification system to improve ventilation and air quality

The efficacy of reducing carbon dioxide (CO 2) concentration using new types of air purification systems, Air handling units in office buildings was examined in India. There are experiments done using an air purification system. The results indicate there was a 40% reduction in CO2 levels. Majorly Carbo dioxide, Sulfur dioxide, Nitrogen dioxide. All these gases showed a necessary decrease in percentage. The description of the air purification system and its benefits can be used even in Dubai to control indoor air pollution. Also, the cost of maintenance can be reduced.

9. Using circular economy principles to recycle materials in guiding the design of a wet scrubber-reactor for indoor air disinfection from coronavirus and other pathogens.

Airborne microbes like SARS-CoV-2 can be deactivated using the proposed wet scrubber reactor. An easy-to-reproduce and relatively inexpensive component is used in the design of the wet scrubber reactor, which is a structure made of clay and glass. Viruses associated with severe acute respiratory syndrome (SARS) have recently been discovered to be the agent of the COVID-19 pandemic, which began in 2020 as a result of the emergence of SARS-CoV-2. There is a danger that commercial air filters will plug when high particulate matter content air is passed through them, and this is a common problem that is currently facing the industry. It is necessary to ensure that commercial fabric fabrics filters and packed beds are capable of strong inactivation efficiencies to prevent bacterial growth and virus growth, otherwise, infection may occur. There have also been negative health effects associated with negative ion air purifiers (NIAPs). Electrostatic precipitation, ultraviolet radiation, and plasma can deactivate bioaerosols in cellular membranes. Infectious diseases spread faster in indoor environments, especially in public spaces. A good way to control this problem is by continuously disinfecting the air to make sure that it is disinfected and free of pathogens so that people can breathe it. Engineering solutions based on a circular economy approach will help achieve sustainability goals to a greater extent. In addition to the use of clay ceramic foams in the design of the new air filter, this new design of the air filter also makes use of widely available natural recycled materials like clay and glass cullet. Providing cleaner natural resources (air, water and land) for healthy living was the purpose of developing the design rationale based on two sustainable development goals (SDGs 3 and 15). (Andrei Shishkina, 2021)

10. Sustainable Building for a Green and an Efficient Built Environment: New and Existing Case Studies in Dubai

    As a part of the book Sustainability, Energy and Architecture, the chapter explains and illustrates Dubai's sustainable buildings (new and existing) as well as the sustainable principles that have been implemented in these buildings and their performance. This chapter contains case studies, representing three newly constructed buildings and three refurbished buildings. It also highlights Dubai's first carbon-neutral warehouse and the first certified LEED office building in the Middle East. There are several energy-efficiency components and water-recycling elements that have been incorporated into the world's tallest tower and one of the highest buildings in the world, the Burj Khalifa, as part of its water-recycling system. This study indicates that it’s possible to have an energy-efficient design and monitor indoor air quality. (Aboulnaga, 2013)

11. Comparative Analysis of international standards for green building

    The German Sustainable Building Council offers one of the most comprehensive sustainability certification systems for urban districts. As far as they are concerned, the system's explicit goal is to be able to impact the very earliest design decisions around the project. This system is designed to incentivize developers and architects to consider the ecological implications of their designs from the start, rather than having to make changes after the project is underway. By doing this, the council hopes to have a more lasting impact on the sustainability of the district.
    This is important because it impacts the very earliest design decisions. It ensures that sustainability

guidelines are baked into the design process from the beginning, rather than trying to retrofit sustainability into an existing design. This allows for much more efficient use of resources, since it eliminates the need for costly redesigns.To determine how the DGNB-UD system can be applied at the early stages of design, the Technical University of Denmark has tested the system in two experimental design projects for similar locations. The results showed that the system could be used to evaluate the sustainability of a project at the early design phase. This system provides a quick and easy way to assess the impact of design decisions on the environment, health and safety, as well as economic and social aspects. As part of this paper, the characteristics of these two independent design processes, compare them, and discuss their general characteristics. The research results demonstrated that this system was able to provide a comprehensive analysis of a project's sustainability, taking into account multiple factors including environmental impact, health and safety, economic implications, and social factors. This system provides a comprehensive yet efficient way to assess the potential consequences of different design decisions, allowing for the optimization of a project's sustainability. Additionally, the paper compared and contrasted the two design processes in order to identify their similarities and differences. (D Alimova, 2023)

12. Preliminary analysis of a catastrophic landslide event on 6 August 2020 at Pettimudi, Kerala State, India

One of the most distinctive geographical features of peninsular India is the Western Ghats, which cover 47% of the region and contribute greatly to the risk of landslides in this area. In the recent past, it has been established that the phenomenon of catastrophic landslides in the direction of the windward slope of the Western Ghats precipitated by heavy rains can be explained by the unique physiography of the area and its climate. The steep topography of the Western Ghats, high precipitation levels, and the presence of impermeable rocks such as laterite and quartzite, all contribute to the instability of the slopes and make them vulnerable to landslides. Additionally, deforestation has caused a decrease in the amount of vegetation stabilizing the slopes, further increasing the risk of landslides. In the Idukki District, Pettimudi as a result of a massive downpour on 6 August 2020, a disastrous landslide occurred. The 2018 Kerala Landslide was caused by heavy rains that loosened the soil of the hillside, as well as the deforestation that had taken place in the area. This combination of factors made the slopes of the hillside unstable, leading to the landslide. A preliminary analysis was carried out to better comprehend the details of the landslide. In addition, it analyzed the main reasons for slope failure and the course of the event.

To better understand the events of the 2018 Kerala Landslide, a detailed investigation was conducted to identify and analyze the causes and contributing factors. In this case,landslide pushed the existing tea plantations from the shola forest mountainous region. A majority of the main causes for the flood can be traced to the ecological destruction caused by deforestation, harmful land usage in the uplands, and the sand mining process in the streams and rivers that have contributed to the silt build-up in the streams and rivers. Deforestation has led to an increase in soil erosion, which in turn has caused silt to build up in the streams and rivers. This silt build-up has caused an increase in the volume of water in the streams and rivers, which has in turn contributed to the landslides in the slopes of the area in Shola Forest and plantations of tea near by. Additionally, the sand mining process has resulted in a decrease in the amount of vegetation available to help hold soil in place, leading to further soil erosion and landslides. A total of 1200 meters were measured as the length of the slope, 30-120 meters as its width, 3-7meters as its depth, and 125 meters as the height of the landslide scar. Sand mining removes vegetation and destabilizes the soil, making it vulnerable to erosion. This is especially true in areas with steep slopes, as the increased erosion can cause landslides. The measurements provided are a testament to the destruction caused by the sand mining process. As a result of the landslide, it was estimated that approximately 70125 metres2 were affected by the disaster. As a result of the heavy rain that triggered the Pettimudi landslide, 66 residents were killed, among which four are still missing, and the amount of rainfall was measured at 61.6 centimetres per day, the highest rainfall value in the area. This massive amount of rainfall was a major contributing factor to the extent of the destruction, highlighting the dangerous consequences of unchecked sand mining. The heavy rain caused the soil to become unstable, leading to the landslide. The sheer weight of the affected soil caused the collapse of many buildings in the area, including homes, which resulted in the death of 66 residents. Additionally, the amount of rainfall that was recorded was much higher than the average amount for the area, leading to the increased instability of the soil.

13. Design of New Green Building Using Indian Green Building Council Rating System

An eco-friendly building incorporates passive architecture into its planning and design. Buildings that are energy-efficient or sustainable are also known as high-performance buildings because it is designed to utilize energy, water, and resources efficiently. Passive architecture is a design approach that seeks to reduce the energy load of the building by taking advantage of natural forces such as sunlight, wind, and air temperature to optimize the building's performance. It relies on natural materials such as clay, stone, and wood to provide insulation and reduce energy demand. It also incorporates passive solar design to reduce the need for mechanical heating and cooling systems. The building and its ancillary units should be designed to maximize their efficiency, the variable approach maximizes the efficiency of water, energy, and recyclables that are consumed during construction and deconstruction. During a building's lifespan, this will play a significant role in improving human health as well as the quality of the environment.

There has been extensive research done in the past 20 years that has contributed to increasing the sustainability of the building sector as an instrument and negate the environmental impact. Green building methods have been developed that have increased the social, ecological, and economic aspects of the green building environment as well.

It is well known that TERI-GRIHA, which has recently been renamed as GRIHA, is regarded as one of the best and most widely accepted national green rating systems, having absorbed numerous modifications and changes submitted by architects and experts throughout the country. GRIHA, which stands for Green Rating for Integrated Habitat Assessment, is a rating system that evaluates a building's environmental performance, taking into account various aspects such as energy, water, and materials. By encouraging the use of locally available materials, the efficient use of energy and water, as well as the use of renewable energy resources, it helps to reduce the environmental impact of buildings in a variety of ways. There are several attributes of the system that the researcher can take advantage of in the development of an application: the use of automated calculations, the preparation of pivot tables, the creation of various graphs, bar charts, flow charts, trees, and the possibility of performing an application using visual basics. In addition to providing a direction to help green designers in employing green concepts and reducing environmental impacts, the IGBC rating program provides a framework for enabling them to use green concepts more effectively to reduce environmental impact. The four main concepts are energy & water efficiency, sustainable materials and resources and indoor environment quality (Magar, 2020).

14. The implementation of Green Building in the UAE: Challenges and Critical Success Factors.

The paper indicates that even though the UAE government has been proactive in specifying standards, there is still a lack of knowledge and understanding amongst the public, which can lead to implementation difficulties. As such, the government needs to create more initiatives to increase awareness and

understanding of existing specifications to ensure successful implementation. The UAE Green Building Regulations were established in 2010 to reduce energy consumption and carbon emissions in the local construction industry. The regulations are designed to promote the utilization of sustainable building supplies and practices in all new developments. The statistical analysis looked at the data collected from interviews with stakeholders and experts in the construction industry in the UAE. It found that each of these five categories had unique challenges that needed to be addressed to successfully implement green building in the UAE. Two systems are currently being used in the UAE to determine whether a building is "green" and how much it costs to maintain it; the LEED system developed by the United States Green Building Council and the Dubai Green Building Council system are being implemented by Dubai as a basis to have more buildings including the green building regulations that is set to take place in 2012. This transition was initiated in 2012 and took place in 2016.
As a second approach, Estedama developed the Pearling system, which is based on the Abu Dhabi building design methodology, and used as a guiding principle for the Abu Dhabi 2030 plan and has been developed by Estedama. Estedama, means sustainability in Arabic language, is a program developed by the Abu Dhabi emirate, which is part of the Emirate's framework for a more sustainable, greener and more environmentally friendly city. This program was developed to come up with a blueprint for a city that can set an example to other cities in the region in terms of sustainability. Rather than concentrating on buildings and structures as a whole, Estidama's aim is to create whole communities and cities to be more sustainable, ensuring that it achieves its goal of achieving sustainability over the long term.

A statistical analysis of the findings of the study has shown that all four main categories of success factors play a significant role in facilitating the implementation of green buildings in the UAE, with the socio-environmental, organizational, economic, and financial factors all being important to the success of green building implementations. This study concluded that it is important that the government provide significant incentives to encourage the implementation of green buildings. This is so that they can be used more efficiently. The government could provide incentives like reductions in energy and water consumption fees for green buildings. This would stimulate the market and help motivate the private sector to switch to green buildings.

Investments in green buildings are considered to be beneficial from a financial perspective by researchers and practitioners.There is a particular applicability of this to the Middle East region, where most of the clients are only interested in the quality cost of a building and will usually award the project to the contractor that offers the lowermost proposition during the tender stage.

The economic implications of this recommendation for the UAE building market require further study. Firstly, the purpose of this study is to make significant contributions to the knowledge of green building in Dubai for two major reasons. Generally, there is very little literature that focuses on the critical success factors for green building implementation, and in particular, a large sample size is used in the context of UAE, which makes this study a particularly significant contribution.The UAE is a country with a unique social context due to the conditions of the majority of the population living there for short periods of time and mostly being tenants rather than owners. Due to the country's specific context, sustainable development has become an important concept.

15. Strategies on Smart Energy Management Policies in India

As urban areas grow, the need for transportation, housing, and other services increases and so does the demand for energy. As more people move into cities, the demand for energy rises, which leads to increased carbon emissions unless planners are able to implement strategies to balance and lower energy usage. Australia and India held seminars on Smart Energy Management for Maintainable Cities as part of TERI and UNSW's cooperation initiative. These seminars were aimed at building capacity and sharing knowledge about how to create sustainable urban environments and how to use energy efficiently in cities. The topics covered ranged from smart energy management to urban resilience to adaptation to climate change.

It is essential that smart cities use more local resources if they want to reduce their energy impact. By doing this, they are less likely to be dependent on fossil fuels in the future. A major part of the endeavor involves the use of energy efficiency as an important part of it. In 2002, the Indian Government passed the Energy Conservation Act, which is designed to reduce the intensity of the use of energy in the country, resulting in the creation of the Office for Energy Efficiency by the government to assist the country in implementing the act. Several energy redeemable enterprises have been implemented by the Office of Energy Efficiency so that people can use less energy by doing so.

In addition to this, a building energy efficiency program, which is known as the National Energy Efficiency Mission (NMEE), was established under the National Weather Variation Act (NWVA) to reduce India's energy consumption and to implement energy efficiency objectives in the country. Through the NWVA's National Sustainable Habitat Mission (NSHM), we are striving to reduce the energy consumption of the community by 50% by the year 2030.

The Green Building Code has been included in a draft set of building bylaws that is designed to help state and regional governments to implement the green building code in their building bylaws. This is a concerted effort of the Solar Nationwide Assignment (SNM), which was created under the NWVA to cross all grid and off-grid solar applications with a coordinated approach.

In 2015, the Ministry of Housing and Urban Activities (MoCUA) established the Smart Mission Cities, an initiative that uses Internet of Things (IoT) technology to facilitate sustainable urban expansion and to achieve energy efficiency and cost reductions while maintaining a sustainable urban growth program. It is important to note that the National Policy of Energy (NPE), which is considered one of the country's most important policies, aims to provide the citizens of the country with rational and reliable energy, as well as reducing the consumption of fossil fuels, promoting the production of low carbon energy, and creating a conducive environment that can lead to economic development.

Several solutions are being explored for making cities more energy efficient, including the use of public transportation, reducing driving, encouraging the use of electric and hybrid cars, and applying solutions based on information and communication technologies (ICT). It is predicted that cities in India will require 3 times more cooling over the next decade, resulting in an increased amount of electricity to be generated as well as an increase in carbon footprints.

The focus in Delhi is on the adoption of SEM in various areas, such as construction, transportation, water, garbage, and public services, with the barriers to the use of SEM in cities of India due to the legal and economic challenges that exist. Energy-efficient buildings should not only provide comfort for the occupants of a building, but also assist in fostering the importance of energy independence within the house. SEM solutions can be divided into three clusters depending on their pertinency: building energy-effectiveness details, demand response solutions, and low-cost solutions.

A variety of space heating, air aeration, and air conditioning systems have been developed over the years, including mutable speed coolers, home-based devices for controlling the temperature, and intelligent fuzzy logic controllers. A wasteland resource depot is incorporated into a strategy for water sustainability and energy management. In order to achieve this strategy, supply, treatment, and distribution need to be managed. As part of the smart water technology, sensors and meters are being used to capture and distribute data in real-time, and SCADA systems for controlling and monitoring the water systems remotely are being used to establish proofs and improve their effectiveness.

A fuel-efficient, low-carbon road transport is a growing market in India, with two primary programs aimed at expanding this market through a variety of initiatives designed to increase sales of these vehicles. A fuel economy standard for light-duty passenger cars has been began in 2017 by the Ministry of Road Transport and Highways in order to reduce total fuel consumption of the vehicles. To determine these criteria, a commercial average fuel budget should be used. There are biogas plants and pipe composting systems in 80% of the homes around India's metropolitan areas, which focuses on garbage collection based on the biodegradable and non-biodegradable. . Compared to other cities in India, Alappuzha is renowned for its cleanliness. A major challenge facing the trash business in India at this point is that there is a need to increase staffing at the level of collection in order to meet demand. Despite the importance of the separation of trash, there are no technical solutions that are easily available and convenient to use. The Energy Preservation Act, 2001 has been passed by the Indian legislature and several measures are introduced both in Indian regulations and legislative to aid in the implementation of SEM in India. In recent years, Indian energy management has been revolutionized through programs like the Jawaharlal Nehru national solar mission along with the smart metropolises assignment had a huge impact on the country's energy management environment. As a result of SEM, governments should implement these rules to deal with issues caused by SEM, as well as advocate emission reduction in their respective countries. (Sujit Kumar, 2022).

16. Sensors for Sustainable Smart Cities: A Review

For the purpose of accomplishing three main objectives, this review summarizes and discusses the literature on the application of sensors to smart cities: to provide an overview of the most important Smart Cities implementations globally; to provide an overview of the six main topics of smart cities sensors; and to figure out the advantages and disadvantages with deployments within a smart city. Essentially, a smart city refers to the combination of all the technologies and subsystems necessary to create it, such as distributed energy generation, smart grids, smart meters, smart buildings, smart sensors, e-mobility, the Internet of Things, and the citizenry. A smart city has a number of these technologies integrated into its ideal model. It should be noted that the ideal model of a smart city incorporates a number of these technologies.

Having sensors for securing a smart city is an imperative step for sustainable development as achieving sustainable development in smart cities relies on different approaches to human and environmental security.

With the help of intelligent sensors, a number of parameters are monitored in real time as part of the energy management process, these sensors are based on the internet of things (IoT), which can be adapted to microcontrollers and virtual sensors as part of the energy management process.

It is anticipated that advances in the implementation and use of sensors in order to develop smart cities can enable the residents to enter a better quality of life, as well as improvements in the use and implementation of sensors. Smart cities can face a wide range of challenges and opportunities related to the development of new sensors and new ways of detecting, preventing, and anticipating future dangers. Currently, security sensors are being developed in a way that can improve their sensitivities, resolutions, and precision as well. (Mauricio A. Ramírez-Moreno, 2021)

17. Green Rating for Integrated Habitat Assessment—A green-building rating system for catalysing climate-change mitigation/adaptation in India.

Energy-related CO_2 emissions caused by buildings account for 39% of all greenhouse gas emissions related to buildings, and operational CO_2 emissions make up 28%, while embodied carbon emissions make up 11% of overall CO_2 emissions. A significant proportion of the greenhouse gases produced by the world come from the top 10 emitting countries, primarily residential buildings, which are responsible for generating more than two-thirds of the total emissions of greenhouse gases. As part of the UNFCCC Demonstration at Kyoto, India showcased its first indigenous GBRS, the Green Rating for Integrated Habitat Assessment (GRIHA), which is authorized by the Government of India. The Indian government should provide guidelines on how the states, municipalities, and other development authorities can implement green initiatives and policies that support the country's commitment to CC. There is an assessment framework called ClimateSMART Cities Assessment Framework (CSCAF), which is designed to aid municipalities towards climate action and to make them more responsive and less vulnerable to CC. CSCAF is an assessment tool that provides a systematic and holistic approach for cities to evaluate their existing policies, plans, and projects in terms of climate action. It also provides guidance on how to develop a comprehensive climate action strategy and how to implement climate projects. In the guidelines, there are six important themes, such as the adoption and promotion of green building, that play an important role in mitigating and adapting to climate change in the built environment. A report prepared by WRI India for codes related to green building, namely: green-building codes and certification/rating systems for building efficiency. A study has been conducted on existing institutional mechanisms for incentivizing GRIHA-rated projects and provides recommendations for other cities that might want to implement them.

An examination of institutional mechanisms for incentivizing projects that are certified green is presented in this study. This study recommends integrating GBRSs into municipal bodies' existing frameworks in order to ensure effective ground implementation of resource efficiency initiatives on the ground as well as supporting the development of smart cities so that they can meet CSCAF requirements. Data and information collection for this study were limited in terms of the project proponents' reluctance to share financial and building performance data, the difficulty in accessing municipal/local-body data, and the inability to obtain information about GBRS-linked inducements in the Indian states and Union territories in which the study was conducted. For a successful incentive structure according to local institutional mechanisms, it is important to further analyses of building efficiency levels and their performances and cost for GRIHA-rated projects in order to enable the most appropriate design of incentives. (Priyanka Kochhar, 2022)

18. Computational intelligence techniques for HVAC systems: A review

It is estimated that buildings produce 40% of energy consumption globally and 30% of CO2 emissions, the advanced methods for assessing the energy efficiency and controlling the emissions from buildings and these have led to the development of different computational assessment. CI (Computational Intelligence), a methodology for solving problems HVAC system’s issues faced during design phase, and the management phase is reviewed in this article. When it comes to HVAC problems, metaheuristic algorithms were the preferred CI method, and in recent years, multi-agent systems (MAS) have become increasingly popular because of the ability to effectively find solutions for the HVAC optimization problems by sorting them into smaller tasks. Metaheuristic algorithms are part of the larger field of Multi-Agent Systems (MAS), which uses agents such as robots or software programs to solve complex problems. MAS is a branch of artificial intelligence that studies how agents interact and collaborate in dynamic environments. Metaheuristic algorithms are optimization techniques that rely on an iterative approach to find near-optimal solutions. They are often used to solve complex optimization problems, such as those found in HVAC systems. Examples of metaheuristic algorithms include simulated annealing, genetic algorithms, and ant colony optimization.

The Computational Intelligence Techniques are used in fields such as Science including chemistry physics and even in robotics and machines. As computing power has become more available and building energy efficiency standards have become more stringent, CI techniques have been used for controlling and detecting HVAC faults. It is difficult to model a sensitive objective function with ANNs, but they are useful for solving nonlinear problems. In addition to offering energy efficiency, robustness, and the ability to react more quickly to external disturbances, logic controllers with fuzzy logic generate more accurate results than other similar controllers. A metaheuristic algorithm is the most common type of CI technique for its specificities and the ability to search. Stochastic optimization techniques use Evolutionary Algorithms (EAs), whereas individual optimization techniques aim to find the optimal solution. Particle swarm optimization is an effective stochastic-created optimization algorithm, but its efficiency is highly dependent on weight and inertia parameter tuning. It depends on the quality of the data whether pattern recognition-based methods are useful for FDD. It is becoming more and more popular for developed countries to invest in energy-efficient HVAC systems, and genetic algorithms and machine learning algorithms are being employed to solve problems pertaining to optimization. There are many simulation programs that you can use, and Matlab/Simulink is the most popular.

19. Intelligent Energy Management Systems: A review

    In order for a system to be useful, it should be able to detect and, in some cases, predict the environment where it will be installed, as well as take the data input to learn the users' ways of activities, favorites, consumption for each device. It also detects and predict any active context. This is why intelligent systems are so important in the modern world. They can process data more quickly and accurately than humans, enabling them to make better decisions in a fraction of the time. Intelligent systems are also better at learning from data, allowing them to adapt to changing environments and user preferences over time.

    As a result of considering the non-functional wants, the intelligent systems should maintain a low-level of intrusiveness by how they interact with users, the physical infrastructure, and how they interact with them from a communication perspective to a communication perspective in terms of how they interact with them from a user perspective. A system like this should take up a minimum amount of processing power and memory and should require the least amount of input from the user in terms of input and output. Additionally, it is essential that the systems are designed in order to limit their impact on physical infrastructures, such as the amount of power they consume or the amount of space taken up, or both. A smart system should be easy to deploy by users as well as do not require the expertise of an expert to be able to install it.

Energy management systems are developed in a different manner to cater to some basic functional and nonfunctional requirements such as Building characteristics, Occupants behaviour, System efficiency and operation and climatic conditions, this is done mainly to follow the methdos used previously and a framework of these methods.

There has been a lot of interest in multi-agent systems as a model for state-of-the-art energy management systems. Artificial intelligence systems with multiple autonomous agents that work together to achieve a common goal are called multi-agent systems.

They have been used to model complex systems such as energy management, traffic control, and economic markets. The open-source system Oberloier and Pearce developed with the help of the National Science Foundation was designed to measure power consumption based on the Digital Universal Energy Logger Node, which they developed together. Energy management systems often include temperature and humidity sensors as part of their process of managing power consumption in order to help reduce and manage energy consumption. An ambient intelligent system using an Intel Galileo board is equipped with the LM35d. The LM35d is a low-power, precision temperature sensor that provides a linear output proportional to the Celsius (or Fahrenheit) temperature. It can be used in conjunction with an energy management system to detect changes in temperature, allowing for more efficient and accurate energy consumption In energy-saving systems, motion sensors and light sensors are essential parts of the system, which allow energy consumption to be as efficient as possible. In energy management systems, the use of smart plugs for environmental sensing is often used.

The devices are usually made with multiple sensors on a single device that is used for energy management systems The digital STROM system was developed that can be used to communicate with other nodes within the smart home in order to feed data to the power meter Direct Control IEMS are those systems whose environment can be modified by actuators in order to control the environment. Basically, this term refers to all systems that are capable of processing data on their own, deciding what to do, and executing it without human intervention This is done by incorporating a Smart Meter Energy Management System into their device Additionally, these systems is used to suggest the replacement of inefficient appliances and devices that lead to energy wastage by using energy-efficient technology. Based on a framework CAFCLA, a recommendation system was developed for home maintenance in order to promote efficient energy use in homes. 20.

20. CAFCLA stands for Context-Aware Flexible Control and Learning Architecture, and it is a platform for developing and deploying intelligent home energy management systems.

Most of systems in the present day use Machine Learning, Rule Engines, Deep Learning models ,Data and Pattern Mining algorithms, and provide intelligent energy-saving recommendations so users can control their energy usage, and make intelligent energy-saving decisions. It has been developed a system that combines both a rule-based deployment with a fuzzy logic algorithm so that a smart meter can be controlled directly using the algorithm, allowing it to be flexible and flexible. The system is designed to take advantage of contextual meta-data derived from smart devices, in order to classify them using extra-tree classifiers, a combination of machine learning and data mining techniques. As part of a workshop on energy management, Dahihande et al developed a system based on mining algorithms for energy management has also been suggested to use MDP as a method to schedule HVAC appliances in a smart home and their energy storage system in a smart way to maximize efficiency. As a result of the necessity to enable interaction between the IEM systems and the users, each IEM system comes with its own User Interface in order to enable interaction. Smart systems use a wide variety of interfaces these days, ranging from smart watches, simple command-line environments, Mobile texts, to applications on cell phone and smart watches, there are many different technologies available to us today. Additionally, there are differences in the ways in which a user interface is presented, meaning that a simple user interface is used for system manipulation, while a complex gamified environment is used for behavioral change systems. There will be an intelligent recommendation system that is based on edge data. It is worth noting that the smartphone app provided a more compressed view of the main dashboard of the system, whereas the smartwatch app designed for the device only displayed the energy footprint breakdown and notifications when the watch wase triggered. (Stavros Mischos, 2016)

Summary

Many key areas in the field of buildings and construction are addressed in the above literature reviews. Problems related to monitoring structural health, detecting damage, and validating sensors are identified, along with the need to understand the impact of environmental changes on structural integrity. There is also a focus on the challenges of implementing green building practices, such as a lack of awareness and understanding among professionals and the public, as well as the need for better regulations to monitor indoor air quality. Additionally, the COVID-19 pandemic has highlighted the importance of addressing sick building syndrome and ensuring occupant health.

Solutions to these problems include the use of advanced sensing and monitoring techniques, such as impact-echo-based sensors and deep learning-based procedures, for accurate damage detection and continuous structural health monitoring. Artificial intelligence (AI) applications play major part in enhancing different attributes of civil engineering, incorporating structural engineering, construction management, and environmental engineering. The integration of AI techniques like artificial neural networks and expert systems helps enhance decision-making and improve efficiency in these fields. Transitioning to green buildings requires a holistic approach, including considerations of indoor environmental quality, thermal comfort, and energy efficiency. While there are challenges in implementing green building regulations, efforts such as improving awareness, providing incentives, and integrating sustainability principles can contribute to successful implementation. Furthermore, strategies for smart energy management policies, such as leveraging local resources, promoting energy efficiency, and utilizing IoT technology, can contribute to sustainable urban development.

Chapter 3- Project Analysis

3.1 Project Description

This project aims to conduct an in-depth analysis of the green building regulations implemented in Thrissur, Kerala and Dubai, UAE, with a specific focus on their environmental sustainability aspects. The objective is to compare these regulations, examining their effectiveness in promoting sustainable practices and reducing greenhouse gas emissions.

Furthermore, this project seeks to address the challenge of ensuring optimal occupant comfort while minimizing the environmental impact of residential buildings. To achieve this, a smart HVAC system following the ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers) will be implemented in a residential house located in Kerala. The purpose of this system is to optimize energy usage and indoor air quality, while simultaneously minimizing greenhouse gas emissions associated with heating, ventilation, and air conditioning.

The implementation of the smart HVAC system aligns with the broader goal of promoting sustainability in the built environment. By integrating advanced technological solutions, this project aims to create a sustainable living environment where the comfort of occupants is prioritized while ensuring minimal environmental harm.

Through an extensive analysis of the green building regulations and the implementation of innovative smart solutions, this project seeks to contribute to the advancement of sustainable building practices in Thrissur, Kerala and Dubai, UAE.

The literature review indicates that there the field of buildings and construction faces challenges related to monitoring structural health, implementing green building practices, ensuring indoor air quality, and addressing the impacts of the COVID-19 pandemic. However, through the integration of advanced sensing techniques, AI applications, and smart energy management policies, solutions can be found to improve structural monitoring, enhance energy efficiency, promote sustainable building practices, and ensure the well-being of occupants.

Chapter 4- Data Analysis

4.1 Comparison of Green Building Regulations Thrissur, Kerala & Dubai, UAE.

The Green Building Rating System used in Thrissur, Kerala, India is the Green Rating for Integrated Habitat Assessment (GRIHA). The green building rating system evaluates the environmental performance of the building. It is a national green building rating system developed by The Energy and Resources Institute (TERI) and The Ministry of New and Renewable Energy (MNRE), Government of India. GRIHA assess various aspects of a building 's sustainability including indoor environmental quality, energy efficiency, , sustainable materials and water conservation. It promoted the use of eco-friendly materials, energy-efficient designs, and renewable energy sources in building construction and operation. (MNRE & TERI, 2010)

The Dubai Green Building regulation used in Dubai; UAE is known as Al Sa'fat – Dubai Green Building System. The Al Sa'fat system makes the building safer for occupants while ensuring the environment is protected. The system promotes innovative ways to combine green systems and technologies in building design, which leads to improved performance, less energy use and efficient electrical and mechanical systems. This method helps to reduce the effect on the environment and the amount of carbon emissions produced. Below table indicates the comparison between the AL Sa'fat and GRIHA –

Description	Al Sa'fat	GRIHA
Scope and Application:	The regulations apply to all new buildings and major renovations in Dubai, regardless of the type or size of the building.	GRIHA is a voluntary rating system applicable to all building types in Kerala, including residential, commercial, institutional, and industrial buildings
Certification and Standards:	The regulations mandate compliance with either LEED (Leadership in Energy and Environmental Design) or an equivalent standard approved by the Dubai Municipality	GRIHA is an Indian green building certification system, specifically developed for the Indian context, with its own rating parameters and criteria.

Focus Areas:	The regulations prioritize energy efficiency, sustainable materials, site developments water efficiency, indoor environmental quality, and waste management.	GRIHA emphasizes site selection and urban planning, conservation of water, efficient energy use, sustainable materials, waste management, and indoor air quality.
Climate Considerations:	Dubai's regulations are designed to address the unique challenges of a desert climate, with specific requirements for thermal insulation, shading, and cooling technologies.	GRIHA considers the tropical and humid climate of Kerala, with emphasis on solar passive design, natural ventilation, rainwater harvesting, and proper waste management.
Local Adaptation:	The regulations align with the local sustainability goals and initiatives of Dubai, aiming to reduce carbon emissions and enhance the city's global standing.	GRIHA promotes sustainable practices that are tailored to suit the local context of Kerala and contribute to its eco-sensitive zones and environmental conservation.
Implementation and Compliance:	Compliance with Al Safat regulations is mandatory for all projects falling within its scope. Building permits are granted based on meeting the stipulated green building requirements in Dubai.	The GRIHA certification is voluntary, and projects can choose to participate and seek certification from the GRIHA Council upon fulfilling the desired rating criteria.

Table 1. Comparison of Al Sa'fat and GRIHA

While both Al Sa’fat and GRIHA promote sustainable building practices, they have different scopes, application areas, and local considerations. Al Sa’fat is a mandatory regulation in Dubai, aiming to enhance sustainability in the city, while GRIHA is a voluntary certification system in Kerala primarily focusing on the Indian building context.

The below section indicates the similarities between Al Sa’fat and GRIHA.

While there are several differences between the Dubai Green Building Regulations (Al Sa’fat) and the Kerala Green Building Regulation (GRIHA), there are also a few key similarities:

Focus on Sustainability: Both Al Sa’fat and GRIHA aim to promote sustainable practices in the construction and operation of buildings. There is a strong emphasis on the indoor environment, usage of a sustainable environment, conservation of water, efficient use of energy, management of waste, and sustainable materials within the construction industry.

Environmental Considerations: Both regulations take into account the environmental factors specific to their regions. Al Sa’fat is designed to address the challenges of a desert climate in Dubai, while GRIHA considers the tropical and humid climate of Kerala.

Certification Framework: Both Al Sa’fat and GRIHA provide a framework for assessing and certifying sustainable buildings. Al Sa’fat mandates compliance with LEED or an equivalent standard, while GRIHA has its own green building certification system with its own rating parameters and criteria.

Promotion of Innovation: Both regulations encourage the use of innovative technologies and design strategies to achieve sustainable outcomes. They incentivize the adoption of renewable energy systems, efficient building systems, and green building practices.

Contribution to Local Sustainability Goals: Both Al Sa’fat and GRIHA support the broader sustainability goals of their respective regions. Al Sa’fat aligns with Dubai's sustainable development initiatives, while GRIHA promotes sustainable practices in line with Kerala's environmental conservation efforts.

Overall, while there are differences in their scope, application, and regional considerations, both Al Sa’fat and GRIHA share a common goal of promoting sustainability in the built environment.

As we see in the comparison and similarities, the major difference is that the Regulations are related to the climatic considerations and local adaptation.

Also one of the findings in this study is that both regulations are not considering the Biophilia into the rating system and regulation. Biophilia refers to the inherent human connection with nature and the positive impact of incorporating natural elements and features in the built environment. It recognizes the importance of creating spaces that enhance the occupants' well-being, productivity, and overall experience through exposure to nature.

Although biophilic design principles are gaining recognition worldwide, they may not be explicitly measured or included as a separate category within the specific green building regulations of Dubai or Kerala. However, it's important to note that aspects of biophilia, such as access to natural light, views of nature, indoor plants, and incorporation of natural materials, can indirectly contribute to other categories like indoor environmental quality, occupant comfort, and urban design.

While biophilic design principles are not explicitly measured, it doesn't mean that designers and builders in Dubai or Kerala cannot integrate biophilic elements voluntarily into their projects. Incorporating biophilia into building design can enhance the overall sustainability and occupants' well-being, even if it's not a formal measuring index within the specific regulations of these regions.

While both Dubai and Kerala emphasize sustainability and environmental performance in their green building regulations, they may not explicitly require or incorporate Life Cycle Assessment as a mandatory measuring index. It is, however, important to take into account the life cycle impacts of materials and buildings in order to gain a better understanding of their environmental footprints and identify areas of improvement that can be implemented.

The concept of a Life Cycle Assessment can be viewed as a comprehensive method that assesses how a product, material, or building impacts the environment throughout the entire scope of its life cycle, including the extraction, manufacture, transportation, use, and disposal of raw materials.LCA considers factors such as energy consumption, greenhouse gas emissions, resource depletion, and waste generation.

Integrating Life Cycle Assessment in green building regulations can encourage builders and developers to prioritize materials and designs that have lower environmental impacts over their entire life cycle. This approach supports more sustainable choices by considering the cradle-to-grave environmental implications of construction projects.

SMART HVAC DESIGN FOR RESIDENTIAL HOUSE IN KERALA, INDIA.

The smart HVAC design was proposed in this design to provide a solution for the rising humidity and temperatures in the state of Kerala and particularly the city of Thrissur. (meteoblue, 2023)

The data below shows the mean annual meteoblue temperature from the year 1979 -2023 by Meteoblue a meteorological services created at the University of Basel, Switzerland.

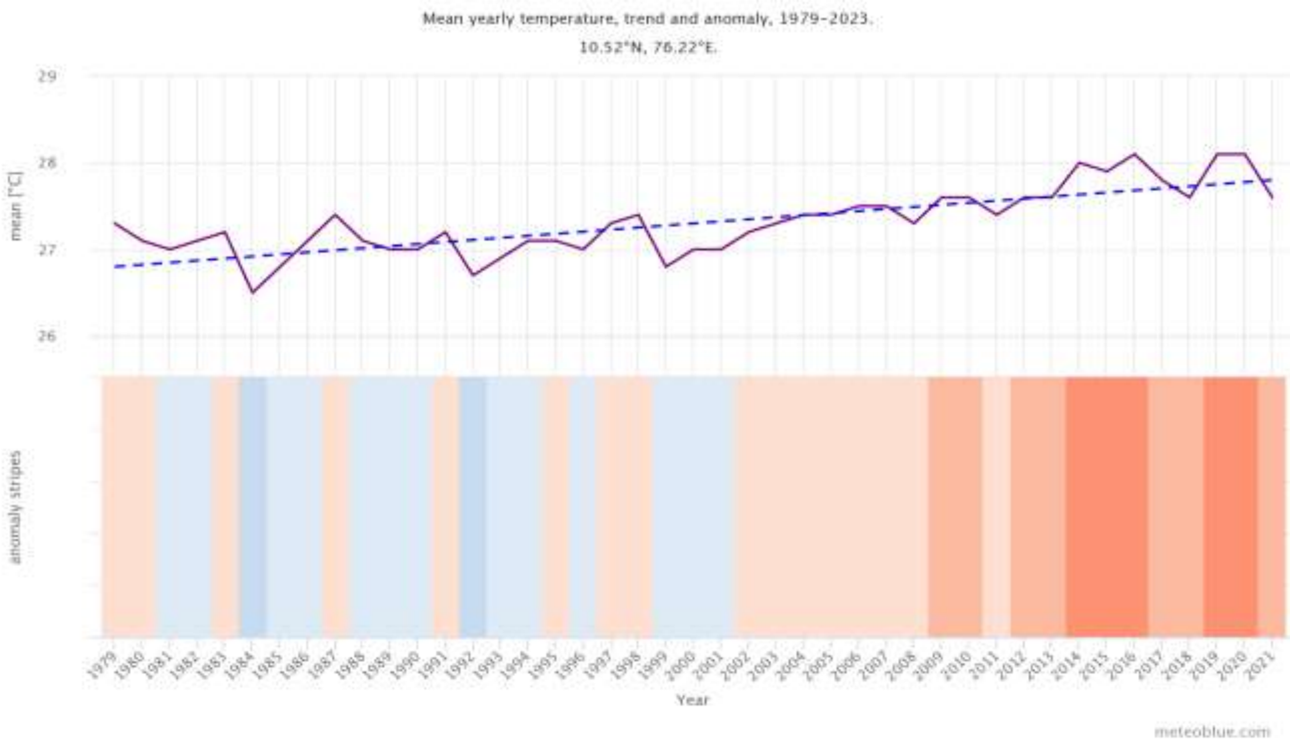

Figure 3. Mean Average Temperature of Thrissur (meteoblue, 2023)

The graph above indicates the increase in temperature by nearly 1 degree Celsius. The purple graph shows how the average yearly temperature in Thrissur, region has changed over time. The dotted blue is for the overall trend in climate change. The slope of the line in the graph tells us if the temperature in Thrissur is changing. If the line goes up from left to right, it means the temperature is increasing, and Thrissur is getting warmer due to climate change. If the line is flat, there is no clear change in temperature, and if the line goes down, it means Thrissur is getting colder. As the graph indicates the line is going up from left to right confirming that the temperature has increased considerably.

The below graphs as taken from Indian Meterological data archive indicates that the humidity levels are to the higher side. The graph also indicates the other major meteorological parameters over the year 2023 below. (Archive, 2023)

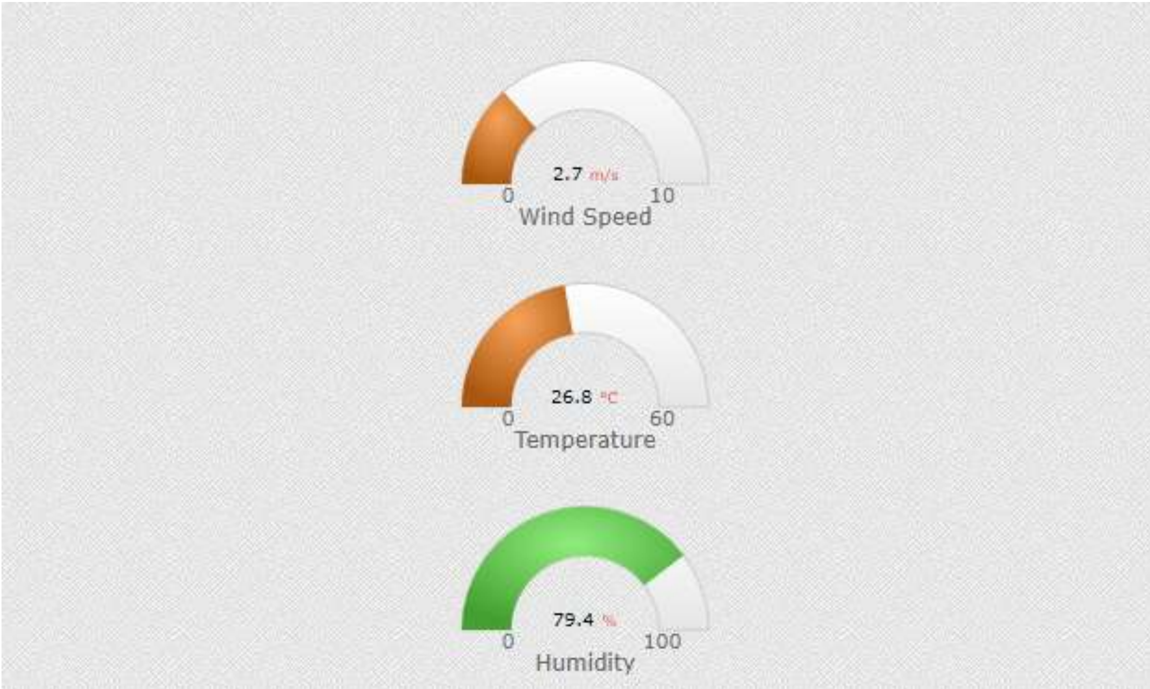

Figure 4. Image taken from India Meteorological Data Archive (Archive, 2023)

Inorder to regulate the temperature and maintain a comfortable indoor environment a Smart HVAC system is designed to the residential house in Kerala, India.Smart HVAC systems offer energy-efficient operation, remote monitoring and control capabilities, predictive maintenance features, data analytics for optimization, and integration with smart home technology. These systems optimize energy usage, provide convenience, detect potential issues in advance, provide insights for better performance, and seamlessly integrate with other smart devices for enhanced automation.

The smart HVAC systems in residential houses have the following advantages over the traditional Air conditioners used in Thrissur currently.

1. Smart HVAC systems provide energy-efficient operation, leading to cost savings and reduced environmental impact.
2. These systems offer remote monitoring and control capabilities, allowing users to adjust settings and receive notifications from anywhere.
3. Smart HVAC systems employ predictive maintenance algorithms, helping to detect and address potential issues before they lead to system breakdowns.
4. Data analytics capabilities provide insights into energy consumption, occupancy patterns, and environmental conditions, enabling optimization for better performance.

5. Integration with smart home technology ensures seamless control and enhances overall home automation capabilities.
6. Smart HVAC systems improve indoor comfort by maintaining optimal temperature and humidity levels based on occupancy and environmental conditions.
7. These systems can learn and adapt to individual preferences and usage patterns, further enhancing comfort.
8. Energy-saving features such as occupancy sensors and scheduling functionalities help optimize energy usage and reduce waste.
9. Smart HVAC systems contribute to improved indoor air quality by employing advanced filtration and ventilation technologies.

Design Details

The Design for the House in Kerala has been prepared as per the ASHRAE standard for Ventilation and Acceptable Air Quality. The plan for the house is shared in the Appendix 1. The zones for the house was considered and the occupancy of the house was also considered to arrive at the below values for ventilation and air conditioning. As Thrissur is tropical and humid climate zone, the heating was not considered under this design.

The Formula is used from Ashrae Ventilation for Acceptable Indoor Air Quality - (ASHRAE, 2015)

- Breathing Zone Out door Airflow - **Vbz = Rp * Pz + Ra * Az.** where,

Rp = Outdoor airflow rate required per person as determined from ASHRAE 62.1 Table 6.2.2.1 (Unit:

CFM/person or L/s/person)

Pz = Number of people in the ventilation zone during use.

Ra= Outdoor airflow rate required per unit area as determined from ASHRAE Table 6.2.2.1 (Unit:

CFM/ft2 or L/s/m2)

Az = Net occupied floor area of the ventilation zone. (Unit: ft2 or m2) (ASHRAE, 2015)

Sl.No	Zone Description	Occupancy Category	Floor Area	Fresh Air Flowrate based on ASHRAE occupancy								
				People Outdoor Air Rate	Area Outdoor Air Rate	Occupant Density	No. of People	Breathing Zone Outdoor Air Flow	Kitchen / Pantry Extract	Total Toilet Extract	Total Extract	Total Fresh Air
			Az	Rp	Ra			Vbz				
			(m²)	(L/s/P)	(L/s/m²)	(P/100m²)	(Pz)	(L/s)	(L/s)	(L/s)	(L/s)	(L/s)
1	LIVING	27. Bedroom/living room	10	2.5	0.3	10	1	6			9	10
2	BEDROOM	27. Bedroom/living room	12	2.5	0.3	10	1	7		15	15	20
3	BEDROOM	27. Bedroom/living room	12	2.5	0.3	10	1	7		15	15	20
4	DINING	27. Bedroom/living room	9.6	2.5	0.3	10	1	6			0	10
5	KITCHEN	21. Kitchen (cooking)	8	3.8	0.6	20	2	11	12		12	15
6	WORK AREA	21. Kitchen (cooking)	4.3	3.8	0.6	20	1	6			0	10
	Ground Total		**56**								**51**	**85**
1	BEDROOM	27. Bedroom/living room	12	2.5	0.3	10	1	7		15	15	20
	First Floor Total		**12**								**15**	**20**

Figure 5. Smart HVAC Design (Values)

The Sensors to be provided are as follows –

Temperature Sensors: Monitor the ambient temperature to ensure accurate temperature control and comfort.

Humidity Sensors: Measure the level of humidity in the air to regulate and maintain optimal humidity levels for comfort and prevention of mold or moisture-related issues.

Occupancy Sensors: Detect human presence in a room or area to adjust HVAC settings based on occupancy, optimizing energy usage.

CO2 (Carbon Dioxide) Sensors: Measure the concentration of CO2 in the air and regulate ventilation accordingly to maintain indoor air quality.

Air Quality Sensors: Monitor and detect pollutants such as VOCs (volatile organic compounds), particulate matter, or odors to ensure a healthy and clean indoor environment.

Light Sensors: Measure the intensity of light to optimize lighting control, which can impact HVAC functions in terms of temperature regulation and energy consumption.

Outdoor Climate Sensors: Gather data on outdoor temperature, humidity, and weather conditions to adjust HVAC settings accordingly and optimize energy efficiency.

Pressure Sensors: Measure pressure differentials in ducts or airflow to ensure proper ventilation and airflow balance throughout the system.

Leak Detection Sensors: Detect leaks or water accumulation in HVAC equipment or pipes to prevent damage and improve system efficiency.

Power Monitoring Sensors: Monitor energy consumption and provide data for energy management and optimization.

By using a combination of these sensors, a Smart HVAC system can gather real-time data, make informed decisions, and adjust HVAC settings for optimal comfort, energy efficiency, and health.There are plenty of local vendors available in the region which provides affordable sensors of each of the above type to be incorporated in the site.

Limitations of Study

The design has been prepared as per ASHRAE standards (American Society of Heating, Refrigerating and Air-Conditioning Engineers), India uses ISHRAE (Indian Society of Heating, Refrigerating and Air-Conditioning Engineers). However, ASHRAE is accepted in the region. One another limitation is lack of awareness among the people of the region to move to smart HVAC systems and the long term benefits.

Chapter 5 - Conclusion

5.1 Conclusion

GRIHA, the green building rating system used in Thrissur, Kerala, India, evaluates and promotes sustainable practices in various aspects of building design and operation. It emphasizes on efficient energy use, conservation of water, maintain healthy indoor environmental quality and usage of sustainable material. GRIHA encourages the adoption of environmental friendly materials, designs where conservation of water and efficient energy use is prioritized, and incorporating renewable energy sources to minimize the environmental impact of buildings.

In contrast, Al Sa'fat is the green building regulation implemented in Dubai, UAE. It focuses on ensuring occupant safety while safeguarding the environment. Al Sa'fat promotes the use of innovative green systems and technologies in building design to enhance overall performance, reduce energy consumption, and optimize electrical and mechanical systems. It also aims to minimize the carbon emissions associated with building operations in order to lessen environmental impact.

Both GRIHA and Al Sa'fat contribute to sustainable building practices by prioritizing usage of sustainable materials, water conservation, waste management , indoor environmental quality, and energy efficiency. While GRIHA is tailored to suit the specific context of Kerala, Al Sa'fat aligns with Dubai's sustainable development initiatives. These green building initiatives in Thrissur and Dubai play a significant role in creating more sustainable and environmentally conscious built environments in their respective regions.

Both the Dubai and Kerala green building regulations currently do not explicitly consider biophilia or life cycle assessment (LCA) as separate categories within their frameworks. However, integrating biophilic design elements voluntarily can enhance occupant well-being and sustainability. Meanwhile, incorporating LCA into the regulations would encourage sustainable choices and address the effect of changes of environment on the existing and new buildings and materials throughout their entire life cycle.

The design proposed for the smart HVAC system in Thrissur, Kerala addresses the rising humidity and temperatures. The temperature data shows a significant increase over time, indicating the impact of climate change. To regulate temperature and provide a comfortable indoor environment, a smart HVAC system is designed for residential houses. This system offers energy-efficient operation, remote monitoring and control capabilities, predictive maintenance features, and integration with smart home technology. Sensor components such as temperature, humidity, occupancy, CO_2, air quality, and more are incorporated into the system, facilitating real-time data gathering for informed decision-making and optimal comfort.

5.2 Recommendations

The main recommendations are after further study to incorporate the biophilia into the regulations for both regulations inorder to bring more importance to people's well being. Life Cycle Assessment (LCA) evaluates the effect on the environment due to the use of products or buildings from raw materials to disposal, considering energy consumption, emissions, and waste. Integrating LCA into green building regulations promotes sustainable choices by prioritizing materials and designs with lower environmental impacts throughout their life cycle. A smart HVAC system is proposed to ensure that the residential spaces are incorporated in the most efficient manner and with less impact on the environment.

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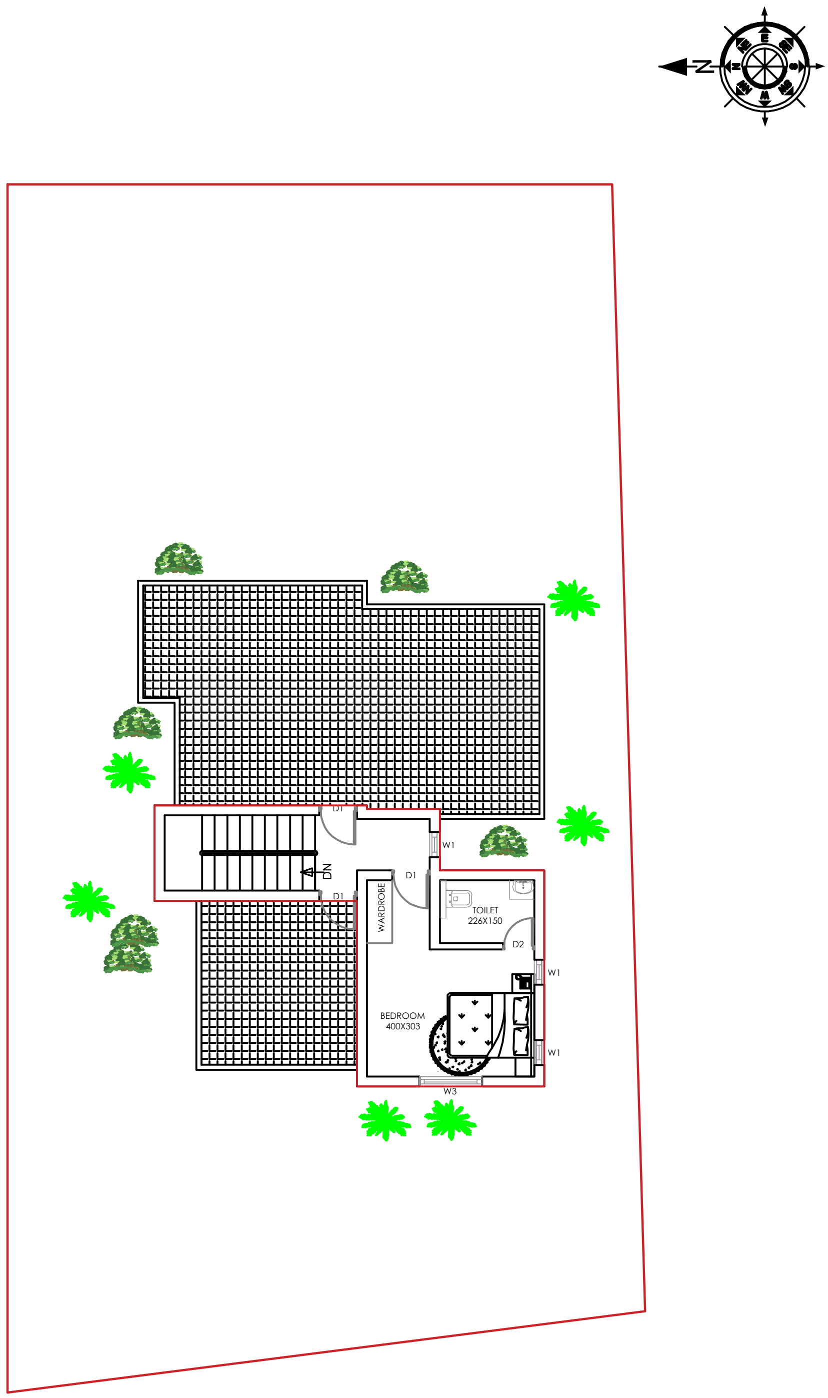
Appendix

Siya Residential House plans – Thrissur, Kerala, India.

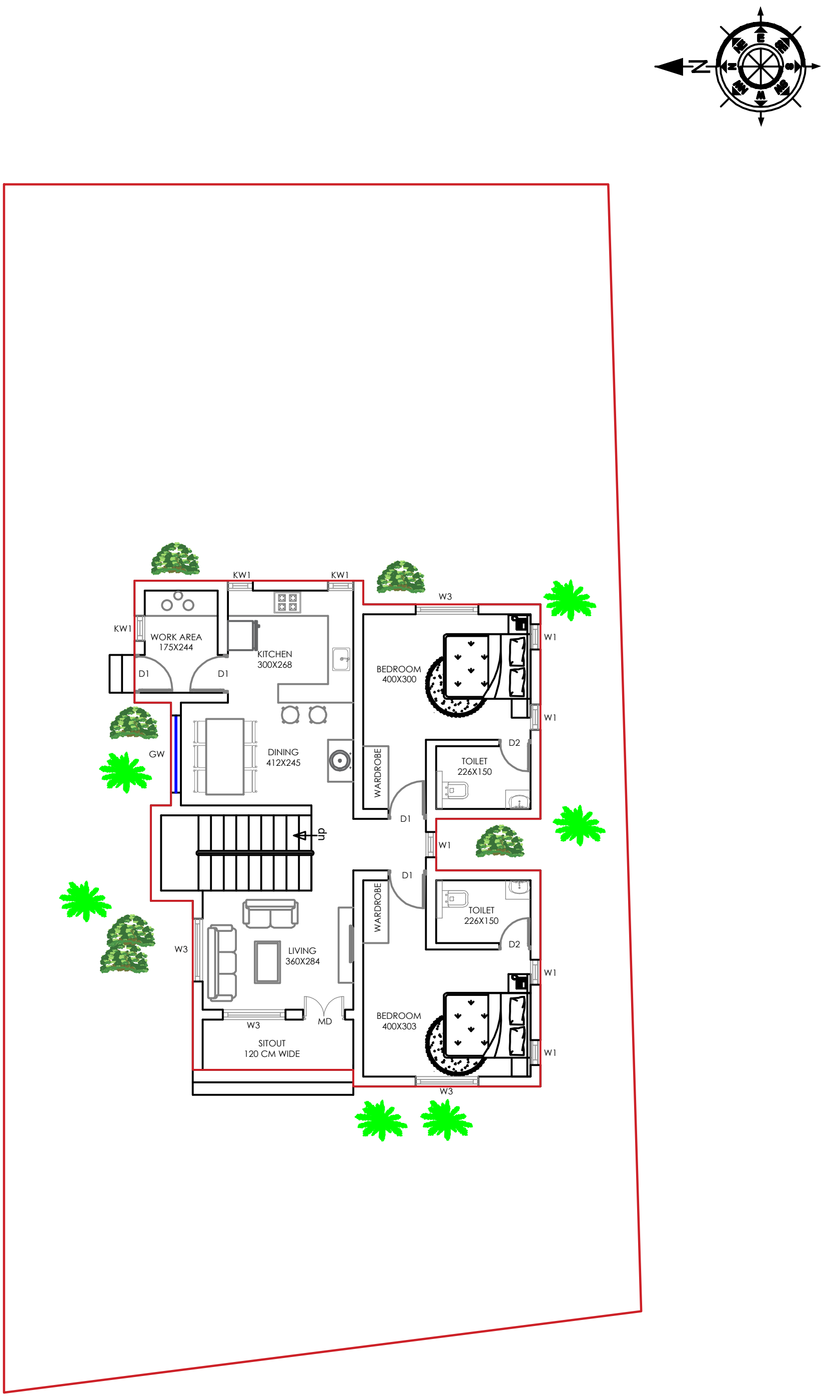


AREA DETAILS :-

PLINTH AREA DETAIL OF PROPOSED BUILDING

FIRST FLOOR : 399.23 sq.ft

ALL DIMENSIONS ARE IN METERS	SHEET No. 02	DATE : 10.08.2021



AREA DETAILS :-

PLINTH AREA DETAIL OF PROPOSED BUILDING

GROUND FLOOR : 1088.80 sq.ft

ALL DIMENSIONS ARE IN METERS	SHEET No. 01	DATE : 10.08.2021