Sandaru, S.A.D., Liyanage, D.L.C.P., Anuradha, I.G.N., Kumarathunga, J.U. and Kalugala, C., 2023. An IoT-based electrical and electronic appliance management system for Sri Lankan residential buildings. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ramachandra, T. and Ranadewa, K.A.T.O. (eds). *Proceedings of the 11th World Construction Symposium*, 21-22 July 2023, Sri Lanka. [Online]. pp. 149-161. DOI: https://doi.org/10.31705/WCS.2023.13. Available from: https://ciobwcs.com/papers/

AN IOT-BASED ELECTRICAL AND ELECTRONIC APPLIANCE MANAGEMENT SYSTEM FOR SRI LANKAN RESIDENTIAL BUILDINGS

Samarakoon Arachchige Dinusha Sandaru[1], D.L.C.P Liyanage[2], I.G.N Anuradha[3], Janani Uvasara Kumarathunga[4] and Chanuri Kalugala[5]

ABSTRACT

Sri Lankan household energy consumption was accounted for around 34% of national energy consumption in 2017, and residential applications were accounted for 36% of national energy waste in 2018. Therefore, reducing the energy wastage in the household environment is essential. Researchers from all around the world are working to develop IoT-based solutions to reduce energy wastage, but there are certain challenges in adapting them to the local context as those techniques were developed for foreign domestic usage. As a result, it is crucial to come up with IoT-based solutions which are appropriate for the local environment to assist the reduction. Therefore, this article examines the importance and feasibility of adopting IoT-based electrical and electronic device control systems for household use in Sri Lankan environments. Further, a mobile application was developed to monitor and control the system, which was installed for a residential building after an analysis of the domestic requirements. This system may simply fix into an existing building, making it a cost-effective application for reducing energy wastage in developing countries.

Keywords: *Electrical and Electronic Appliance Management System; Energy Wastage; Internet of Things (IoT); Smart Building.*

1. INTRODUCTION

The population growth has expanded dramatically because of the industrial revolution, technological innovation, and improvements in comfort, resulting in higher energy consumption (Pearson & Foxon, 2012). When global warming causes environmental concerns like climate change, energy supplies are exhausted because of this high energy demand (Owusu & Sarkodie, 2016). Building energy usage has reached an all-time high when compared to other sectors (Anuradha & Halwatura, 2021; Anuradha et al., 2019).

[1] Master's candidate, Department of Civil Engineering, University of South Wales, United Kingdom, Dinushasamarakoon01@gmail.com
[2] Senior Lecturer, Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka, dlchamara@sjp.ac.lk
[3] PhD candidate, University of Western Sydney, Australia, namalanuradhagamage@gmail.com
[4] Quantity Surveying graduate, Department of Quantity Surveying, Sri Lanka Institute of Information Technology, Sri Lanka, janauvasara@gmail.com
[5] Academic Instructor, Department of Quantity Surveying, Sri Lanka Institute of Information Technology, Sri Lanka, chanuri.k@sliit.lk

Throughout its entire cycle, a structure consumes energy in a variety of ways. Construction utilizes about half of all non-renewable materials that humans utilize (energy, water, and raw materials) (Yuksek & Karadayi, 2017). Figure 1 indicates the energy consumption from 2018 to 2031 in Sri Lanka (Sri Lanka Electricity Board [SLEB], 2017).

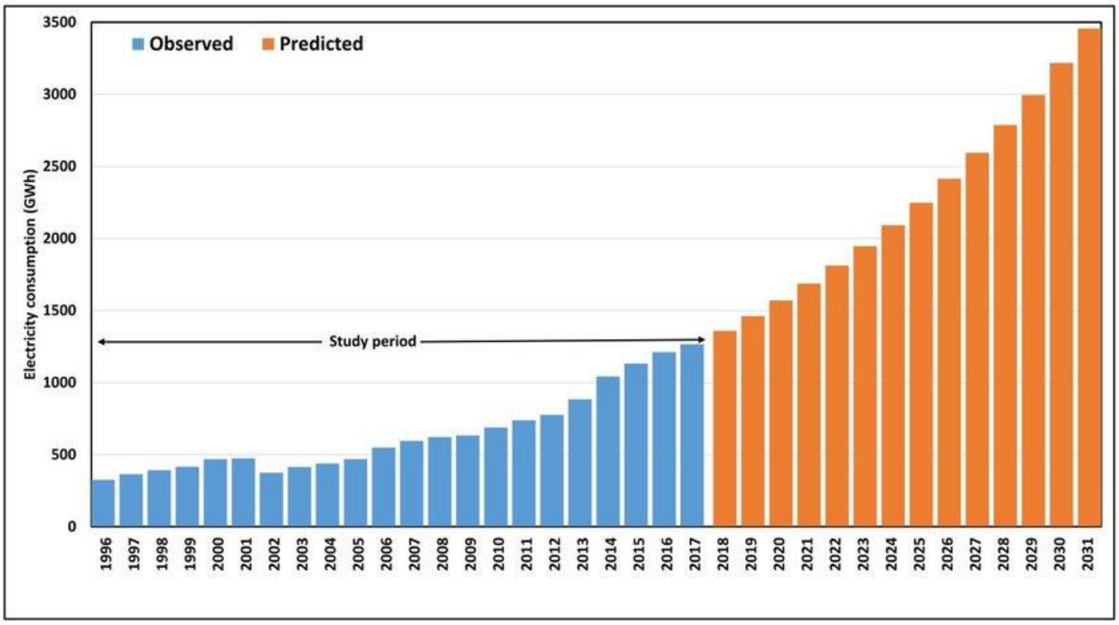

Figure 1: Increment of Energy Consumption in Central province, Sri Lanka (SLEB, 2017)

Figure 1 indicates that the energy consumption from 2018 to 2031 is projected to have a 7% growth rate (Sri Lanka Electricity Board [SLEB], 2017). According to the Energy Conservation Fund (ECF) of Sri Lanka, residential and commercial energy consumption is accounted for around 51.10%, while industrial energy consumption is accounted for around 24.41% (Fernando & Jayasena, 2009). Modern architecture is hampered by several functional needs that must be met to reach a higher standard of living today. Lighting has been a priority in modern architectural designs as a building function that is used to achieve the building's most attractive appearance (Almeida, 2010). Lighting produces a visual environment in a building, and it is a crucial component of energy usage. Lighting energy accounts for around 17% of the electricity consumed by office buildings in United States (Pohl, 2016). When it comes to energy wastage caused by lighting, poor lighting control is the most common cause (Derby, 2006). People make common behavioural blunders by failing to turn off lights when there is an adequate daylight available and when lighting is not necessary for the reticular area. Energy losses caused by the above mentioned human behavioural errors can be considerably reduced with the help of an appropriate lighting control system (Tetlow et al., 2014). The mishandling of electrical appliances and equipment is a major source of energy wastage in buildings when it comes to electronic equipment. According to recent studies, an efficient home appliance system can save up to 30% of total home appliance energy usage (Michaels, 2018). Nevertheless, construction industry is still adapting traditional technologies (Anuradha et al., 2021). This research focuses on using an IoT system to control these devices and assist them to minimise their electrical energy wastage.

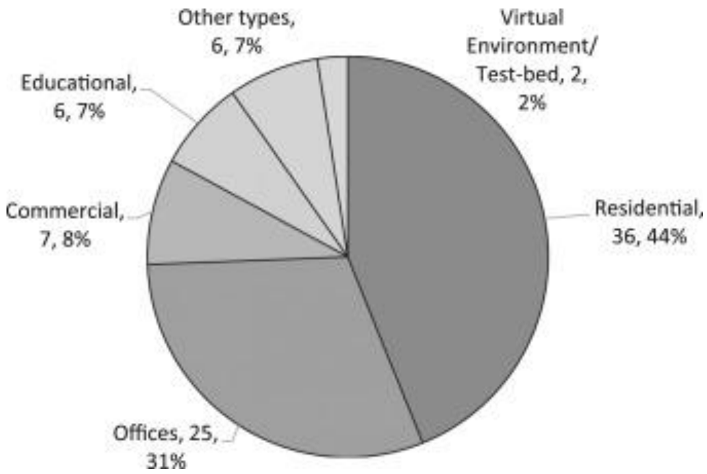

Figure 2: The energy wastage according to the building type (Delzendeh et al., 2017)

One of the most essential aspects of modern civilization is energy conservation. Energy efficiency will likely to become one of the most essential construction elements in future buildings (Acosta et al., 2016). Smart home devices, including smart meters, energy monitoring systems, and connected appliances, provide real-time and detailed information about energy consumption within a household. These devices often come with user-friendly interfaces or smartphone applications that allow homeowners to access and analyse energy-related data easily. The primary goal of this study is to reduce energy wastage in Sri Lankan homes by better regulating the lighting system and home appliances. Building management systems (BMS), currently available in the market are not suitable for the usage in Sri Lankan homes due to several reasons; (I) the majority of the BMS systems have been developed for industrialized countries and not suitable for Sri Lankan set up, (II) those solutions are really expensive and therefore consumers are reluctant to invest more money in such systems, and (III) the dearth of understanding of the people about the field. Thus, the study aims to create an IoT-based lighting and electrical, electronic device management system which is more suited for household use in Sri Lanka. Therefore, the objectives of the study were set up as: (i) to investigate the significance of IoT-based applications in Sri Lanka, and (ii) to develop a lighting control system and an electrical, electronic appliance management system.

2. LITERATURE REVIEW

Based on evaluations of IoT and smart applications, IoT is defined as a network of interconnected devices and systems that collect data from physical components using sensors and actuators, allowing data to be accessed remotely (Ande & Rojatkar, 2017; Sharma & Tiwari, 2016). IoT comes hand-in-hand with the concept of Smart Homes, where electronic systems and products can be automated for easy control by the users to improve comfort, convenience, efficiency and security (Li et al., 2011). According to Busatto et al. (2019), the combination of IoT with Home Automation systems (HASs) is a promising alternative that can guarantee higher energy efficiency. There are comparable functionalities in the smart home devices can be supported to fulfil consumers' specific needs and preferences. The functionality, ease of us, data accuracy, compatibility, energy saving features, privacy and security, and price and value are some key factors to assess how well the devices align with their specific needs, preferences, and long-term goals for energy management and automation. Smart Home Technologies (SHTs) are built from a network of devices, interfaces, sensors and monitors that can work together to enable automation and allow the domestic environment to be controlled locally as well as remotely (Cook, 2012). Lighting systems, hot water systems, fridges, windows, garage doors, curtains, and washing machines are among the most prominent controllable appliances and devices (Robles & Kim, 2010). Several factors influence the impact of lighting on a building's energy consumption (Zhao & Magoulès, 2012). Claddings of a building, percentage of openings are all important considerations. Lighting plays a significant role in the daily lives of people, not only during the night but also during the daytime where artificial lighting is used indoors (Tang et. al., 2017). According to a study by Spyropoulos and Argiriou (2011), lighting energy usage is calculated as a variable percentage of the building's total energy consumption, ranging from 15% to 60%. The Luminous Energy Index (LENI), which quantifies the annual energy consumption of lighting per square meter (kWh/m^2/year), is a criterion for estimating lighting energy consumption (European Standards, 2006). The adoption rate of LED as the main light source has increased in the residential segment due to its high efficiency, long lifespan, and the ability to perform more challenging controls on LED compared to florescent lamps and halogen bulbs (Baumgartner et al., 2012). It is possible to improve living standards in terms of convenience, customizability, ambience and power saving through the use of an LED-based intelligent lighting system (Tang et. al., 2017). Implementing an efficient lighting system can handle the overall problem of optimizing the availability of natural light in a structure, regardless of the metrics used to measure the availability of sunlight in a building (Yu & Su, 2015). Changing energy consumption patterns is critical to reduce energy losses. Nevertheless, changing the behaviour of people is very difficult (Yang & Lee, 2014). A study showed that 15% of the energy consumption in residential buildings was due to artificial lighting (International Energy Agency [IEA], 2015). Daylight harvesting is a process where daylight is used to counterbalance the amount of electrical energy needed to light up a space (Xu et al., 2019). This process can be used to save up to 27% or even 40% of lighting power in regions that receive adequate to high amounts of daylight, respectively (Wen et al., 2006; Tang et. al., 2017). Occupancy control is a common approach for managing lighting use; occupancy sensing control systems turn lights on in a place when motion is detected, then turn lights off after a pre-set interval if no motion is detected (Guo et al., 2010). Electrical appliances in standby mode are one of the most common sources of energy wastage, accounting for up to 10% of total energy consumption in buildings (Olatunji et al., 2019). Providing adequate feedback to building occupants, can dramatically reduce overall energy use in between 5-20% (Derby, 2006). However, relying solely on people's awareness and behaviour is not an effective strategy. Indeed, a recent experimental investigation found that more than 30% of energy savings were achieved after installing a monitoring system in a residential building (Jiang et al., 2009). Philips Hue, LIFX, and OSRAM Lightify are several of the leading smart lighting systems in the market. SHT developers have identified that the most significant barriers towards the adoption of these technologies are the upfront cost, lack of awareness, and concerns regarding privacy (GfK, 2016). A significant issue identified with these products is the lack of closed-loop feedback to control the illuminance level of the space, thereby daylight harvesting cannot be conducted without the use of external sensors (Tang et. al., 2017). Studies related to the users' perspectives have revealed that while there is an interest regarding the energy-saving potential of smart home devices and lighting management systems, there are also market barriers to adoption such as high cost, interoperability of different technologies, privacy, and security loopholes such as the threat of hacking (Wilson et. al., 2017). Research conducted on improvement of smart homes proposed solutions such as connecting the smart homes to the cloud or modifying residential gateways in smart homes to include the home energy management system (Han & Lim, 2010). An IoT-based system which allows the user to control the power supply via a mobile app or the web will result in the user's ultimate happiness while also conserving energy. People are more likely to operate electrical equipment efficiently when they are at their fingertips. When a gadget is not in use but in standby mode, it has become a habit to leave electrical equipment plugged in even when it is not in use. This may not appear to consume a lot of energy, but it has been demonstrated that avoiding this can save the energy wasted.

3. RESEARCH METHOD

This system development is divided into two halves. The first step, the lighting management system comprises the NodeMCU as the lighting management's main processing unit. As well as all sensors (DHT11, LDR, and PIR motion sensor) that may be linked to the NodeMCU. The sensors are connected and operated by the NodeMCU, and it is used to retrieve and process data obtained through the sensors, as well as update it to the cloud via the WI-FI module (Google fire-based MQTT broker). The data from the sensors can be shown via a smartphone app or a Google Fire-based app, as well as a mobile app produced with Kodular App Inventor. Also, NodeMCU performs as a relay module for lighting control. The on-off and timer facility are given to the plug points through the mobile app. When compare with other platforms having costly licensing hooks and closed source practices, the GCP stack is best controller for lighting management system. The key aspects such as compatibility, user interface, functionalities such as voice control, scheduling, and automation are offered in this app.

The next step is the development of electronic appliance management. The mobile app controls the lighting system using a Thing-speak MQTT broker. The MQTT is an emerging and efficient transport protocol has been used the early 2000's and now with ISO Standard. Further, it will be able to increase velocity and reduce complexity for IoT products and services. The PIR sensor is used to detect their motions and turn the light on, but during the day, it will turn off. The PIR sensor will detect movement if someone enters the area, but the light will not turn on because the LDR sensor determines the time (the daytime or the night-time). When person wants to turn on lights throughout the day, they can do so with the use of a smartphone app. A timer to turn lights on and off can also be set via the mobile app.

The hardware components required for the development are NodeMCU, PIR motion sensor, LDR sensor module, power supply, relay module, and voltage converter unit. Arduino IDE, and Kodular app invertor can be listed as the required software in this step. Further, for remote access purpose, connection for online service is essential. This technology is designed to manage the lights efficiently. This has been built as a one-box assembly to make installation easier. Therefore, there is no need to modify the existing electrical wiring during installation in the building. The main unit in this circuit is the NodeMCU which is directly connecting with all sensors and other subcomponents. The mobile application facilities turn on and off motion detection and regulate lighting. As a result, the motion detection sensor and the NodeMCU have been connected. Even if the room is inhabited, keeping the lights on will waste energy due to adequate daylight.

The LDR sensor will be used to check the presence of sunshine in the room, and only when there is no proper sunlight, the motion-detecting sensor is activated. An LDR sensor has been used to connect the NodeMCU to the PIR motion sensor. The relay module controls the lighting. The LDR sensor outputs a 5v DC signal, but to operate the lighting, it must regulate a 230v AC. Therefore, the PIR motion sensor output is connected in the terminal to the 5v-230v relay module supply. Then the schedule is done. The D8 pin on the NodeMCU ESP8266 is connected to a 5v-230v relay. When a current is allowed to pass at the precise time, the D8 pin will stop allowing the current to flow when the timer expires. The current passing will activate the relay via the D8 pin. The relay will be connected to the lighting. As a result, the lighting will be controlled by the current travelling through the D8 pin. Next in order to control the IoT base, the ESP8266 D9 pin is set as the switch in the mobile app. When the light is turned on via the mobile app, a signal is sent to the NodeMCU. The D9 pin sends a current to the relay module to turn on the light when the app sends a signal to do so.

Developing an electronic appliances management unit for time scheduling, the D10 pin on the NodeMCU ESP8266 is connected to a 5v-230v relay. When a current is allowed to pass at the precise time, when the timer expires, the D10 pin will stop allowing the current to flow. The current traveling will activate the relay via the D10 pin. The relay will be connected to the lighting. As a result, the lighting will be controlled by the current travelling via the D10 pin. Next, the ESP8266 D11 pin is set as the switch in the mobile app for the IoT base control. When the light is turned on via the mobile app, a signal is sent to the NodeMCU. The D9 pin sends a current to the relay module to turn on the light when the app sends a signal to do the same.

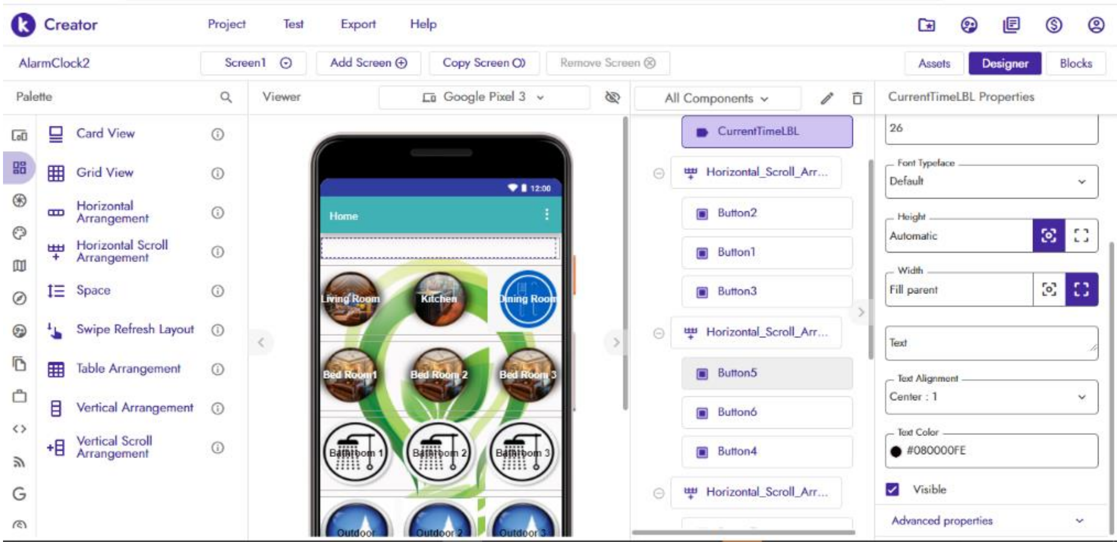

Figure 3: Development of main screen of mobile app

3.1 MOBILE APP DEVELOPMENT

The mobile application for this system was created using the Kodular application maker tools. The main screen shown in Figure 3 had then to be created first. The main screen's basic sketch design was developed using palettes. Buttons, labels, text boxes, a clock, a firebase database, horizontal arguments, a time picker, and other elements were added as palettes to the main panel.

The designing stage of the process ends after adding the palettes to Figure 1. Then, in the portion of the block, the backend development had to be completed.

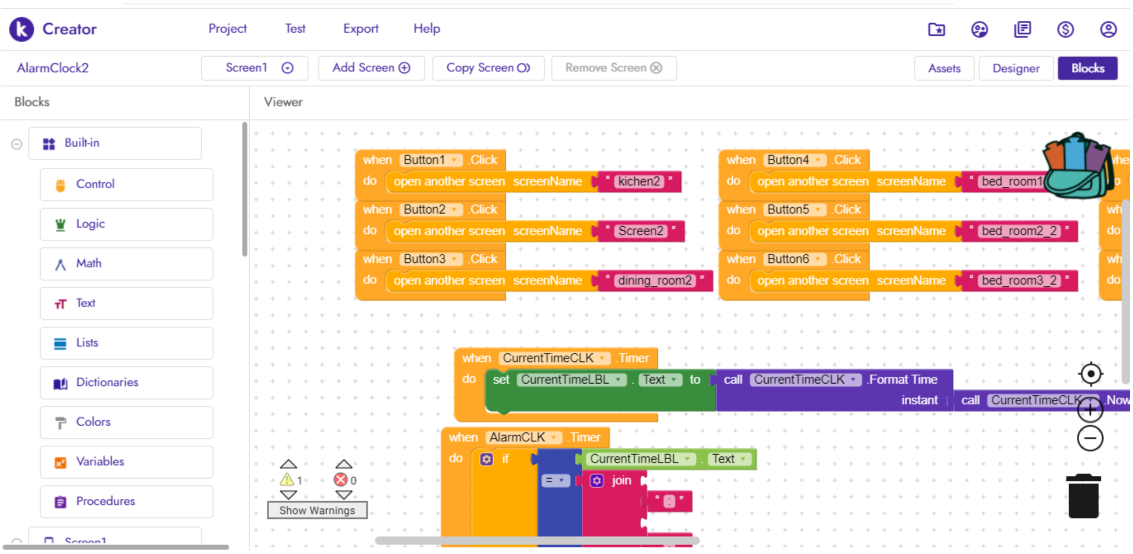

Figure 4: Backend Development of the Mobile App

The functionality of the pre-set palettes was coded at this point, as were the logical arguments for the relevant functions. The mobile app includes the occupancy control and IoT control for Lighting control by switching to turn on and off the occupancy control. The ESP8266 will be instructed to transmit a current through the D7 pin by turning on the mobile app.

3.2 Linking the System

The mobile application and the NodeMCU were linked using API Key and Firebase URL. Therefore, the API key and firebase URL have been added to that palette. The switch is turned on, the value '1' will be printed in the relevant database. If the switch is turned off, the database will print '0'. The API key and a firebase URL are also provided in the NodeMCU ESP8266 coding. NodeMCU reads the relevant sub-database when it runs. The number '1' is then printed in the database, and the current is then passed through a pre-set digital output. If the sub-database prints '0,' the current will stop flowing.

3.3 Implementation of the System

This assembly has been simplified as much as possible to reduce the installation cost. The device installation requires little extra effort. It is necessary to install the lighting management unit on the top of the ceiling, and it is preferable to install the unit in the middle of the coverage area for optimum sensor functionality. There are two connecting points: one for line in and one for line out. The existing system does not require any changes. The system only must be connected to the centre of the light and the physical switch. The NodeMCU should then be connected to a wireless network. If there is an open network, the devices will connect to it automatically. When network is secured, the NodeMCU should be given the password and username while coding. When NodeMCU is running, it communicates with a specific device. Firebase database by Google, the program should then be installed on the phone. The gadgets are controlled by a smartphone app. The details of the same Google Firebase database are coded into the mobile app. The program should then be installed on the phone. The gadgets are controlled by a smartphone app. The details of the same Google Firebase database are coded into the mobile app.

4. DISCUSSION

The choice between a commercial smart home device and NodeMCU depends on the requirements, technical expertise, and budget. A plug-and-play solution with convenience and support, a commercial smart home device may be a better option. However, if you enjoy tinkering, have programming skills, and want full control over your smart home system, NodeMCU provides an affordable and customizable platform.

The NodeMCU was coded with the password and username of a Wi-Fi network. When the network is available, ESP8266 Wi-Fi module automatically signs into the network and accesses the google firebase database which was given instructions to access when programming.

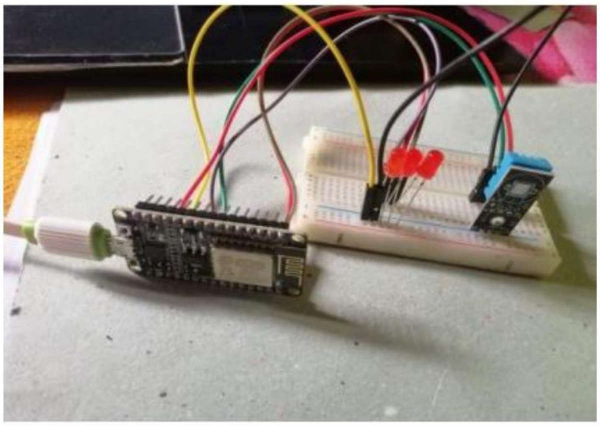

Figure 5 (i): NodeMCU connected with LED

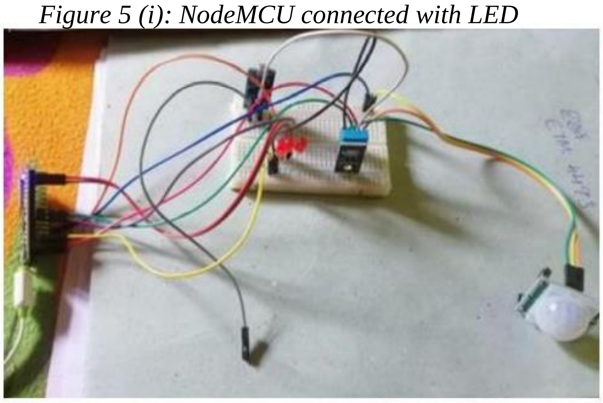

Figure 5 (ii): Motion Sensor Connected Circuit

The Google Firebase database login information was provided by the mobile application given in Figure 6. The living room was selected for the experiment. When light 01 was turned off, the associated LED to the light 01 output was also turned off. The LED turned on when it was configured to turn on light 01 from the phone. The ability to control lighting and electronic appliances with a single touch of the fingertip has undoubtedly increased convenience. As shown in Figure 7 the motion sensor was enabled automatically. Further, it was subsequently established that this system also protects the home from electrical risks. The light then began to react to the movements it had sensed.

A timer was inserted into the mobile application. The NodeMCU functioned as expected when the timing was set by the mobile application. The timer option as display in Figures 8 and 9, is set to 15.32.44, and the LED will switch off at that moment.

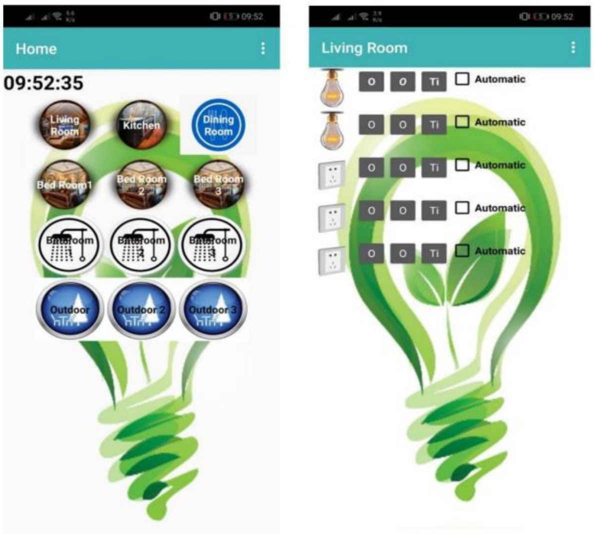

Figure 6: Comparison of Screen 1 (left) of Mobile App and Screen 2 (right) after clicking the living room icon

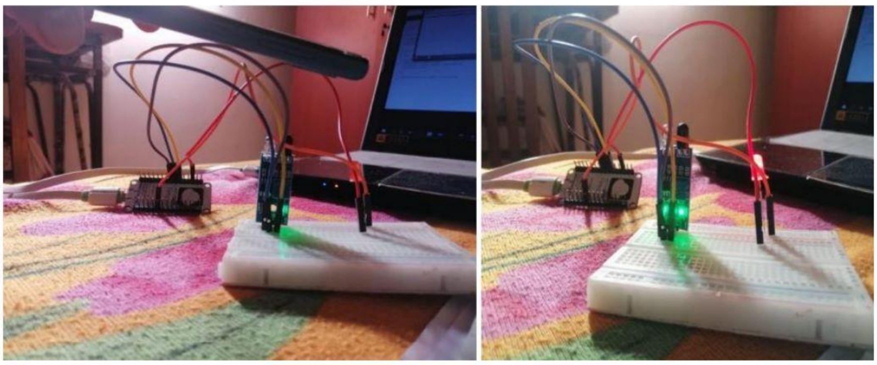

Figure 7: Motion Detection functioning LED acting accordingly

Figure 8: Timer Function

Figure 9: Timer Setting

Because the lighting control system considerably increases occupant safety and comfort while also achieving the primary aim of energy saving, it is clear that this technology is not only practical but also a tremendous step in the right direction for sustainability. This method has countless practical applications, and with the attention and cooperation of stakeholders, it may be used throughout a project to support renewable energy and energy efficiency. By enabling users to contribute to the objective of energy saving, a system like this not only encourages sustainability but also has the potential to increase productivity and mental pleasure of residents.

5. CONCLUSIONS

The automation control and mobile application are key advantages of IoT based system. Further, the extent of energy savings and cost reduction achievable with NodeMCU depends on the specific applications you develop, the devices you integrate, and how effectively you optimize and manage your smart home system. The comfortability comes as a benefit of this system when reducing the power energy waste. The ESP8266 Wi-Fi module is a low-cost device that runs on extraordinarily little power. The prototype developed in this study uses extraordinarily little energy. Additionally, this system is designed to be installed without requiring any changes to current electrical wiring. This system provides a platform for innovation and customization, allowing you to explore various possibilities to achieve energy efficiency and cost savings in your smart home setup. Further, it is most suitable for overcoming the behavioural mistakes that lead to electricity energy waste. These systems also allow users to use a mobile application to keep track of the electricity system in the house. Furthermore, because of this mobile app and ESP8266 module is linked through the Google Firebase database, this system can work over the internet. It is conclusive that the benefits of this system far outweigh any potential misgivings that users may have when it is first introduced. Even with regards to concerns about the additional cost and effort of installing this system into existing buildings, users can rest assured that the long-term benefits and cost-saving potential of this system significantly exceed the initial investment. Users' capacity to contribute to the system's greater sustainability objective as well as its inhabitants' well-being may serve as a powerful incentive for them to use it. This technology may be pushed as a means of minimizing the energy waste that occurs on a regular basis in residential buildings in Sri Lanka.

6. REFERENCES

Acosta, I., Campano, M. Á., & Molina, J. C. (2016). Window design in architecture: Analysis of energy savings for lighting and visual comfort in residential spaces. *Applied Energy*, *168*, 493–506. doi: https://doi.org/10.1016/j.apenergy.2016.02.005

Almeida, H. S. (2010). Thermal Comfort Analysis of Buildings Using Theoretical and Adaptive Models. Corpus ID: 53624706. Technical University of Lisbon. Retrieved from https://fenix.tecnico.ulisboa.pt/downloadFile/395142105419/resumo.pdf

Anuradha, I. G. N., & Halwatura, R. U. (2021). Life Cycle Embodied Carbon and Initial and Maintenance Cost Analysis for the roof materials available in Sri Lanka. *11th International Conference on Sustainable Built Environment (ICSBE) 2020*. Retrieved from https://www.researchgate.net/profile/Ign-Anuradha-2/publication/355482861_LIFE_CYCLE_EMBODIED_CARBON_AND_INITIAL_AND_MAINTENANCE_COST_ANALYSIS_FOR_THE_ROOF_MATERIALS_AVAILABLE_IN_SRI_LANKA/links/617409b7eef53e51e1d3089b/LIFE-CYCLE-EMBODIED-CARBON-AND-INITIAL-AND-MAINTENANCE-COST-ANALYSIS-FOR-THE-ROOF-MATERIALS-AVAILABLE-IN-SRI-LANKA.pdf

Anuradha, I. G. N., Liyanage, & Devapriya, K. A. K. (2021). Developing a cost-effective web-based communication and information management system for construction projects. In *General Sir John Kotelawala Defense University – 14th International Research Conference*. Retrieved from http://ir.kdu.ac.lk/handle/345/5170

Anuradha, I. G. N., Perera, B.A.K.S., & Ekanayake, B. J. (2019). Significance of whole life embodied energy and embodied carbon of wall materials compared to their initial/maintenance costs. *The International Journal of Construction Management*, *22*(6), 1090–1103. doi:10.1080/15623599.2019.1683690

Baumgartner, T., Wunderlich, F., Jaunich, A. O., Sato, T., Bundy, G., Grießmann, N., Kowalski, J., Burghardt, S., & Hanebrink, J. (2012). *Lighting the way: Perspectives on the global lighting market*. 2nd ed. McKinsey. Retrieved from https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/lighting_the_way_perspectives_on_global_lighting_market_2012.ashx

Cook, D. J. (2012). How Smart Is Your Home? *Science*, *335*(6076), 1579–1581. doi: 10.1126/science.1217640

Delzendeh, E., Wu, S., Lee, A. Y., & Zhou, Y. (2017). The impact of occupants' behaviours on building energy analysis: A research review. *Renewable & Sustainable Energy Reviews*, *80*, 1061–1071. Retrieved from https://doi.org/10.1016/j.rser.2017.05.264

Derby, S. (2006). The effectiveness of feedback on energy consumption., *A Review for DEFRA of the Literature on Metering, Billing and direct Displays*, *486*(2006), 26. University of Oxford. Retrieved from https://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf

Fernando, M. N., & Jayasena, H. S. (2009). Practicing energy efficient design for commercial buildings in Sri Lankan industry. *Building Resilience*, 782. Retrieved from https://core.ac.uk/download/pdf/1661761.pdf#page=807

GfK. (2016). *Smart Home: A Global Perspective*. CES 2016. Las Vegas, USA. Retrieved from https://scholar.google.com/scholar?&q=GfK%20%282016%29%20Smart%20home%3A%20a%20global%20perspective.%20Paper%20presented%20at%20the%20CES%202016%2C%20Las%20Vegas%2C%20USA%2C%2012%20Jan%202016

Guo, X., Tiller, D. K., Henze, G. P., & Waters, C. E. (2010). The performance of occupancy-based lighting control systems: A review. *Lighting Research & Technology*, *42*(4), 415–431. Retrieved from https://doi.org/10.1177/1477153510376225

Han, D. S., & Lim, J. (2010). Design and implementation of smart home energy management systems based on zigbee. *IEEE Transactions on Consumer Electronics*, *56*(3), pp. 1417–1425. Retrieved from https://ieeexplore.ieee.org/abstract/document/5606278

International Energy Agency [IEA] (2015). *World Energy Outlook 2015*. Retrieved from https://www.oecd-ilibrary.org/energy/world-energy-outlook-2015_weo-2015-en#:~:text=The%20World%20Energy%20Outlook%202015,and%20analysis%20on%20trends%20in

Jiang, X., Van Ly, M., Taneja, J., Dutta, P., & Culler, D. E. (2009). Experiences with a high-fidelity wireless building energy auditing network. *In Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems*, (pp. 113-126). Retrieved from http://fredjiang.com/papers/jiang09sensys.pdf

Li, X., Lu, R., Liang, X., Shen, X., Chen, J., & Lin, X. (2011). Smart community: an internet of things application. *IEEE Communications Magazine*, *49*(11), 68–75. Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=d86166459090c8db93109eb0992623dca8527679

Michaels, J. (2018). *Commercial buildings energy consumption survey*, US Department of Energy: Washington, DC, USA. Retrieved from https://www.eia.gov/consumption/commercial/data/2012/pdf/user_guide_public_use_aug2016.pdf

Olatunji, O. O., Akinlabi, S. A., Madushele, N., Adedeji, P. A., Ishola, F., & Ayo, O. O. (2019). Wastage amidst shortage: Strategies for the mitigation of standby electricity in residential sector in Nigeria. *Journal of Physics*, *1378*(4), 042062. Retrieved from https://iopscience.iop.org/article/10.1088/1742-6596/1378/4/042062/pdf

Owusu, P. A., & Sarkodie, S. A. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), 1167990. Retrieved from https://doi.org/10.1080/23311916.2016.1167990

Pearson, P. J. G., & Foxon, T. J. (2012). A low carbon industrial revolution? Insights and challenges from past technological and economic transformations. *Energy Policy*, *50*, 117–127. Retrieved from https://doi.org/10.1016/j.enpol.2012.07.061

Pohl, J., 2016. *Commercial Buildings Energy Consumption Survey: Energy Usage Summary.*, U.S. Energy Information Administration: Washington. Retrieved from https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS%202018%20CE%20Release%202%20Flipbook.pdf

Robles, R. J., & Kim, T. (2010). Applications, systems and methods in smart home technology: a review. *International Journal of Advanced Science and Technology*, *15*, 37–48. Retrieved from https://www.academia.edu/download/33169395/4.pdf

Ande G.A. & Rojatkar, D. V. (2017). *A survey: Application of IoT. International Research Journal of Engineering and Technology (IRJET),4* (10), 347-350. e-ISSN: 2395-0056. Retrieved from https://www.irjet.net/archives/V4/i10/IRJET-V4I1062.pdf

Sharma, V., & Tiwari, R. (2016). A review paper on "IOT" & Its Smart Applications. *International Journal of Science, Engineering and Technology Research (IJSETR)*, *5*(2), 472-476. Retrieved from https://fardapaper.ir/mohavaha/uploads/2020/11/Fardapaper-A-review-paper-on-%E2%80%9CIOT%E2%80%9D-It%E2%80%9Fs-Smart-Applications.pdf

Spyropoulos, G. N., & Argiriou, A. A. (2011). Energy consumption and the potential of energy savings in Hellenic office buildings used as bank branches—A case study. *Energy and Buildings*, *43*(4), Retrieved from https://www.sciencedirect.com/science/article/pii/S0378778810004561?casa_token=ZTEdZl0uhlQAAAAA:iN5S4dlzJU1HmwQcVIlO0_F_sOnu18WylhkYwKEKa5tYoqcSTlyzrwRo6Tnt2llKBrdKKFptmJ2-

Sri Lanka Electricity Board [SLEB]. (2017). *Annual Report – 2017*. Retrieved from https://www.ceb.lk/front_img/img_reports/1595829497CEB_Annual_Report_2017.pdf

Tang, S. C., Kalavally, V., Ng, K. P., & Parkkinen, J. (2017). Development of a prototype smart home intelligent lighting control architecture using sensors onboard a mobile computing system. *Energy and Buildings*, 138, 368–376. Retrieved from https://www.sciencedirect.com/science/article/pii/S0378778816319971?casa_token=LZ1rindvPVcAAAAA:4vjTB7AAbKPwwwI3ko7EYFuFRZSH3_3_GwZbYXG3G-RwX5KX_VI1YL6ULvtOQwfOfS-_yD4_16hp

Tetlow, R. M., Beaman, C. P., Elmualim, A., & Couling, K. (2014). Simple prompts reduce inadvertent energy consumption from lighting in office buildings. *Building and Environment*, *81*, 234–242. Retrieved from https://www.sciencedirect.com/science/article/pii/S0360132314002194?casa_token=nl_70cYgsYsAAAAA:IZli2uElkYYQICHYPdpAXmyGlGABQyFZrGO_uWT2BgV-4t9cd6AU_8zXYlF6WYgA9du4pnQ_MGQQ

Wen, Y., Granderson, J., & Agogino, A. M. (2006). Towards embedded wireless-networked intelligent daylighting systems for commercial buildings. In *Sensor Networks, Ubiquitous, and Trustworthy Computing* (Vol. 1, pp. 326–331). Retrieved from https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=00d640f75ed79f11d04f4630304ee0551b9bab49

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2017). Benefits and risks of smart home technologies. *Energy Policy*, 103, 72–83. doi: 10.1016/j.enpol.2016.12.047

Xu, L., Wei, Y., Zhang, J., & Jin, P. (2019). Design and analysis of an active daylight harvesting system for building. *Renewable Energy*, *139*, 670–678.

Yang, H., & Lee, H. (2014). Lighting Scheduling for Energy Saving in Smart House Based on Life Log Data. *Procedia Environmental Sciences*, *22*, 403–413.

Yu, X. G., & Su, Y. (2015). Daylight availability assessment and its potential energy saving estimation –A literature review. *Renewable & Sustainable Energy Reviews*, *52*, 494–503. Retrieved from https://www.sciencedirect.com/science/article/pii/S1364032115007893

Yuksek, I., & Karadayi, T. T. (2016). Energy-Efficient Building Design in the Context of Building Life Cycle. *Energy efficient buildings*. 10, 93-123. Retrieved from https://books.google.com/books?hl=en&lr=&id=7cKQDwAAQBAJ&oi=fnd&pg=PA93&dq=Energy-Efficient+Building+Design+in+the+Context+of+Building+Life+Cycle.+In+InTech+eBooks.&ots=UASkmIhvCr&sig=UGe403SNgaUw4CcaVFhiJ2sOXMA

Zhao, H., & Magoulès, F. (2012). A review on the prediction of building energy consumption. *Renewable & Sustainable Energy Reviews*, *16*(6), 3586–3592.

Zhongying, W., & Sandholt, K. (2019). Thoughts on China's energy transition outlook. *Energy Transitions*, *3*(1–2), 59–72. Retrieved from https://link.springer.com/article/10.1007/s41825-019-00014-w