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Addressing the Prevailing Energy Crisis in Sri Lanka: A Case for Cost-Efficient Energy Consumption

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Abstract: ***The economic crisis in Sri Lanka has significantly influenced people's lives, leading to shortages of basic needs such as medicine, food, and fuel. The prevailing situation has taken the country further away from achieving Sustainable Development Goal 7, which is to provide affordable, reliable, sustainable, and modern energy for all. Despite the potential for renewable energy, Sri Lanka's key energy sources are primarily oil and coal. Therefore, the government had to revise the electricity tariffs recently to cover the cost of coal. As a result, most people are still unaware of the electricity bill value they expect at the end of the month. This study proposes a web-based system that focuses on the micro-level aspects of the problems mentioned above. The monthly electricity bill prediction is a vital component of this system, guiding users to adopt a cost-effective electricity consumption pattern. The system also operates an online donation program, aiming to provide long-term energy solutions to recognised rural communities, thereby addressing the issue of energy poverty in these regions. The work involved in incorporating these technologies into a web application is further explained in this research, accompanied by architectural diagrams. Furthermore, literature reviews were conducted to facilitate comparisons and interpret the results, ultimately leading to a definitive conclusion.***

Keywords: ***Electricity Management, Rural Electrification, Solar Energy, Sustainable Development Goals.***

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I. INTRODUCTION

A Series of Sustainable Development Goals (SDGs) addresses some of the global challenges people face. Those SDGs, which include 17 goals and 169 targets, were proposed by an Open Working Group established by the UN General Assembly in New York [1]. Among these goals, the SDG-7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Sri Lanka has significant potential for renewable energy sources, including solar, wind, and hydropower. Despite that, Sri Lanka's key energy sources are primarily oil and coal [2]. The primary reason for this is the limited public awareness of renewable energy sources. The existing energy infrastructure is also inadequate to provide efficient services.

Sri Lanka is currently emerging from an unprecedented level of macroeconomic crisis [3]. Annual average inflation rose from 46.4% in December 2022 to 49.6% in January 2023 [4]. People have been experiencing regular hour-long power outages for the past year due to a lack of coal at power facilities. As a solution, the electricity tariffs were initially revised in August 2022, marking the first revision since November 2014. However, Fig. 1 shows that in February 2023, tariffs were revised again as proposed by the Ceylon Electricity Board (CEB) [5]. This disproportionately affects the minority community. As a result, most people are unaware of the electricity bill value they expect at the end of the month.

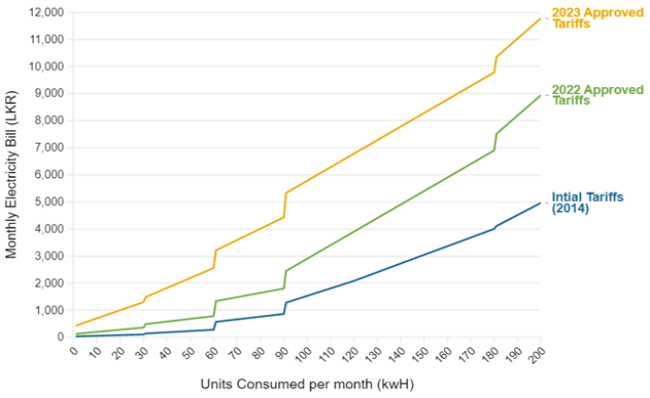

Fig. 1. Changes in tariffs on monthly electricity consumption.

To address the above problem, it is suggested that an online bill prediction feature be provided. This functionality would enable users to estimate their electricity bills based on their usage, thus providing them with a clear understanding of their charges and allowing them to adjust their consumption patterns accordingly.

In addition, this research proposes an online donation mechanism to raise funds for "sustainable rural electrification". These donations are used to install solar solutions in rural villages and small-scale industries throughout Sri Lanka. When considering potential overseas donors, the online donation program is more convenient. Conventional donation methods, such as sending a check or making a wire transfer, can be time-consuming and insecure. On the other hand, the online process provides transparency and accountability, allowing donors to track the progress of their donations and ensure that their contributions are being used for the intended purpose.

To execute the functionalities mentioned above, a web application is proposed in this research. MERN framework stands out as a more efficient option for building this project due to its popularity, real-time updates, scalability, and ability to handle large volumes of data.

II. LITERATURE REVIEW

Several studies have proposed solutions to address Sri Lanka's energy crisis. These solutions include promoting the use of renewable energy and implementing energy efficiency measures.

The government has set a target to meet the total demand from renewable and other indigenous energy resources by 2030 as part of the Sri Lanka Energy Sector Development Plan [6]. This plan outlines strategies to promote renewable energy development, including establishing a regulatory framework, financial incentives, and capacity-building programs. However, achieving this target poses several challenges, including the high upfront costs of renewable energy technologies and the lack of adequate infrastructure and regulatory frameworks.

The Sri Lankan government also propose loan schemes for extensive and medium-scale renewable power development [6]. This approach may help attract private sector investments in renewable energy projects and promote the growth of the renewable energy sector. However, it is essential to note that these benefits may not necessarily reach the poorest populations immediately. Large and medium-scale renewable energy projects may take time to develop, and the initial costs may be high, making them less accessible to lower-income households.

Research by Paul Monigatti and the team proposes a pilot system for managing domestic electricity consumption to reduce demand peaks and consumer costs based on real-time pricing and usage data [7]. However, the system also has potential downsides. Consumers may need to invest in new technology to use the system, which could be a barrier for those with limited financial resources. Additionally, concerns may arise about data privacy and security when collecting and sharing personal energy usage information.

These studies focus on the macro-level aspects of the problem. There is a lack of research on the micro-level aspects of the problem, such as awareness and access to renewable energy among communities, especially in rural areas.

III. METHODOLOGY

The choice of the development framework for the application is a critical decision that can impact the system's functionality and efficiency. In this study, we have chosen the MongoDB, Express.js, React.js, Node.js (MERN) technology stack as our framework of choice due to the following reasons.

MongoDB is a NoSQL document-oriented database. It can handle large amounts of data. It predominantly stores all of the information for security purposes [8], making it an ideal choice for applications that deal with a large number of donation records.

Express.js, a lightweight web application framework, can efficiently handle the HTTP requests and responses of the system, creating strong APIs [8]. When considering the proposed functionalities, the application requires real-time updates and interactions with the server.

React.js is a popular front-end library that provides a fast and efficient user interface, allowing users to interact seamlessly with the application.

Node.js is a powerful runtime environment for synchronous requests [8]. It offers high scalability and flexibility, making it easier to manage and expand the application in the future.

Fig. 2. The following shows a high-level architectural diagram of the web application.

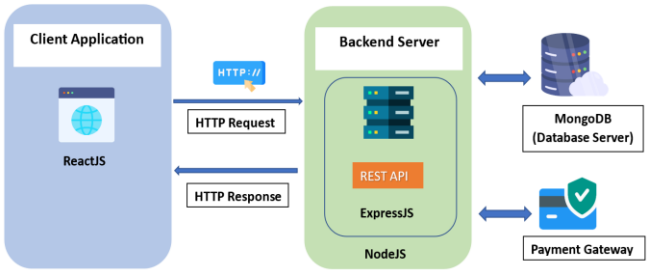

Fig. 2. High-level architectural diagram of the system.

This system aims to address common issues, such as high electricity costs and energy shortages, which have arisen due to the country's energy crisis. The monthly electricity bill prediction is a vital part of the system. This feature enables users to manage their electricity consumption by providing a detailed report of their expected electricity charges, allowing them to adjust their consumption patterns accordingly.

The predicted monthly bill is calculated based on real-time electricity pricing and tax rates (tariffs) imposed by the Sri Lankan government. To provide the user with accurate results, the system performs a complex calculation process, as shown in Fig. 3.

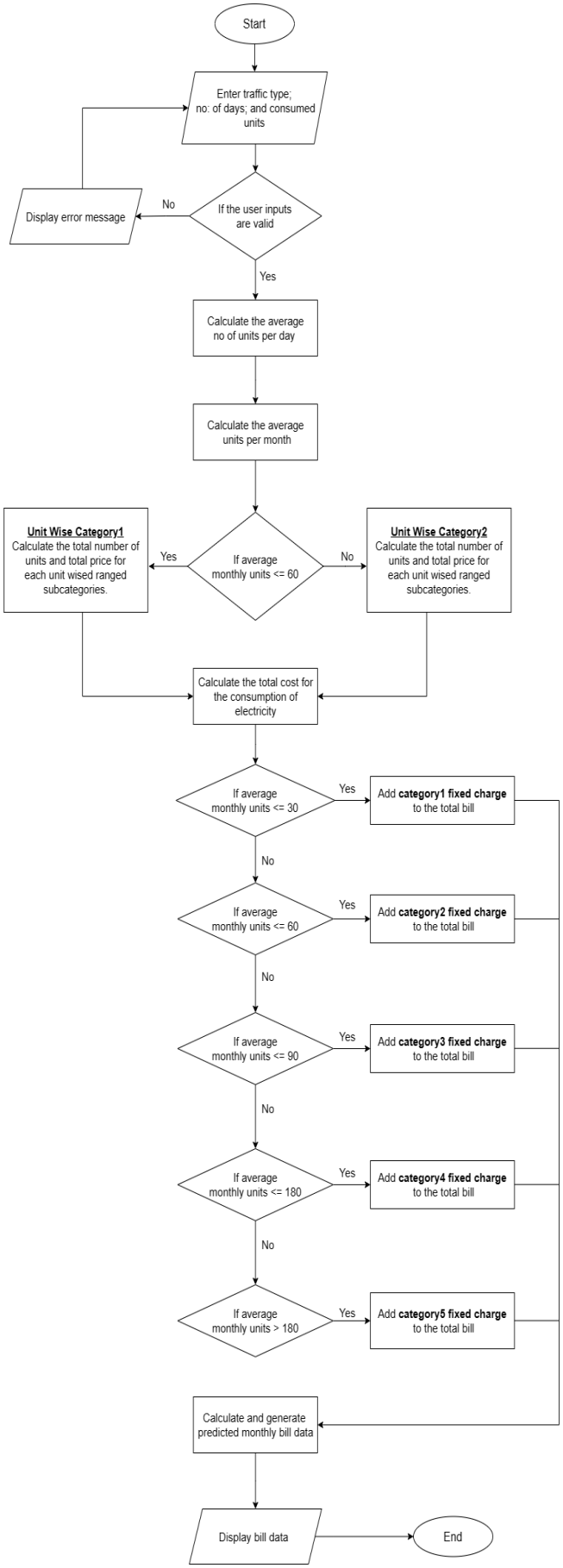

Fig. 3. Flow chart of the monthly bill calculation process.

Fig. 4 below illustrates the approach employed by the system to predict monthly electricity charges based on user-entered details.

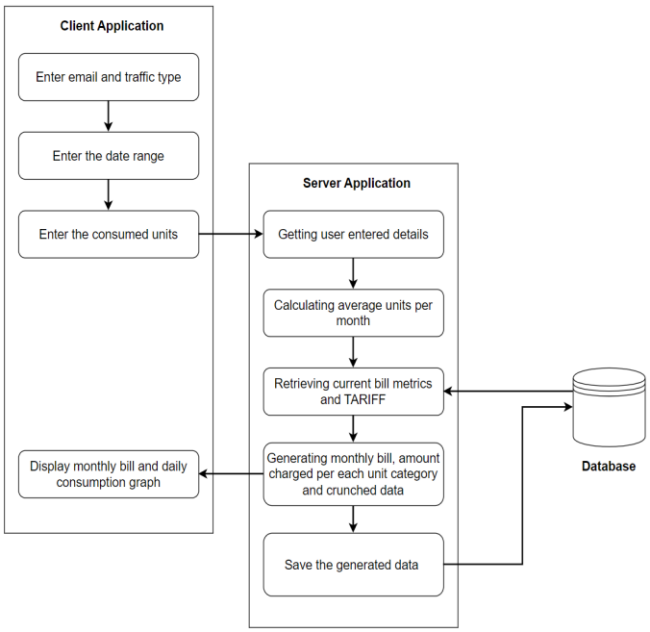

Fig. 4. Monthly bill prediction flow diagram.

When considering methods to reduce electricity bills, one of the most affordable and efficient options is to utilise solar solutions. Accordingly, the system employs several approaches to raise awareness about the use of renewable energy resources and promote the installation of solar panels among citizens.

As reported by the Sri Lanka energy balance, electricity sales to domestic and commercial customers have increased marginally, while the sales to industrial customers have decreased [9]. Hence, the web application mainly focuses on installing domestic and commercial-scale solar solutions. A detailed flow chart displaying the quote request process and the plan generation process is shown in Fig. 5.

Despite the government's various approaches to addressing Sri Lanka's energy shortage, electricity tariffs remain unaffordable for the majority of citizens, especially in rural areas.

An online donation program, designed to provide long-term energy solutions to rural communities without access to reliable electricity, is implemented by the system, thereby addressing the issue of energy poverty in these regions.

The flow diagram in Fig. 6 illustrates how the system manages the rural project management and donation processes.

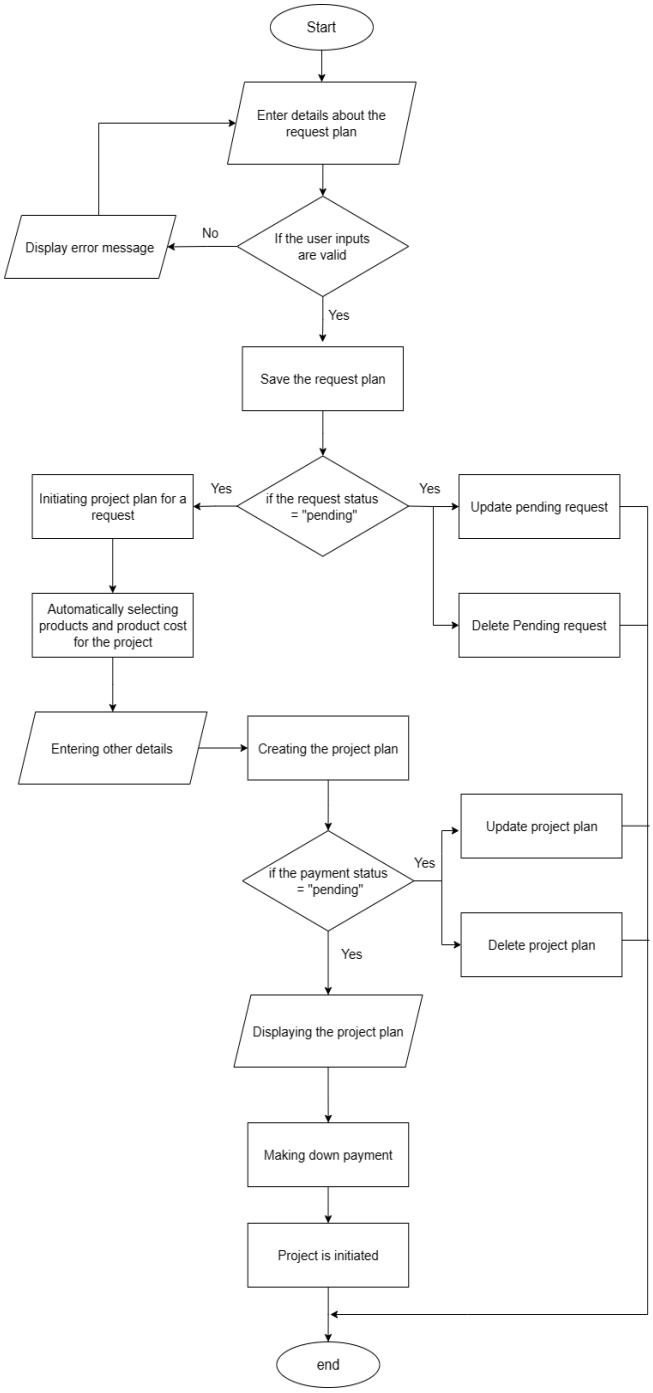

Fig. 5. Flow chart for requesting a quote and the project plan generation process.

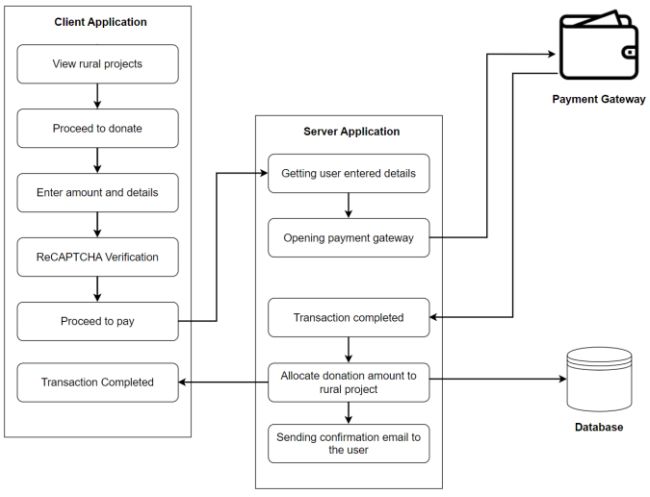

Fig. 6. Donation submission flow diagram.

IV. PROPOSED SYSTEM

The client party is provided with a web-based solution which addresses micro-level aspects of Sri Lanka's energy crisis in a practical approach. This system includes several features as follows:

A. Online bill prediction feature

This is a web-based tool that enables users to enter their electricity consumption for a specific period or several days and predict their total bill for the entire month. Initially, the user needs to select their traffic type and enter the period and meter reading using the calculation form shown in Fig. 8.

Upon submission, the user will be able to view a detailed table that outlines the step-by-step calculation of the expected monthly charge, alongside a chart representing the electricity charge versus the day of the month, as depicted in Fig. 7.

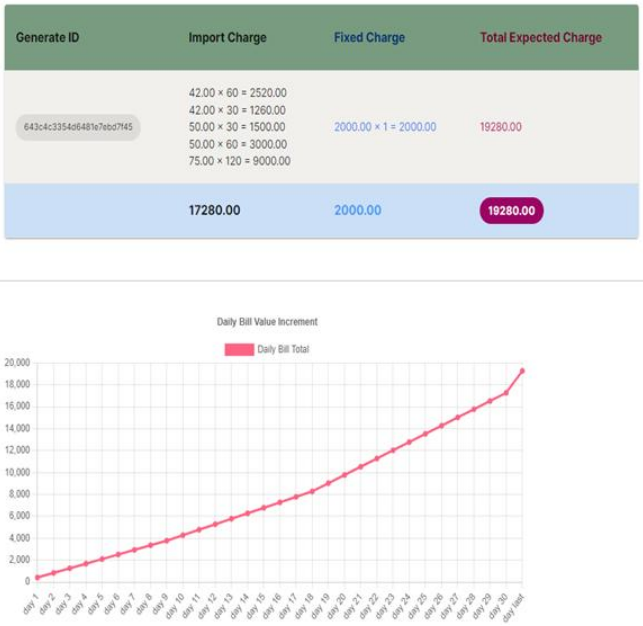

Fig. 7. Graphical representation of the predicted monthly bill.

These calculations are based on real-time electricity pricing in Sri Lanka. Users can utilise this data to make decisions regarding their energy consumption. This is an effective method of reducing energy bills.

Moreover, the system will regularly store and analyse user consumption details, which will help provide users with cost-effective electricity management strategies and ensure a better user experience.

B. Solar solutions and consultations

Due to the lack of knowledge and unavailability of efficient consultation services, people are reluctant to switch to solar power from traditional power-generating methods.

To assist with such cases, the web application provides users with up-to-date information about solar solutions, including solar panel implementations, solar streetlights, and various household solar equipment.

Moreover, users can register in the system and request quotes for solar panel implementations at affordable rates. After entering client details, approximate electricity consumption details, and grid details, a request can be submitted successfully using the form shown in Fig. 9.

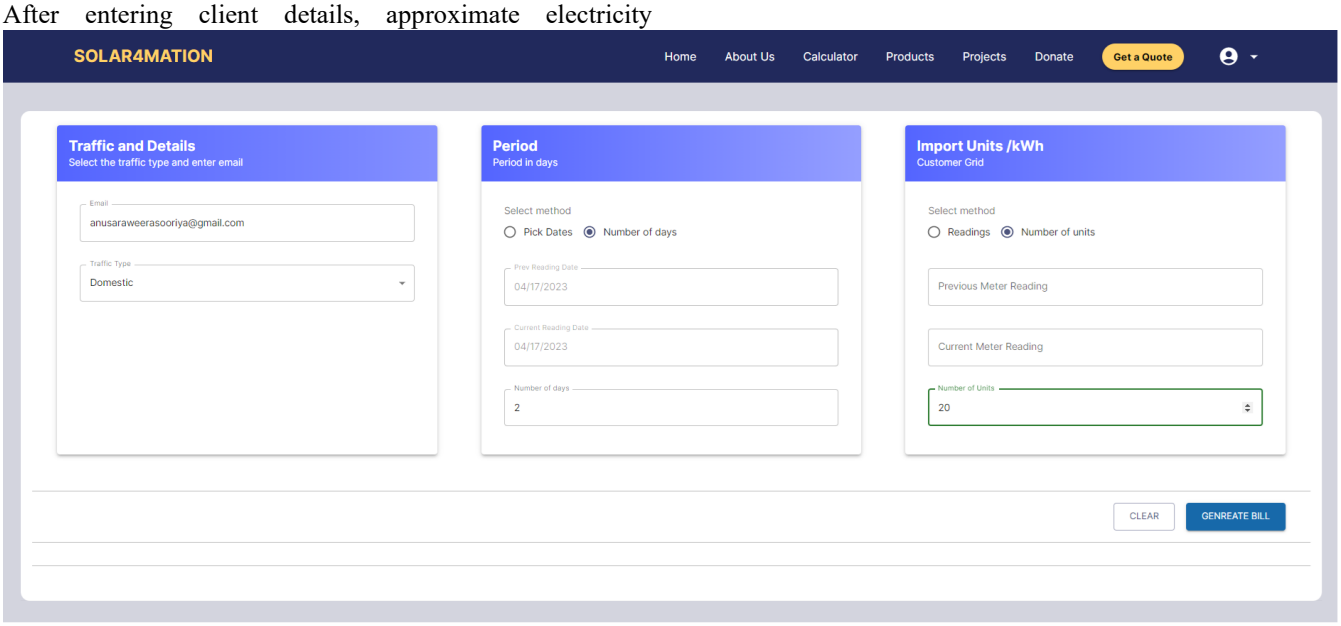

Fig. 8. Monthly bill calculation form.

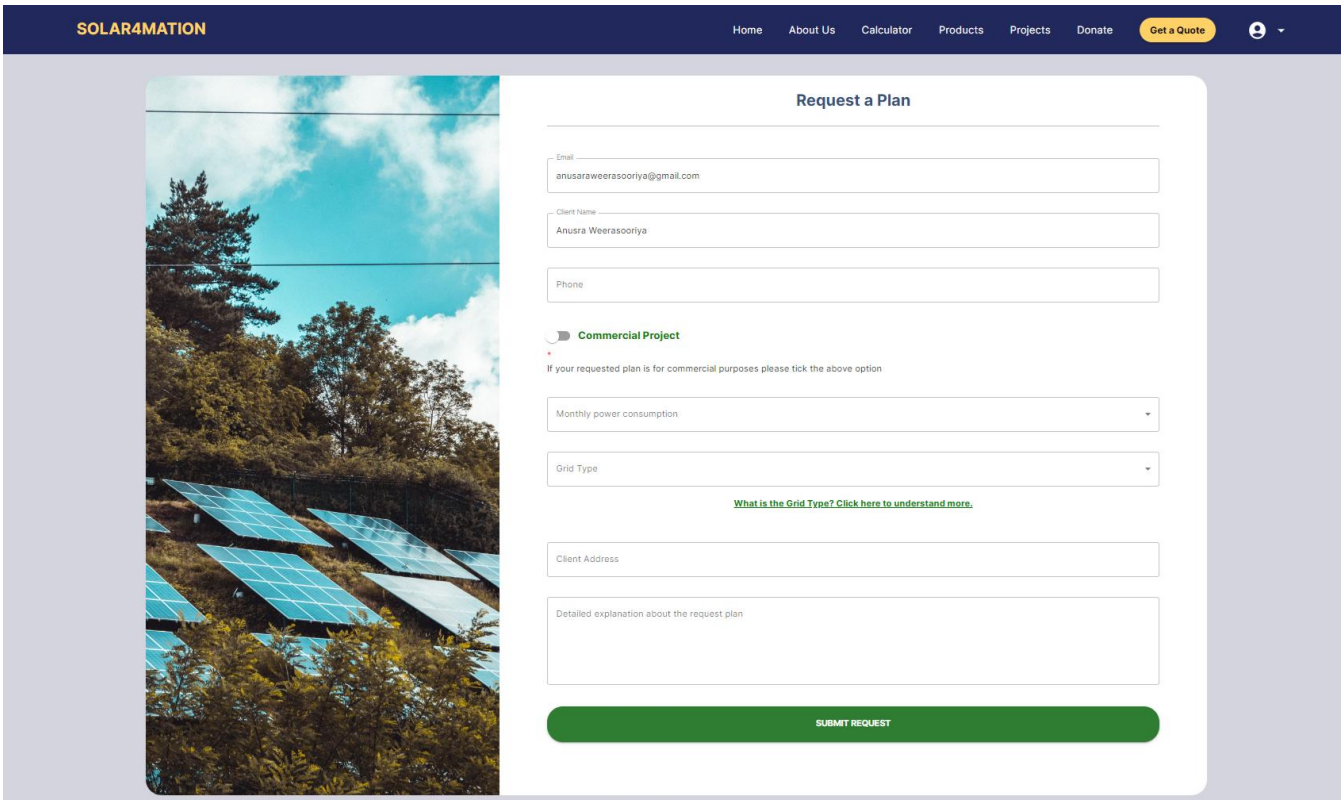

Fig. 9. Quote request submission form.

There are two primary configurations of solar power systems: off-grid and on-grid systems. The total energy provided by the off-grid solar power system fulfils the desired electrical load of houses and recharges the batteries, while excess electricity generated by the on-grid solar power system enters the grid [10]. Based on user requirements, the proposed system suggests the most suitable option among these solar power systems. Users can complete the quote request form accordingly.

Upon successful submission, the user will be able to view the progress of the request through their user profile and receive notifications when a project plan is ready for review. If interested in proceeding with the project plan, the user can make a down payment and conduct installation activities under the guidance of professionals.

C. Online donation feature

The online donation program is designed to raise funds for implementing solar solutions in recognised rural areas.

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The system administrator can enter details of the proposed rural project into the system, which will then be open for donations. By using the web application, donors can view project details and proceed to donate by entering their donor details and the contribution amount in the donation form shown in Fig. 10. After selecting a payment method, the user will be directed to the payment gateway, where they can confirm their contribution.

The user will also receive a donation confirmation via email. If the donor is a registered user, the system allows them to view details of all their donations through their user profile. Moreover, the donor will also be able to track the progress of the rural projects, as shown in Fig. 11, via the web application and ensure that their contributions are being used for the intended purpose.

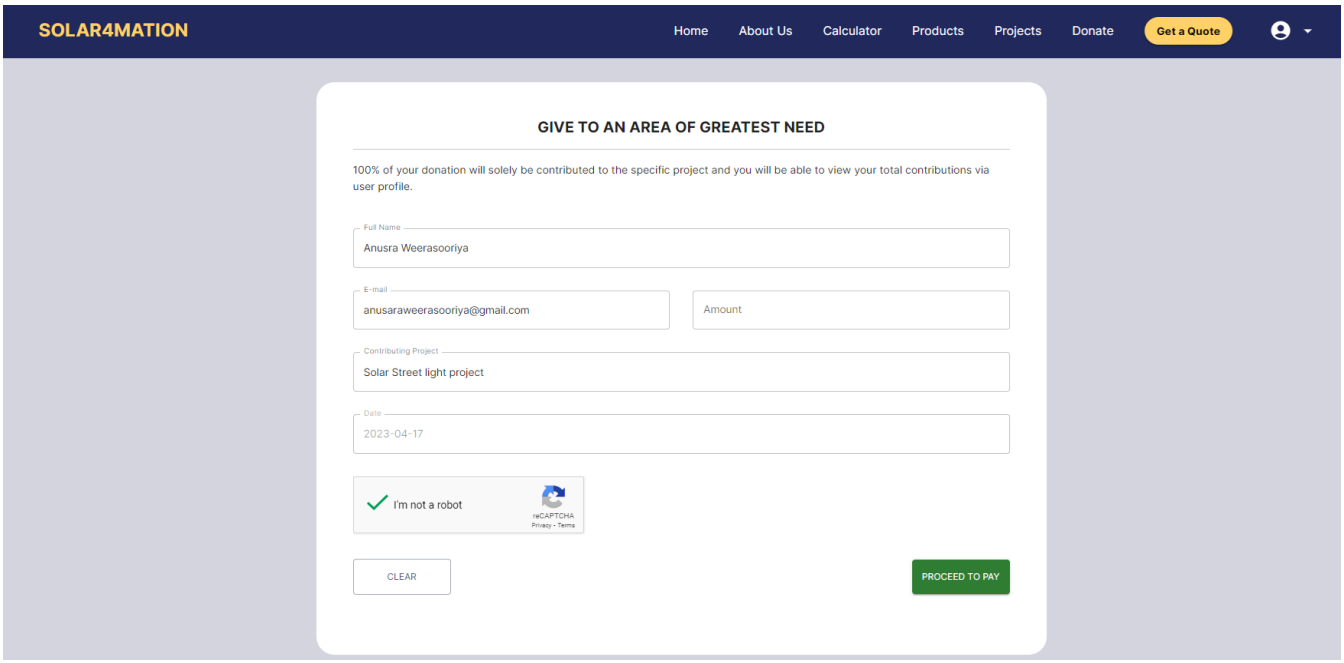

Fig. 10. Donation submission form.

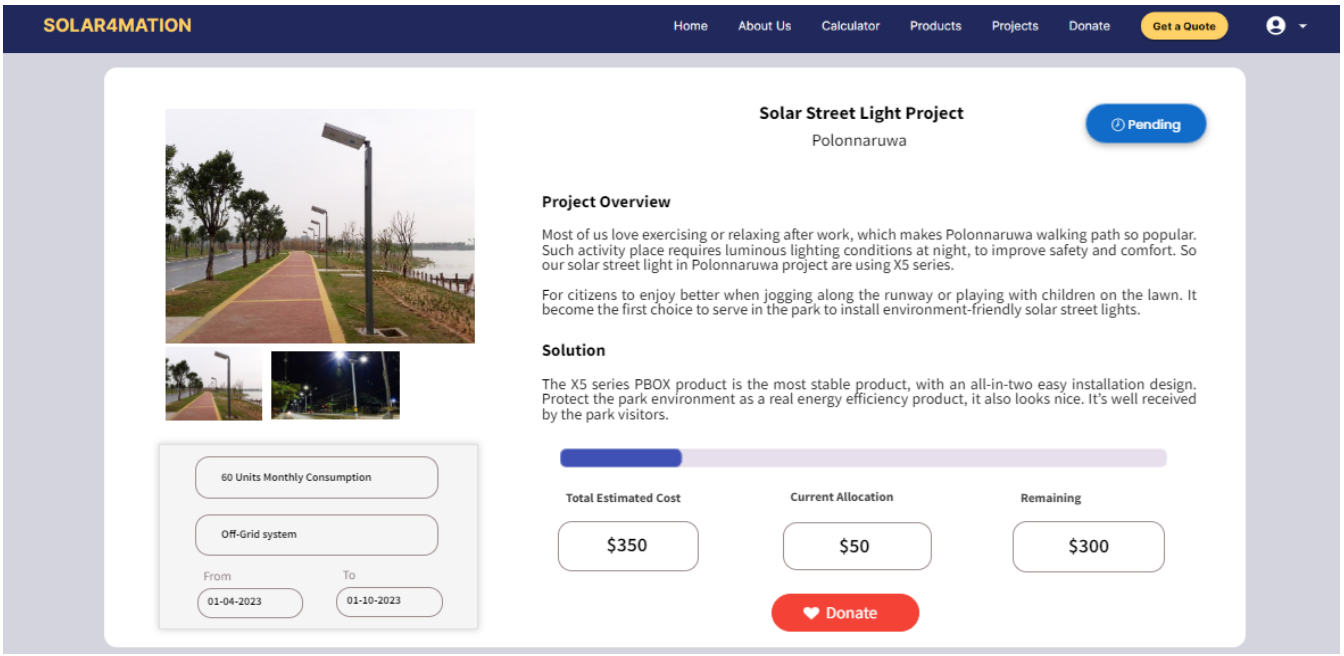

Fig. 11. Rural project details.

V. RESULT AND DISCUSSION

This study focuses on the seventh Sustainable Development Goal promptly. Table I below illustrates the new gaps in the literature revealed by this study. Numerous research projects and initiatives have been undertaken to provide electricity access to the Sri Lankan population. As a result, Sri Lanka's electricity access for 2020 reached 100.00% [11]. Despite the development, the sustainability and affordability of energy remain problems for Sri Lankan citizens. In light of the current situation in the country, providing a web-based solution to predict the monthly charge for users' power consumption addresses a crucial problem in cost management.

Awareness of inefficient energy consumption directs the user's interest towards cost-effective energy solutions, such as solar power. Hence, this research provides a significant step towards sustainability.

The online donation program and the subsidised solar solutions will make renewable energy solutions more accessible and affordable to households, especially in rural areas.

Table I: SDG-7 research gap in Sri Lanka

	7th Sustainable Development Goal	
	Addressed by other approaches	*Addressed by this research*
Electrification	✓	
Fossil-fuel technology	✓	
Investments	✓	
Renewable energy for industrial electrification	✓	
Energy efficiency		✓
Cost management		✓
Sustainable rural electrification		✓
Lack of funds		✓

Before making the web application available to the general public, it must be thoroughly tested for potential issues. Data security is critical when it comes to payment management and user management. Therefore, password hashing and CVV encryption mechanisms are implemented to ensure the protection of the user's sensitive data. Usability testing ensures that menus, buttons and links are visible and consistent across all interfaces. In addition, unit testing, integration testing, system testing, and other general testing methodologies are used to optimise the system.

VI. CONCLUSION

Sri Lanka is facing significant challenges in the energy sector. Access to clean energy remains an important issue, exacerbated by the current economic crisis and high inflation rates. To address these problems, the research proposed a web application with functionalities such as an online bill prediction feature and an online donation mechanism to fund sustainable rural electrification projects. The MERN stack has been chosen as the framework for this application due to its efficiency, scalability, and ability to handle large volumes of data.

While several studies have proposed solutions to address Sri Lanka's energy crisis, this research contributes by focusing on micro-level aspects such as community awareness about the usage of renewable energy and managing sustainable rural electrification projects through online donations.

Moreover, the proposed web application aims to provide a user-friendly and convenient platform that allows users to engage in cost-efficient electricity management with a better understanding.

In conclusion, this research offers a practical solution to address Sri Lanka's energy crisis, with the potential to impact the lives of millions of people and significantly contribute to achieving SDG 7. That is to ensure access to affordable, reliable, sustainable, and modern energy for all.

DECLARATION

The authors K. A. Weerasooriya, W. D. D. M. Wanniarachchi, A. A. D. P. Nadeera and D. G. J. C. Kularathna, M. V. N. Godapitiya and D. I. De Silva hereby acknowledge that this research paper titled “Addressing the Prevailing Energy Crisis in Sri Lanka: A Case for Cost-efficient Energy Consumption”, is our original work and all sources of information and ideas used in the research have been referenced appropriately.

We confirm that we have not received any financial or other benefits that may have influenced the research outcome or my interpretation of the findings, and we have no conflicts of interest or competing interests to the best of our knowledge.

We also declare that the article does not require ethical approval or consent to participate, as no human or animal subjects were involved in the study. Hence, it is conducted by moral principles.

We confirm that the research data associated with this article are accurate and have been analysed to draw valid conclusions. This data can be accessed without any condition and is available on websites maintained by the government authorities of Sri Lanka. We also include links to the relevant websites under the references section of the article.

All authors have equal participation in this article in terms of analysis and interpretation of research data. Each author has contributed significantly to the concept and design of the web-based application proposed in this research. We were also involved in drafting and revising the article for its important technical content. Dr. D. I. De Silva, Senior Lecturer, and Ms. M. V. N. Godapitiya, Academic Instructor at the Sri Lanka Institute of Information Technology, have given final approval for the article version to be published.

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