<u>**ElectroEfficient**: AI-Based Electricity Consumption Monitoring System</u>

Project/Thesis ID. 2023: 17

Session: BS Fall 2020

Project Supervisor: Yusra Khalid

Submitted By

Abdullah Bin Rashid

Syed M. Anas Bin Faisal

Ahsan Akbar

Syeda Fiza Rizvi

Department of Computer Science

Sir Syed University of Engineering & Technology

Certification

This is to certify that **Abdullah Bin Rashid (2020F-BCS-057), Syed Muhammad Anas Bin Faisal (2020F-BCS-079), Ahsan Akbar (2020F-BCS-266),** and **Syeda Fiza Rizvi (2020F-BCS-068)** have successfully completed the final project **ElectroEfficient** at the Sir **Syed University of Engineering & Technology**, to fulfill the partial requirement of the degree **Bachelor of Science in Computer Science.**

External Examiner

Project Supervisor

Yusra Khalid

Senior Lecturer

Chairman

Department of Computer Science, Sir Syed University of Engineering & Technology

Project Title (mention project title here)
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

Abstract

The hike in electricity prices over the past year has undoubtedly placed immense strain on the population of Pakistan, amplifying the need for innovative solutions to mitigate the impact. Numerous studies have shown that the primary driver of energy consumption in a household is user behavior. Modifying user behavior to enhance energy usage results in efficient energy consumption, reducing power consumption costs.

One promising solution lies in developing an AI-based mobile application named "**ElectroEfficient"** to monitor electrical energy consumption and analyze data to help individuals control their power bills. This application would empower users with real-time insights into their energy usage patterns, enabling them to make informed decisions about when and how they consume electricity. By identifying & recommending energy-efficient practices, this application can not only alleviate the financial burden on households and businesses but also foster a culture of responsible energy consumption. Additionally, it aligns with the broader goal of promoting energy conservation and sustainability, which is increasingly crucial in the face of rising energy costs and environmental concerns. Expected outcomes include heightened energy consumption awareness, reduced carbon emissions, lower electricity bills, and the adoption of sustainable energy practices.

Undertaking

I certify that the project **ElectroEfficient** 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.

Abdullah Bin Rashid

2020F-CS-057

Syed Muhammad Anas Bin Faisal

2020F-CS-079

Syeda Fiza Rizvi

2020F-CS-068

Ahsan Akbar

2020F-CS-266

Acknowledgement

The successful completion of this project stands as a testament to the collective effort and collaboration of a dedicated group of individuals. We express our deepest gratitude to those who played pivotal roles in contributing to the fruition of our endeavors.

Our sincere appreciation goes to our Supervisor **Ms. Yusra Khalid**, whose mentorship and expertise provided invaluable guidance throughout the project lifecycle. Their insights significantly influenced the strategic direction and depth of our research.

Special recognition is extended to our Co-Supervisor, **Sir S.M. Fazal ul Karim**, whose meticulous efforts in both the IoT and hardware domains substantially enhanced the overall quality of our work. Their commitment to excellence and collaboration did not go unnoticed. We are indebted to him for their constructive critique and thoughtful suggestions, which greatly contributed to the refinement and polish of our project.

Acknowledgment is also due to our friends and families for their unwavering support during the challenges and demands of this project.

Additionally, we express our gratitude to Sir Syed University of Engineering & Technology for their provision of resources and support, contributing to the seamless execution of our project.

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Chapter 1

1.1 Introduction

The surge in electrical energy consumption is a critical concern, and numerous studies underscore that user behavior stands as the primary driver behind household energy usage. Optimizing user behavior for improved energy utilization holds the key to achieving efficient energy consumption, thereby mitigating power consumption costs. However, the existing system poses certain challenges, including a deficiency in providing regular updates to consumers regarding their daily electricity usage within their homes. Furthermore, acquiring consumption updates poses difficulties, presenting a gap in user awareness and control.

Current power meters installed in residences exhibit limitations, offering real-time information solely on the total power usage without the capability to present consumption data over extended periods, such as days, weeks, or months. Moreover, these meters are often inconveniently located, rendering regular monitoring a challenging task. Accessibility is another issue, as these meters do not facilitate easy access for users. Addressing these limitations is essential to instill a culture of informed and efficient electricity consumption among households.

Traditionally, the process of monitoring electricity consumption has relied on manual meter readings, presenting challenges such as time-consuming procedures and inconvenience. However, the emergence of the Internet of Things (IoT) has reshaped this landscape, offering an innovative solution through automated and remote data collection. This transformative capability has given rise to the global popularity of Smart Energy Meters, marking a significant opportunity to embark on the development of our own IoT-based electricity energy meter.

In this project, we aim to develop a cutting-edge Smart Electricity Monitoring System that seamlessly integrates IoT and AI technologies. Utilizing the ESP32 microcontroller along with sophisticated sensors such as the SCT-013 for precise current measurement and the ZMPT101B for advanced voltage measurement, our smart meter is designed to measure voltage, current, power, and total energy consumption in kilowatt-hours (kWh). Complemented by an AI-powered mobile application, this system ensures real-time data transmission and provides users with accessible, insightful dashboards for monitoring electricity usage from any location. Beyond core functionalities, our project prioritizes user-centric features, offering the flexibility to establish personalized electricity consumption limits and delivering tailored energy consumption recommendations. This not only informs users but also empowers them to exercise control over their energy usage, fostering a proactive approach to minimize consumption and promote energy conservation.

1.2 Statement of the problem

The current electricity crisis in Pakistan is characterized by a substantial increase in electricity rates. This price surge is causing severe financial strain on the average Pakistani household, where electricity bills traditionally consume between 15% to 20% of their income. This alarming situation underscores the urgent need for comprehensive reforms with a primary focus on enhancing affordability, transparency, and promoting efficient electricity management practices. The potential issues with the current system include a lack of updates for consumers regarding their daily electricity usage within their homes, and difficulties in obtaining consumption updates. Many of the power meters currently installed in homes provide real-time information about the total power usage but lack the capability to display consumption data over days, weeks, or months. Additionally, these meters are often inconveniently located, making regular monitoring challenging, and they do not offer easy accessibility. The inherent difficulty in accessing and viewing these meters has led to a sense of frustration among users. To overcome this obstacle, some have resorted to unconventional methods, such as using CCTV cameras to facilitate remote monitoring. Regrettably, these ad-hoc solutions have proven ineffective. Addressing these issues is imperative to ensure that electricity remains an accessible and sustainable utility for the nation's citizens, rather than an unbearable financial burden.

1.3 Goals/Aims & Objectives

“ElectroEfficient" is an innovative mobile application with the primary objective of enabling users to actively monitor, manage, and optimize their electricity consumption. Our foremost aim is to provide a user-friendly platform that facilitates users with the following key functionalities:

- **Real-Time Energy Monitoring**: It allows users to monitor the real-time electricity usage of each appliance.
- **User-defined Consumption Limits**: Users can establish predefined electricity consumption limits tailored to their needs and preferences and the application promptly delivers personalized energy consumption recommendation to fulfil the users predefined unit consumption requirement and timely notify the user.
- **Alerts**: A notification system generates alerts when there are unusual energy spikes and the consumption exceeds the daily average consumption target, to encourage users to minimize electricity usage.
- **Energy Consumption Prediction**: The application employs advanced predictive analytics to identify energy consumption patterns, predict future energy consumption, and provide personalized recommendations.
- **Data Visualization:** Users can access visual representations of their historical usage data, enabling them to make informed decisions and identify trends and patterns in their electricity consumption.

Through "**ElectroEfficient,**" we aim to promote energy efficiency, reduce electricity costs, and enhance environmental sustainability, benefiting both individual users and the wider community.

1.4 Motivation

The motivation behind this project is rooted in the imperative to address the escalating energy consumption challenges. With a commitment to sustainable practices, our project seeks to revolutionize electricity monitoring through the fusion of IoT and AI technologies. By creating a Smart Electricity Monitoring System, we aim to empower users with real-time insights, encourage conscious energy consumption, and contribute to a more efficient and environmentally friendly future. This endeavor is driven by the conviction that innovative solutions can catalyze positive change, promoting a culture of informed energy usage for the benefit of individuals and the broader community.

1.5 Assumption and Dependencies

The following assumptions and dependencies serve as foundational considerations, guiding the project's development and highlighting areas critical for successful implementation. Regular reviews and adjustments will be made to these assumptions and dependencies throughout the project lifecycle to ensure relevance and alignment with evolving conditions.

1.5.1 Assumptions

1.5.1.1 Sensor Accuracy: We assume that the sensors utilized in the Smart Electricity Monitoring System, particularly the SCT-013 for current measurement and the ZMPT101B for voltage measurement, maintain high levels of accuracy and precision in providing electrical data.

1.5.1.2 Network Reliability: The project assumes a reliable and stable network infrastructure for the seamless transmission of data between the IoT devices and the AI-powered mobile application. Any potential disruptions in network connectivity are considered minimal.

1.5.1.3 User Engagement: The success of user-centric features, such as personalized consumption limits and recommendations, assumes a positive level of user engagement. It is presumed that users will actively interact with the mobile application and respond to the provided insights and alerts.

1.5.2 Dependencies:

1.5.2.1 Hardware Availability: The project is dependent on the availability of hardware components, including the ESP32 microcontroller and the specified sensors. Timely access to these components is crucial for the project's development.

1.5.2.2 Software Compatibility: The successful integration of the IoT system and AI-powered mobile application relies on the compatibility of software components. Dependencies on specific software libraries, frameworks, or versions are considered, and any changes may impact the project.

1.5.2.3 User Adoption: The effectiveness of the project's user-centric features is contingent on user adoption and acceptance. The project assumes that users will readily embrace and utilize the system for efficient energy consumption monitoring.

1.5.2.4 Power Supply: The continuous functionality of the Smart Electricity Monitoring System depends on a stable and reliable power supply, ensuring uninterrupted operation of the IoT devices and sensors.

1.6 Methods

Electric power usage monitoring are crucial due to global consensus on the necessity of decreasing the electrical consumption and changing the centralized paradigm of the grid to be distributed architecture [1]. This trend is being promoted in some cases by national or international commissions, although the penetration rate is not homogenous [2]. The implementation of smart metering is one of the important steps towards the realization of smart grids [3]. The smart meter network is expected to monitor real-time status of the electrical network and communicate the required information to a control node capable of taking decisions [4]. There are numerous studies on the efficient management of smart meter data collection and post-processing. There are various standards set on smart meters [5]

Our development methodology for the electricity consumption monitoring application involves a two-fold approach integrating both hardware and software components. On the hardware side, we are transforming the landscape of electricity consumption monitoring through the creation of a smart meter. Utilizing the ESP32 microcontroller and incorporating cutting-edge sensors—such as the highly precise SCT-013 for current measurement and the advanced ZMPT101B for voltage measurement—our system is designed to measure voltage, current, power, and total energy consumption in kilowatt-hours (kWh). The circuit diagram for the IoT-based Electricity Energy Meter using ESP32 is shown below. The design was created using the Fritzing software and the connection diagram is simple.

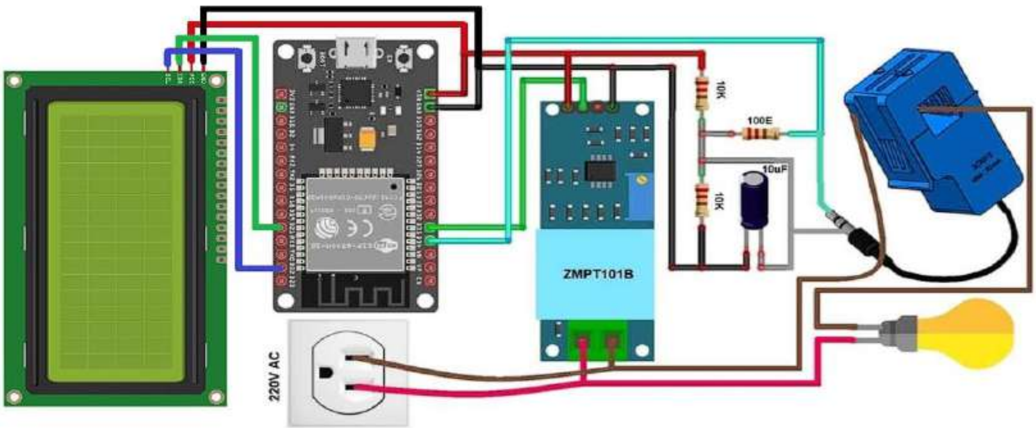


Figure 1: Circuit diagram for the IoT-based Electricity Energy Meter

An AI-powered mobile application is an integral part of our project, ensuring seamless data transmission to the application and providing users with a real-time overview of their electricity usage through an accessible dashboard, accessible from any location. Custom firmware on the ESP32 facilitates the creation of a RESTful API, updating a Firebase Realtime Database with live electricity consumption metrics. Simultaneously, a regression model, trained on historical data stored in Firebase, predicts future consumption patterns.

The Flutter mobile application serves as the user interface, fetching real-time and historical data from Firebase, and presenting it with intuitive visualizations. Rigorous testing ensures the accuracy of data flow, including real-time updates and predictive analytics.

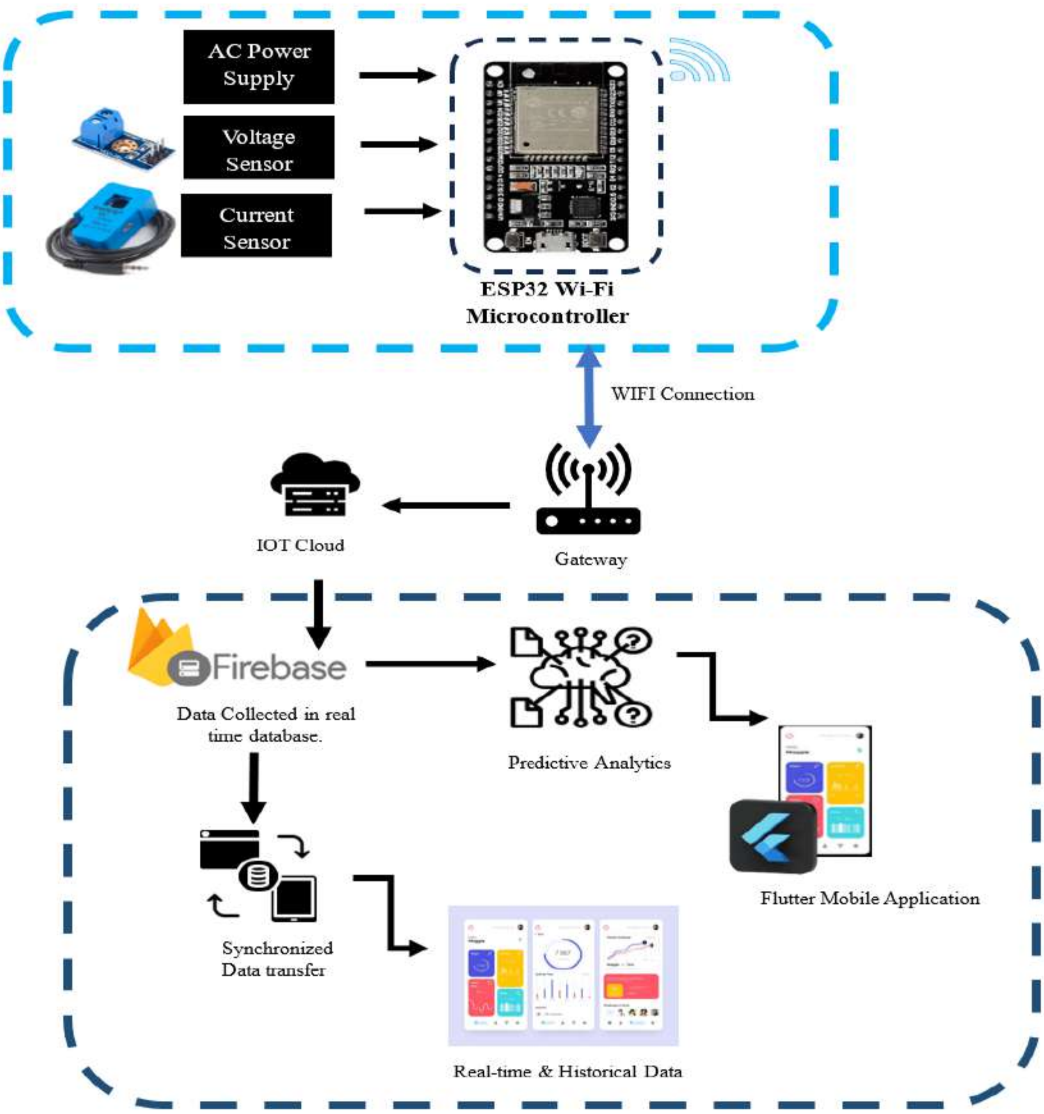


Figure 2: *System Architecture Diagram*

Chapter 2

2.1 Main Components of Hardware Setup

2.1.1 Components Required

Here is a compilation of the essential components required to assemble an IoT-based Smart Electricity Energy Meter, designed for capturing meter readings accurately.

S.N.	Components
1	ESP32 WiFi Module
2	ZMPT101B AC Voltage Sensor Module
3	SCT-013-030 Non-invasive AC Current Sensor
4	20x4 I2C LCD Display
5	Micro-USB Cable
6	Resistor 10K
7	Resistor 100ohm
8	Capacitor 10uF
9	Connecting Wires
10	Breadboard

Table 1: Required Hardware Components

2.1.2 SCT-013 Current Sensor

Figure 3: *SCT-013 Current Sensor*

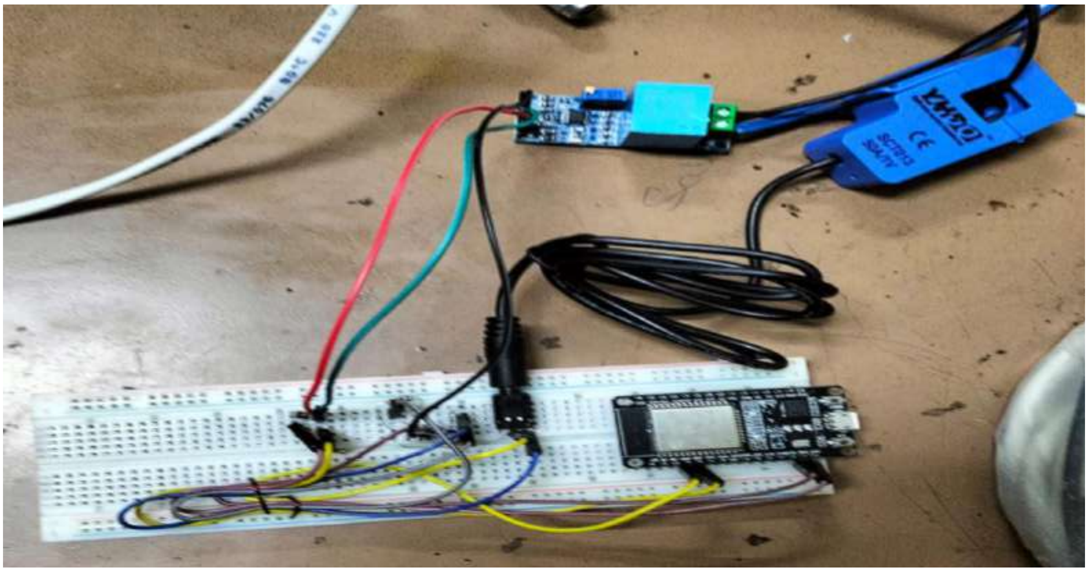
The SCT-013 is a non-invasive split-core type clamp meter sensor designed to measure AC current up to 100 amperes. This type of current sensor is commonly known as a current transformer (CT) and is used for measuring alternating current in a building. The SCT-013 is convenient to use, as it can be easily attached to either the live or neutral wire without any electrical work involving high voltage.

2.1.3 AC Single Phase Voltage Sensor

Figure 4: *ZMPT101B AC Single Phase Voltage Sensor*

The ZMPT101B AC Single Phase Voltage Sensor Module is a high-precision device built on the ZMPT101B voltage transformer. This makes it an ideal choice for measuring accurate AC voltage with an Arduino or ESP32.The module is capable of measuring AC voltage within a range of 250V and offers adjustable analog output. It is easy to use, featuring a multi-turn trim potentiometer for adjusting and calibrating the ADC output.

2.1.4 Hardware Setup



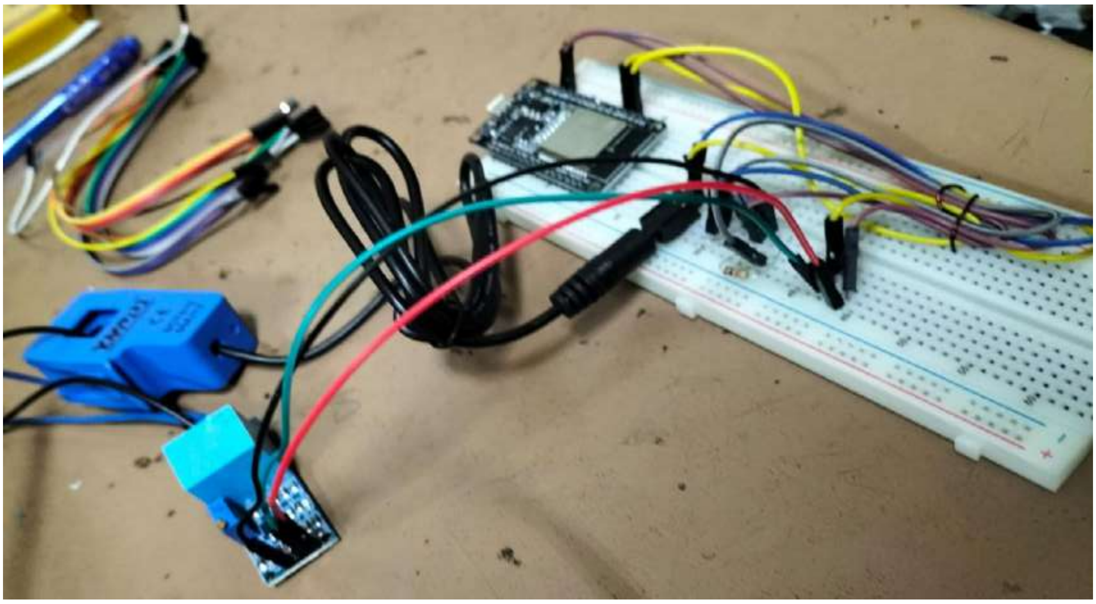


Figure 5: Circuit implementation for the IoT-based Electricity Energy Meter

The VCC & GND pins of both the SCT-013 Current Sensor and ZMPT101B Voltage Sensor are connected to the **Vin** & **GND** of ESP32, which is a **5V** supply. The output analog pin of the ZMPT101B Voltage Sensor is connected to the **GPIO35** of ESP32 and the output analog pin of the SCT-013 Current Sensor is connected to the **GPIO34** of ESP32. Additionally, two **10K resistors** and a single **100-ohm resistor**, along with a **10uF capacitor**, are required to complete the circuit.

Chapter 3

3.1 Summary and Future work

"ElectroEfficient" is an innovative mobile application with a primary goal to empower users in actively monitoring, managing, and optimizing their electricity consumption. The application offers real-time energy monitoring for individual appliances, allowing users to stay informed about their electricity usage. Noteworthy features include user-defined consumption limits, personalized energy consumption recommendations, alerts for unusual energy spikes, predictive analytics for energy consumption patterns, and visual representations of historical usage data. The development methodology employs a comprehensive two-fold approach, integrating both hardware and software components. On the hardware side, a smart meter is created using the ESP32 microcontroller and advanced sensors (SCT-013 and ZMPT101B) to measure voltage, current, power, and total energy consumption. This innovative system aims to promote energy efficiency, reduce costs, and enhance environmental sustainability, benefiting both users and the wider community.

Moving forward, our future work will focus on refining and expanding the functionality of "ElectroEfficient." This includes enhancing the accuracy of predictive analytics, incorporating additional features for more granular energy insights, and expanding compatibility with a wider range of smart devices. We aim to conduct user feedback sessions to further improve user experience and address specific user needs. Additionally, exploring partnerships with utility companies for seamless integration into existing energy infrastructure is part of our future roadmap. Continuous updates and iterations will be made to stay aligned with technological advancements and user expectations, ensuring "ElectroEfficient" remains at the forefront of innovation in electricity consumption monitoring.

Chapter 4

4.1 Conclusion & Recommendation

In conclusion, the development and implementation of "ElectroEfficient" mark a notable advancement in empowering users to actively manage and optimize their electricity consumption. The array of features, including real-time energy monitoring, user-defined consumption limits, predictive analytics, and historical data visualizations, collectively offers a comprehensive solution for informed decision-making. The integration of a smart meter, utilizing advanced sensors and the ESP32 microcontroller, underscores our commitment to delivering accurate and insightful electricity usage data. The potential impact of this project extends beyond individual users, aligning with a broader initiative towards sustainable and conscientious energy practices. "ElectroEfficient" stands as a testament to the transformative possibilities inherent in technology when applied to energy management.

Several recommendations can further enhance the effectiveness and adoption of "ElectroEfficient." First and foremost, a robust user education program should be implemented to ensure users fully exploit the application's capabilities. Additionally, investing in research and development to refine predictive analytics, exploring integration with popular smart home devices, and collaborating with utility companies can significantly broaden the application's utility and user base. Regular updates and responsive customer support are essential to maintaining a positive user experience and addressing evolving needs. By incorporating these recommendations, "ElectroEfficient" has the potential to evolve into a cutting-edge solution that not only meets but anticipates user expectations, contributing meaningfully to the ongoing dialogue on sustainable energy consumption practices.

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