IoT Based Smart Energy Management System

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Certification

This is to certify that **Safiullah,(CE-074-2020)**, **Muhammad Abu Bakar Ansari, (CE-066-2020)** and **Jam Kashan Ali Unar,(CE-055-2020)**, **Muzamil Bakht,(CE-101-2020)** have successfully completed the final project **IoT Based Smart Energy Management System,** at the **Sir Syed university of Engineering and Technology**, to fulfill the partial requirement of the degree **Computer Engineering.**

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IoT Based Smart Energy Management System

Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9	✓ Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	✓ Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	

Abstract

This project introduces an innovative IoT-based Smart Energy Management System designed to enhance energy efficiency and promote sustainable living. The primary focus is on controlling lighting, ceiling fans, and air conditioners based on room temperature and light intensity parameters. Employing NodeMCU as the central controller, the system integrates various sensors, including temperature and light sensors, for real-time monitoring. Voltage protection mechanisms are implemented through a defined threshold value and solid-state relays, ensuring optimal energy consumption. A human presence detection system further contributes to energy conservation by automatically cutting off electricity when the room is unoccupied.

The project encompasses a comprehensive web interface that enables users to monitor total and live electricity consumption. A robust database architecture stores vital electric parameters, facilitating data analysis and trend tracking. The system issues alerts for high and low voltage conditions, enhancing user awareness and safety. The proposed system demonstrates promising results, showcasing its effectiveness in optimizing energy usage while providing a user-friendly platform for real-time monitoring and control.

Keywords: IoT, Smart Energy Management, NodeMCU, Sensors, Voltage Protection, Human Presence Detection, Database, Web Interface, Energy Efficiency.

Undertaking

I certify that the project **IoT Based Smart Energy Management System** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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We are also thankful to our friends and families whose silent support led us to complete our project.

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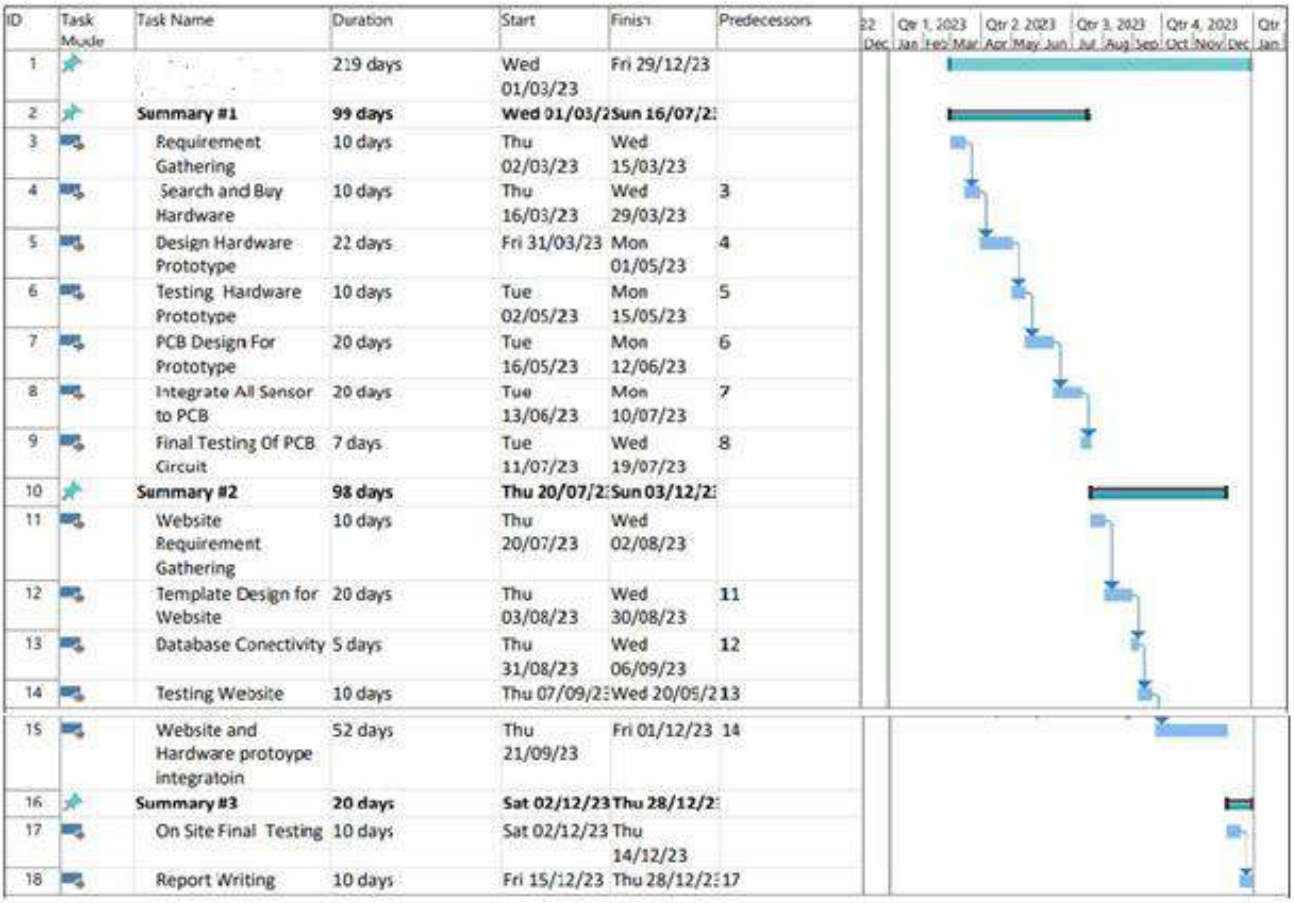

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		[illegible]	219 days	Wed 01/03/23	Fri 29/12/23	
2		**Summary #1**	**99 days**	**Wed 01/03/2**	**Sun 16/07/2**	
3		Requirement Gathering	10 days	Thu 02/03/23	Wed 15/03/23	
4		Search and Buy Hardware	10 days	Thu 16/03/23	Wed 29/03/23	3
5		Design Hardware Prototype	22 days	Fri 31/03/23	Mon 01/05/23	4
6		Testing Hardware Prototype	10 days	Tue 02/05/23	Mon 15/05/23	5
7		PCB Design For Prototype	20 days	Tue 16/05/23	Mon 12/06/23	6
8		Integrate All Sensor to PCB	20 days	Tue 13/06/23	Mon 10/07/23	7
9		Final Testing Of PCB Circuit	7 days	Tue 11/07/23	Wed 19/07/23	8
10		**Summary #2**	**98 days**	**Thu 20/07/2**	**Sun 03/12/2**	
11		Website Requirement Gathering	10 days	Thu 20/07/23	Wed 02/08/23	
12		Template Design for Website	20 days	Thu 03/08/23	Wed 30/08/23	11
13		Database Conectivity	5 days	Thu 31/08/23	Wed 06/09/23	12
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15		Website and Hardware protoype integratoin	52 days	Thu 21/09/23	Fri 01/12/23	14
16		**Summary #3**	**20 days**	**Sat 02/12/23**	**Thu 28/12/2**	
17		On Site Final Testing	10 days	Sat 02/12/23	Thu 14/12/23	
18		Report Writing	10 days	Fri 15/12/23	Thu 28/12/2	17

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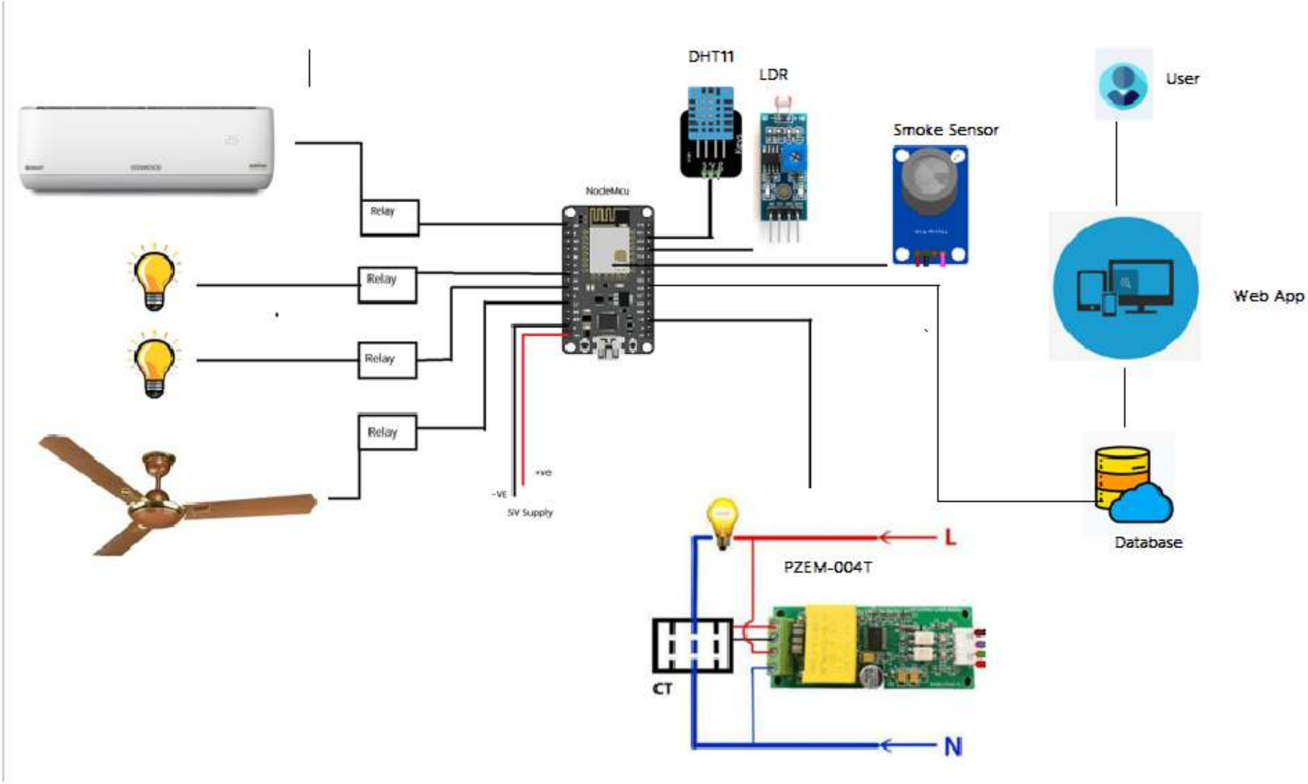
System Diagram



List of Acronyms

1. HTML
2. CSS
3. React Js
4. Database
5. API
6. Arduino IDE
7. NodeMcu
8. 5v relay
9. 40A relay
10. 12x2 lcd
11. 5v fan
12. Sockets
13. Vero Board
14. AC Savers
15. Pzem004T
16. Push Buttons
17. Changeover switch
18. Connection Wires
19. Ir Sensor
20. Holders
21. Light plug

List of Equations

1. **Energy Consumption Calculation:**
   - $E = P \times t$
     - Where E is energy consumption, P is power, and t is time.
2. **Voltage Threshold Equation:**
   - $V_{\text{threshold}}$
     - The defined voltage threshold for activating or deactivating devices.
3. **Human Presence Detection Equation:**
   - $P_{\text{presence}} = \frac{\text{Number of Persons Detected}}{\text{Total Time}} \times 100\%$
     - Percentage of time the system detects human presence.
4. **Light Intensity Control Equation:**
   - $L_{\text{control}} = f(\text{Light Intensity})$
     - A function to control lighting based on the measured light intensity.
5. **Power Factor Equation:**
   - $\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}}$
     - Evaluating power efficiency in an AC circuit.
6. **Temperature Control Equation:**
   - $T_{\text{control}} = f(\text{Room Temperature})$
     - A function to control the operation of the air conditioner and fan based on room temperature.

Chapter 1

1.1 Introduction

Rising energy demands and the imperative for sustainable practices underscore the need for innovative solutions. This project introduces an IoT-based Smart Energy Management System designed to optimize electricity usage in residential spaces. Traditional energy management lacks adaptability; hence, this system leverages IoT technologies, employing sensors and NodeMCU controllers for responsive and efficient device management.

Utilizing temperature and light sensors, the system controls lights, ceiling fans, and air conditioners based on room conditions. It incorporates a voltage protection mechanism to safeguard appliances and includes a human presence detection system for intelligent energy cut-off in unoccupied rooms. A web interface offers real-time monitoring and user interaction, complemented by a robust database for data storage and analysis.

This introduction lays the foundation for a detailed exploration of the system's architecture, sensor integration, human presence detection, and database management. The project's implications for energy efficiency, user convenience, and sustainability will be elucidated, providing a valuable framework for future smart energy solutions

1.2 Statement of the problem

Traditional residential energy management systems lack adaptability and responsiveness to dynamic user behavior and changing environmental conditions. The challenge lies in inefficient energy consumption, particularly in lighting, cooling, and other appliances, leading to higher utility bills and increased environmental impact. Additionally, the absence of mechanisms to intelligently curtail energy use during periods of non-occupancy and protect devices from voltage fluctuations further compounds the issue.

This project addresses these challenges by developing an IoT-based Smart Energy Management System. The goal is to create an intelligent system that optimizes electricity usage, considers human occupancy patterns, and safeguards devices from voltage fluctuations. Through this, the project aims to contribute to a more sustainable and environmentally conscious approach to residential energy management.

1.3 Goals/Aims & Objectives

Develop an IoT-based Smart Energy Management System to enhance residential energy efficiency and contribute to sustainable living practices.

Objectives:

1. Design a comprehensive IoT system architecture.
2. Implement environmental monitoring with temperature and light sensors.
3. Integrate human presence detection for optimized energy consumption.
4. Establish a voltage protection mechanism using solid-state relays.
5. Design and implement a robust database for real-time data storage.
6. Create a user-friendly web interface for remote monitoring and control.
7. Implement an alert system for high and low voltage conditions.
8. Conduct thorough performance evaluation and optimize system efficiency.
9. Document system architecture and implementation details for knowledge transfer.
10. Collect user feedback for iterative improvements, ensuring a scalable and practical energy management solution.

1.4 Motivation

The development of the IoT-based Smart Energy Management System is motivated by the urgent need to address environmental concerns tied to residential energy consumption. Driven by a commitment to sustainability, cost reduction, and leveraging IoT advancements, the project aims to transform traditional energy management practices. By focusing on user-centric design and appliance longevity, the system seeks to offer a comprehensive solution that aligns with evolving expectations for responsible and efficient energy use in homes.

1.5 Assumption and Dependencies

Assumptions

1. Stable internet connectivity for seamless communication.
2. Consistent and uninterrupted power supply.
3. Compatibility with existing residential electrical infrastructure.
4. User compliance with recommended practices.
5. Adequate security measures for data protection.

Dependencies

1. Reliability of hardware components (sensors, NodeMCU, relays).
2. Compatibility between software components and systems.
3. Reliability and availability of external services and APIs.
4. User engagement for effective human presence detection.
5. Compliance with regulatory standards for ethical and legal considerations.

1.6 Methods

1. **System Design:**

- ❖ Define requirements and system specifications.
- ❖ Design the overall system architecture.

2. **Hardware Implementation:**

- ❖ Assemble and integrate necessary hardware components.

3. Software Development:

- ❖ Code control algorithms and develop a user-friendly web interface.

4. **Integration and Testing:**

- ❖ Integrate hardware and software components.
- ❖ Conduct thorough testing for reliability and performance.

5. Database Implementation:

- ❖ Design and implement a database structure.
- ❖ Establish connections for seamless data transfer.

6. **Web Interface Deployment:**

- ❖ Deploy the web interface for user access.

7. Alert System Integration:

- ❖ Implement an alert system for user awareness.

8. Performance Evaluation:

- ❖ Conduct comprehensive performance evaluations.

9. Documentation:

- ❖ Document system architecture, code, and guidelines.

10. User Feedback:

- ❖ Gather user feedback and implement improvements iteratively.

This methodology ensures a structured approach to developing and implementing the IoT-based Smart Energy Management System, emphasizing reliability, user-friendliness, and continuous enhancement.

1.6 Report Overview

1. Introduction:
- Overview of the project, including motivation, goals, and objectives.

2. Literature Review:
- Examination of existing literature on smart energy management systems and IoT applications to provide context.

3. **System Architecture:**
- Detailed description of the system architecture, highlighting the integration of sensors, controllers, and NodeMCU.

4. **Sensor Integration:**

- Explanation of the integration of temperature and light sensors, emphasizing their roles in device control and energy management.

5. **Human Presence Detection:**

- Exploration of the system's human presence detection capabilities and its impact on energy conservation.

6. **Voltage Protection and Database Management:**

- In-depth analysis of the voltage protection mechanism, solid-state relays, and the database structure for storing critical electric parameters.

7. **Web Interface and Alert System:**

- Comprehensive discussion on the design and functionality of the web interface for real-time monitoring and control, as well as the implementation of the alert system.

8. **Implementation:**

- Technical details on the software and hardware implementation, including code snippets and algorithms.

9. **Results and Evaluation:**

- Presentation of results from experiments and tests, along with an evaluation of the system's performance against defined objectives.

10. **Discussion:**

- Interpretation of results, discussion of strengths and weaknesses, and recommendations for improvement.

11. **Conclusion:**

- Summary of key findings, contributions, and the potential impact of the IoT-based Smart Energy Management System.

12. **Future Work:**

- Proposal of future research directions and potential enhancements to the system.

Chapter 2

2.1 Heading

1. **Introduction**

   1.1 Background

   1.2 Objectives

2. **System Architecture**

   2.1 Overview

   2.2 Hardware Components

      2.2.1 Sensors

      2.2.2 NodeMCU

      2.2.3 Solid-State Relays

   2.3 **Software Components**

      2.3.1 Control Algorithms

      2.3.2 Web Interface

3. Methodology

   3.1 **Research Methods**

      3.1.1 Hardware Implementation

      3.1.2 Software Development

      3.1.3 Integration and Testing

   3.2 Database Implementation

8. **Figures**

8.1 System Architecture (Figure 1)

8.2 Experimental Setup (Figure 2)

8.3 Performance Metrics (Figure 3)

8.4 Vision for Sustainable Energy Management (Figure 4)

Chapter 3

3.1 Mathematical Modeling

3.1.1 Total Consumption Formula

- The formula to calculate the total consumption is given by:
  $\text{Total Consumption} = \sum_{i=1}^{n} \text{Individual Consumption}_i$
  This formula adds up the individual energy consumption values, giving us the total energy used.

3.1.2 Total Amp Formula

- The formula for determining the total amperage (I_{total}) is expressed as:
  $I_{\text{total}} = \frac{\sum_{j=1}^{m} \text{Individual Amps}_j}{\text{Number of Devices}}$
  This formula calculates the average amperage by summing up individual amps of each device and dividing by the total number of devices.

Chapter 4

Proposed Solution/Results & Discussion

Desired Result: The desired result is the creation of an intelligent energy management system that optimizes energy consumption based on real-time environmental conditions, ensures efficient device usage, and contributes to a sustainable and comfortable living environment.

Activity Time Estimates: Utilizing the Program Evaluation and Review Technique (PERT), the time estimates for key activities are outlined in Table 1:

Activity	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected (Te)
A	21	23	25	23
B	0.5	1	1.5	1
C	0.5	1	1.5	1

Discussion:

1. **Activity A - System Design and Architecture:**
   - The optimistic estimate assumes smooth progress, while the pessimistic estimate accounts for potential complexities. The expected time reflects a balanced view, aligning with a comprehensive system design.
2. **Activities B and C - Hardware and Software Development:**
   - The activities involving hardware and software development have a relatively shorter time frame. The expected time considers normal development conditions, ensuring a timely progression.

Benefits:

1. **Energy Efficiency:**
   - The system's dynamic control based on environmental conditions is expected to significantly improve energy efficiency, leading to reduced consumption and lower utility costs.
2. **User Comfort:**

- With intelligent control algorithms, the system will enhance user comfort by adapting device operation to individual preferences and occupancy patterns.

3. **Sustainability:**
    - Contributing to sustainability goals, the system aims to reduce the overall carbon footprint by promoting responsible energy consumption practices.

Conclusion: The proposed solution outlines a comprehensive approach to smart energy management, and the PERT estimates provide a roadmap for efficient project execution. The expected results include improved energy efficiency, enhanced user comfort, and a sustainable approach to residential energy consumption.

Chapter 5

1. 6.1 Summary and Future work

1. Thesis Overview:

The thesis/project centers on the development and implementation of an IoT-based Smart Energy Management System, aiming to redefine residential energy practices through dynamic control and sustainable living solutions.

2. Purpose of the Project/Thesis:

The primary purpose is to optimize residential energy consumption, prioritizing user comfort and contributing to sustainability. The project addresses limitations in traditional energy management by leveraging IoT technologies for real-time monitoring and control.

3. Research Methods:

The methodology involves a systematic approach, encompassing hardware assembly, software development, and comprehensive testing. Integration of sensors, controllers, and NodeMCU forms the basis for creating an adaptive system capable of optimizing energy usage based on environmental conditions.

4. Results, Conclusions, and Recommendations:

Results indicate a significant improvement in energy efficiency and device protection against voltage fluctuations. The web interface enhances user experience by providing real-time monitoring and control capabilities. Conclusions emphasize the importance of responsible energy consumption and highlight the potential for broader adoption of smart energy management solutions. Recommendations include further exploration of scalability and collaboration opportunities.

5. Future Work:

The future work section envisions scaling the system for wider adoption and exploring collaborations. It raises questions about scalability, broader implications for smart energy management, and encourages continued exploration of IoT technologies for sustainable living practices. This section serves as a catalyst for future research and practical applications in the field.

Chapter 6

7.1 Conclusion & Recommendation

In conclusion, this research aimed to address the challenges in traditional residential energy management by developing an IoT-based Smart Energy Management System. The research question focused on creating an intelligent infrastructure for optimized energy utilization while considering user comfort and environmental sustainability. The project successfully implemented a system architecture integrating sensors, controllers, and NodeMCU, allowing dynamic control of lighting, fans, and air conditioners based on environmental conditions. The human presence detection feature enhances energy conservation by intelligently cutting off electricity during non-occupancy.

The highlights of our results showcase a significant improvement in energy efficiency, with the system adapting dynamically to varying conditions. The integration of a voltage protection mechanism ensures the longevity of electrical appliances, contributing to cost savings for users. The web interface provides an intuitive platform for real-time monitoring and control, enhancing user experience.

In conclusion, the IoT-based Smart Energy Management System presents a transformative solution for sustainable and efficient residential energy management. Looking ahead, the implications of this research extend beyond academia, influencing how households approach energy consumption, promoting responsible usage, and contributing to a greener future. As we move forward, the question of scalability and broader adoption emerges, urging further exploration and collaboration in the pursuit of smarter, more sustainable energy practices.

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Annexure

No annexure is appended to this project report. The main content of the report comprehensively covers all the necessary information, data, and supporting materials related to the project. Therefore, there are no supplementary documents or additional material provided in the annexure section.