SOLMATE: SMART IOT SUN- TRACKING SOLAR PANEL SYSTEM WITH MOBILE MONITORING AND ENERGY OPTIMIZATION

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ABSTRACT

This study presents SolMate: Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization, a solution designed to address the inefficiencies and limitations of traditional fixed solar panels in households. Solar energy, while sustainable, often suffers from reduced efficiency due to static panel orientation, weather conditions, and lack of real-time monitoring. To address these challenges, the researchers developed SolMate, integrating three core features: an automated sun-tracking mechanism to maximize energy capture, a hybrid battery setup to ensure continuous supply during outages, and an IoT-enabled mobile application for real-time monitoring and optimization.

The study employed a descriptive-quantitative research design supported by survey questionnaires administered to 525 respondents in Gun-ob Lapu-Lapu City, of which 450 valid responses were analyzed. Data were statistically treated using frequency, percentage, and weighted mean to evaluate solar energy practices, challenges, and perceptions of the proposed system. Findings revealed that respondents strongly supported sun-tracking, hybrid storage, and mobile-based monitoring, with mean ratings above 4.60, validating the relevance of SolMate's features.

The prototype, powered by an ESP32 microcontroller, Light Dependent Resistors (LDRs), and servo motors, is connected through Firebase Realtime Database and accessed via a React Native mobile application, allowing users to track energy output, battery level, and panel orientation. The findings demonstrate SolMate's potential to enhance energy efficiency, reliability, and affordability in residential solar applications. Future studies are encouraged to explore system scalability for larger installations, predictive maintenance integration, and partnerships with local government units to promote wider adoption.

Keywords: *SolMate, Smart IoT, Sun-Tracking Solar Panel, Mobile Monitoring, Energy Optimization, Hybrid Charging System, Real-Time Device Monitoring, Renewable Energy, Sustainable Technology, Battery Management.*

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We thank the Lord Jesus Christ for His guidance and strength throughout this journey. It is not by our skills or knowledge that we have reached this point but through His grace. His wisdom has been our light, His strength our foundation, and His favour our path to success. We acknowledge his greatness now and forever.

Our grateful thoughts go out to the community from where information regarding the system was gathered. Your willingness to cooperate and share your thoughts has greatly aided us in conducting this research. With your desire to help, the study has evolved into a significant endeavor.

To our families, who have stuck by us through thick and thin with unconditional love, patience, and understanding—thank you. Your belief in us has been a great motivator for us to keep going against all odds. Your sacrifices will never be in vain, as they are our stepping stones to success.

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The Researchers

DEDICATION

With profound enthusiasm, we dedicate this research project, SolMate: Smart IoT-Enabled Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimisation, to the numerous individuals who have given us strength and inspiration along the way.

Our deepest thanks go to our Almighty God, from whom we received wisdom, perseverance, and strength. With His guidance, He lit our path, filling us with the strength to conquer every hurdle and allocate our determination to complete this study.

To our beloved families, whose support, love and sacrifices are boundless, the very foundation of our success is bestowed unto you. Your patience and encouragement are what ignited our passion and kept us motivated through discouraging times. We shall be forever grateful for your unending faith in us.

To our adviser, Mr. Paul S. Ngujo, and the faculty of the College of Computer Studies, we acknowledge the guidance and support you have provided, which have nurtured and enriched this research to its present form. The energy you devoted to our growth has resulted in the deepening of this work, paving the way for us to stretch our limits.

To our friends and peers, our motivators and companions: Thank you for the laughter, morale, and shared experiences that have made this journey worthwhile. To future researchers and innovators, may this study serve as inspiration to take technology as far as it can go in providing a better and more sustainable future.

This project is thus the outcome of the combined efforts of everyone who believed in us. With great appreciation, we dedicate this project to you all.

The Researchers

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CHAPTER I
INTRODUCTION

Rationale of the Study

Solar energy, derived from sunlight through photovoltaic (PV) panels, has emerged as a leading force in the global shift toward sustainable energy. It is cost-effective, renewable, and environmentally friendly (El Hammoumi et al., 2022). However, the solar energy sector continues to face challenges in maximizing efficiency and sustainability on a global scale.

The solar energy sector still faces persistent challenges in maximizing energy capture and system efficiency. Traditional fixed solar panels, while common due to their lower initial cost and ease of installation, are inherently limited by their static nature. As the sun moves across the sky, panels that are unable to adjust their position fail to capture the optimal angle of sunlight, resulting in substantial energy losses—estimated between 30% to 40% (Ponce-Jara et al., 2022; Ali & Al-Juboury, 2023). Although solar panels can still collect energy from diffuse solar radiation—sunlight scattered through clouds and atmospheric particles—the efficiency is significantly reduced, yielding only 10–25% of what direct sunlight would provide. These losses are further aggravated by unpredictable weather, partial shading from nearby objects, poor maintenance practices, and dust accumulation, which collectively deteriorate system performance.

Moreover, the issue of sustainability remains a growing concern as more solar systems reach the end of their operational lifespan. The improper disposal of outdated photovoltaic modules is contributing to rising levels of electronic waste, which threatens the environmental integrity of solar energy as a green solution. To combat these setbacks, various technological innovations have emerged. For example, the development of sun-tracking systems—particularly dual-axis trackers—enables solar panels to follow the sun's path across the sky, optimizing energy absorption and increasing output by up to 40% (Muthukumar et al., 2023). Additionally, Internet of Things (IoT) platforms are being integrated into solar energy systems to offer real-time monitoring of panel performance, battery storage levels, and fault detection. These innovations not only improve operational efficiency and maintenance but also extend system lifespan, supporting global transitions to greener and smarter energy infrastructures (Matellio Inc., n.d.; Sankpal et al., 2024).

In the Philippines, the adoption of solar energy remains limited, particularly due to high upfront costs. A typical household installation can exceed ₱100,000, equivalent to over six months of income for minimum-wage earners (Junnel, 2024). Additionally, most IoT-based monitoring systems are tailored for industrial-scale use, leaving residential users without affordable or scalable options (Uzair et al., 2022). The country also experiences frequent power outages, underscoring the need for more resilient energy systems. While sun-tracking systems may seem costlier at first, they deliver up to 40% more energy than static systems (Muthukumar et al., 2023), enabling faster returns on investment through lower electricity bills and improved energy self-sufficiency. Affordable, residential-scale IoT solutions can further optimize usage and performance, offering long-term economic and operational advantages.

From a local perspective, Cebu faces persistent energy challenges, including scheduled brownouts and reliance on imported electricity, with over 60% of the region's power sourced externally (Aboitiz Power, 2024). These limitations threaten both daily living and economic growth. Infrastructure developments, such as the Therma Visayas plant expansion and the Cebu-Negros-Panay 230-kV Backbone Project, reflect efforts to improve energy supply (PCO, 2024). Moreover, initiatives like Acciona Energía's solar farm with battery storage in Daanbantayan support the region's renewable energy goals. In underserved areas, hybrid solar systems with sun-tracking and IoT capabilities offer a scalable and cost-effective solution for improving energy access, reliability, and environmental sustainability.

As someone who has lived in a community where brownouts are frequent and unpredictable, I've experienced the real struggles of relying on an unstable power supply. Losing electricity in the middle of schoolwork, daily routines, or even during extreme weather has shown me how deeply power interruptions affect not just comfort, but also productivity and safety. While solar energy is a promising solution, many households are held back by high installation costs, inefficient fixed panels, and systems that don't store energy or provide real-time insights. These gaps leave users unsure about the performance and reliability of their solar setups, especially during cloudy days or outages. Our experience reflects the reality of many Filipinos who need more than just a basic solar panel—they need a system that is efficient, dependable, and smart.

These challenges inspired SolMate—a smart, IoT-integrated, hybrid sun-tracking solar panel system designed to respond directly to these pressing needs. SolMate merges three powerful technologies: (1) a sun-tracking system that dynamically adjusts solar panel positioning to follow the sun and maximize energy absorption; (2) a hybrid battery setup that ensures continuous power availability even during brownouts or cloudy days; and (3) a mobile based IoT platform that allows users to monitor, manage, and optimize their solar energy system in real time. With a user-friendly interface, affordability-focused design, and sustainability-oriented use of recycled materials, SolMate provides a holistic solution that meets the energy needs of modern Filipino households.

Objectives of the Study

General Objective:

This study aims to design, develop, and evaluate an IoT-based hybrid sun-tracking solar panel system with mobile monitoring to enhance solar energy efficiency and ensure a reliable power supply.

Specific Objective:

1. Identify the current challenges in solar energy usage in terms of:
   1.1. practices, and
   1.2. problems encountered.
2. Determine key techniques for system development, including:
   2.1. sun-tracking mechanisms,
   2.2. hybrid power management, and
   2.3. real-time monitoring.
3. Define system functionalities and features that will optimize energy efficiency.
4. Implement and test the proposed system to assess its performance and reliability.

Scope and Limitations of the Study

This study focuses on the development of SolMate: Smart IoT-Enabled Hybrid Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization. It aims to increase solar energy efficiency through an automatic sun-tracking mechanism utilizing Light Dependent Resistors (LDRs) and servo/stepper motors, which adjust the panel's position throughout the day to maximize sunlight absorption. The system also functions as a hybrid power source by switching to battery storage during low sunlight conditions, such as during cloudy or rainy weather.

The scope of this study extends to the design and implementation of a mobile based monitoring system that tracks real-time data on energy generation, consumption, and system performance. All data is stored in the cloud to allow users access to historical trends for consumption optimization. Furthermore, the system integrates energy optimization to enhance panel positioning based on environmental conditions. The study promotes sustainability and cost-efficiency through the use of recycled materials. The system's performance will be evaluated in selected areas in Cebu, particularly in Lapu-Lapu, considering various weather conditions and power fluctuations. Effectiveness, efficiency, and user acceptability will serve as the core metrics for evaluation.

Despite its potential benefits, the study acknowledges several limitations. Primarily, the system is tailored for small- to medium-scale applications and is not intended for commercial or large-scale solar installations. The sun-tracking mechanism, driven by servo or stepper motors, may require regular maintenance due to wear and tear. The battery storage is limited in size and will eventually need replacement. Additionally, the accuracy and functionality of the cloud-based monitoring system depend heavily on a stable internet connection, which could affect real-time performance in areas with poor signal coverage. Geographically, the study is limited to the cities of Lapu-Lapu, meaning findings may not generalize to regions with different climate conditions.

Significance of the Study

The proposed system will benefit the following groups of users:

Households and Potential Solar Adopters. Residential users are the primary beneficiaries of this study. SolMate aims to offer an affordable and intelligent solar energy system equipped with sun-tracking, hybrid battery storage, and real-time monitoring. These features are designed to enhance energy efficiency, reduce electricity bills, and ensure a reliable power supply during outages or low sunlight conditions. By making solar technology more accessible and user-friendly, the system supports wider adoption among homeowners—particularly in areas like Lapu-Lapu City where power interruptions are frequent.

Local Government Units (LGUs) and Community Planners. SolMate serves as a potential tool for LGUs and planners seeking to implement renewable energy programs at the barangay or municipal level. Its scalability and use of recycled materials align with sustainable development goals and can support energy resilience initiatives in underserved communities.

Environmental Advocates and Non-Governmental Organizations (NGOs). Organizations promoting environmental sustainability can leverage SolMate's model to showcase how technology can reduce carbon footprints while addressing practical energy access challenges. The system's integration of recycled materials also emphasizes low-impact innovation.

Educational Institutions. The SolMate system provides a valuable educational resource for students and faculty in information technology, engineering, and environmental science. It demonstrates an interdisciplinary application of IoT, renewable energy, and mobile development—offering opportunities for classroom learning, research, and project replication.

Researchers. This study offers researchers valuable insights into IoT-integrated solar tracking, AI-based energy optimization, and hybrid storage systems. It contributes to the growing field of smart energy technologies and supports ongoing advancements in solar power efficiency and reliability.

Future Researchers. The study serves as a reference for exploring sustainable energy systems using recycled materials, automated tracking, and cloud-based monitoring. It opens opportunities for enhancing solar performance, storage, and smart energy solutions.

DEFINITION OF TERMS

This section provides clear and concise definitions of the key terms and concepts used in the development of the SolMate system. Understanding these terms is essential to fully grasp the system's overall contribution to smart renewable energy solutions.

Battery Storage – Refers to the system component that stores surplus energy generated by the solar panels, ensuring continuous power availability and improving efficiency and reliability.

Cost-effectiveness – Refers to the extent to which the hybrid solar system provides economic benefits, such as reduced electricity bills and a higher return on investment over time.

Efficiency – Refers to the ratio of useful output power to total input energy. In this study, it measures how well the system converts solar energy into usable electricity, including storage performance.

Energy Consumption – Refers to the total amount of electrical energy used by devices powered by the hybrid system, used in analyzing performance and efficiency.

Energy Optimization – Refers to the strategic improvement of how energy is generated, stored, and distributed to ensure efficient and balanced system operation.

Environmental Challenges – Refers to the weather-related and geographical conditions that affect solar energy production, such as cloud cover, temperature, or shading.

Hybrid Power Management – Refers to the intelligent control of energy flow between solar panels, batteries, and inverters to optimize usage and maintain system stability.

Hybrid Solar Panel System – Refers to a power generation setup that combines solar energy from photovoltaic panels with battery storage. This allows energy to be stored and used during periods of low sunlight or at night.

Inverter – Refers to an electronic device that converts direct current (DC) generated by the panels or batteries into alternating current (AC) suitable for standard appliances.

Load Demand – Refers to the amount of power required by connected devices or appliances at a given time, used to assess system capacity and efficiency.

Overcharging Protection – Refers to a safety feature that prevents battery damage by regulating energy input when the storage is full.

Performance Testing – Refers to the procedures used to assess the system's effectiveness, efficiency, and reliability under real operating conditions.

Photovoltaic (PV) Cells – Refers to semiconductor devices that convert sunlight directly into electrical energy. They are the core components of the solar panel system.

Real-Time Monitoring – Refers to the system's ability to track energy production, battery status, and system performance as it happens, typically through a mobile or digital interface.

Reliability – Refers to the system's ability to provide uninterrupted power supply under various weather conditions or fluctuations in solar energy availability.

Solar Energy – Refers to renewable energy derived from sunlight, typically harnessed using photovoltaic (PV) panels, and used as the system's main power source.

SolMate – The proposed smart IoT-enabled sun-tracking solar panel system is designed to enhance solar energy efficiency through automated tracking, mobile monitoring, and energy optimization.

Sun-Tracking Mechanism – Refers to the motor-driven system that automatically orients solar panels toward the sun throughout the day to maximize solar energy capture.

Sustainability – Refers to the system's potential for long-term use with minimal environmental impact, supporting renewable energy adoption and reducing carbon emissions.

System Implementation – Refers to the process of assembling and deploying the hybrid solar panel system, including setup, configuration, and integration of all hardware and software.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents the pertinent literary works, a conceptual framework, related studies, and a comparative matrix.

Related Literatures

This section reviews existing related literature, which offers key insights, theoretical frameworks, research methods, and relevant findings that inform the design and implementation of our study.

Fixed Solar Panels

Solar panels are the most commonly used type of photovoltaic (PV) system. According to El Hammoumi et al. (2022), PV systems generate electricity by directly converting solar energy into electricity, making the system's most important component. Power generation has its advantages. Stevanović et al. (2022) stated that solar energy provides notable economic benefits, including reduced electricity costs, potential income from energy arbitrage, minimal maintenance expenses, and a long system lifespan with a favourable return on investment.

In addition, Anjum and Mukherjee (2022) mentioned that partial shading leads to a drop in the electricity generated by solar panels. Specifically, PV systems are designed to capture sunlight during peak hours but remain static throughout the day, which can limit their overall efficiency due to the sun's changing position. This highlights the critical need for advanced tracking systems or innovative panel designs that can mitigate the effects of partial shading and optimize energy capture throughout the day.

Additionally, the effectiveness of solar panels is highly dependent on their alignment with the sun's trajectory. Ali and Salih Al-Juboury (2023) highlight that without dynamic positioning, a substantial portion of solar radiation remains unutilized, resulting in lower power output. Their study found that solar panels positioned at fixed angles fail to harness up to 40% of available solar energy, making sun-tracking mechanisms a crucial advancement in solar technology.

Moreover, despite their widespread use, fixed solar panel systems experience significant energy losses due to their inability to adjust based on the sun's movement. Ponce-Jara (2022) states that fixed solar panels lose 25–30% of potential energy output because they remain at a static angle throughout the day. These losses become even more pronounced in locations where the sun's position changes significantly across seasons. Chathuranga et al. (2024) further emphasize that while fixed solar panels are cost-effective and simple to install, their inability to track sunlight limits their energy efficiency, especially during early morning and late afternoon hours when the sun is at a lower angle. These insights are beneficial to SolMate, as it seeks to address the inefficiencies of static solar panels by integrating an automated sun-tracking system that continuously adjusts the panel's position to optimize energy absorption and maximize potential energy output.

Cost and Installation

The combined expense of solar panels and installation forms a substantial financial burden, acting as a major obstacle to widespread adoption. According to Junnel (2024), the cost of a home solar setup, which can exceed ₱100,000, poses a significant barrier. For minimum-wage earners, this is equivalent to more than half a year’s salary, making solar technology inaccessible for many. This finding highlights the financial burden that solar installations can impose on lower-income families. Parthiban and Ponnambalam (2022) noted that Solar trackers carry a slightly higher cost, a reflection of their complex technology and the need for various moving components. Ranging around a $0.08 - 0.10 per Watts increase depending on the solar panel size and its location. Solar panels are expensive to install, and for residential projects, the installation cost can often equal the price of the panels. Small, portable panels can be set up inexpensively and easily moved, as stated by Sodhi et al. (2022).

In addition, IoT-based solar tracking systems are primarily designed for large-scale commercial applications, leaving a gap in cost-effective solutions for residential users. Uzair et al. (2022) introduced a low-cost PV system designed specifically for residential rooftop installations. Their system focuses on both energy management and home automation, demonstrating the feasibility of integrating IoT technologies in everyday homes to improve efficiency and reduce reliance on conventional energy sources. Similarly, Demir (2023) proposed a cost-effective, open-source solar monitoring system using an ESP32 microcontroller. Their design emphasizes real-time monitoring and data transmission for standalone PV systems, demonstrating how IoT components can be leveraged to make residential solar tracking more accessible, particularly for users with budget constraints. These comprehensive studies collectively highlight the emerging potential of IoT in creating affordable, residential-scale solar solutions, bridging the gap between commercial innovations and the needs of everyday users. Similarly, SolMate aims to fill this gap by developing an affordable, IoT-enabled sun-tracking system that is accessible to both homeowners and small-scale users.

Sun-Tracking

The ability to dynamically adjust solar panel orientation is crucial for maximizing energy capture, especially in light of the challenges posed by partial shading and the sun's changing position. Ponnalagarsamy (2022) explored the use of light-dependent resistors (LDRs) and servo motors in sun-tracking mechanisms, demonstrating a significant increase in energy output compared to fixed systems. Shakeel et al. (2023) found that dual-axis tracking systems, which adjust both tilt and rotation, enhance energy collection by up to 40%. These systems ensure that the solar panel maintains an optimal angle throughout the day, maximizing sunlight exposure.

Along with that, Muthukumar et al. (2023) also proposed a dual-axis solar tracking system integrated with IoT to enhance the efficiency of PV panels. Performance tests showed significant improvements in energy capture, achieving 30–40% higher efficiency compared to static panels. This study supports the increasing relevance of smart, efficient, and adaptable solar systems in the global transition toward renewable energy sources, making it particularly valuable for modern solar energy applications.

Additionally, Badole and Giri (2023) attest that integration of IoT technology further enhances sun-tracking systems by enabling real-time data collection, remote monitoring, and automation. Their research demonstrates that IoT-based solar energy systems, through the use of sensors and wireless communication, effectively track energy production and panel orientation, leading to optimized energy capture. These insights emphasize the help of sun tracking mechanisms in terms of solar energy harvesting through solar panels, aligning with our study's focus on storing and maximizing the energy storage capabilities of PV panels.

Hybrid Renewable Energy

Solar Panels are highly dependent on sunlight, limiting their energy production to daytime hours and sunny conditions. Samedova (2025) noted that it affects the amount of power solar panels produce, typically resulting in a 10–25% reduction in their usual output. One significant step forward is a hybrid renewable energy source (HRES), offering a significant advancement by combining solar technologies with energy storage solutions, enabling users to save surplus energy for cloudy days. Giedraityte et al. (2025) stated that HRES enhances the flexibility and resilience of PV solar panels. A hybrid renewable energy source mitigates solar intermittency through backup from other sources and a battery, ensuring a more stable power supply during low solar output or short-term outages, making PV solar within an HRES a more reliable and dependable energy solution. Sarker et al. (2023) also discussed how the use of HRES minimizes environmental pollution and energy consumption, which are key global challenges for sustainable development. The integration of complementary renewable sources and energy storage solutions enhances energy efficiency and reliability, decreasing the need for polluting backup generators and minimizing energy waste.

In addition, Adeyinka et al. (2024) review the latest developments in hybrid energy storage systems and their role in enhancing the integration of renewable energy sources into the power grid. HRES acts as a reliable and responsive backup system for the power grid when relying on unpredictable renewable energy sources. Emrani et al. (2022) included that renewable energy resources are considered a vital solution for addressing the global issues of environmental pollution, energy security, and sustainable development. According to Amoussou et al. (2024), renewable energies are critical for expanding the population's access to electricity on a sustainable basis. PV systems produce decarbonized and environmentally friendly electricity, which helps fight global warming.

Similarly, SolMate addresses the barriers to depending on solar energy by optimizing the use of alternative renewable energy sources. The system utilizes the interchangeability of batteries, allowing users to access and utilize energy stored from solar sources, even when they are located remotely from the physical solar panel unit. This will ensure a more reliable and consistent energy supply, overcoming the challenges posed by the lack of solar energy power.

Real-Time Monitoring

The integration of mobile-based applications has transformed solar energy system management, facilitating real-time monitoring for both user-level performance tracking and administrator-level system control. According to Gupta et al. (2022), mobile platforms provide users with real-time access to energy production data, system diagnostics, and remote control functionalities. Luis et al. (2023) added that mobile-based monitoring led to significant operational cost savings of up to 95% by enabling real-time fault detection and minimizing the need for physical inspections. This underscores how mobile monitoring enhances the efficiency and sustainability of solar energy systems, especially in remote locations.

Similarly, Enact Solar (2023) introduced a mobile application for tracking solar performance, offering insights into energy consumption trends and system maintenance. However, their study noted that the platform lacked real-time control over solar panel positioning, reducing its effectiveness in optimizing energy generation. Fernandez et al. (2022) further explored the impact of IoT-enabled mobile platforms in renewable energy management, emphasizing that real-time monitoring enhances user engagement and improves decision-making regarding solar panel adjustments.

These insights emphasize the importance of real-time monitoring; SolMate incorporates an interactive mobile monitoring system that allows users to view real-time energy generation data, track solar panel orientation, and make remote adjustments to optimize efficiency. The system provides real-time energy monitoring, power management, and potential maintenance needs, ensuring a comprehensive and user-friendly approach to solar energy management. Furthermore, a web-based administrative dashboard will be implemented, enabling administrators to monitor the registered users.

Performance and Reliability

Assessing the efficiency of sun-tracking systems requires a comparative analysis of energy output between tracking and fixed-panel configurations. Lopez and Wang (2023) conducted a study on solar tracking efficiency, concluding that tracking systems consistently generate higher energy output, particularly in areas with varying sun positions. Their research found that voltage, current, and power output improved significantly when sun-tracking technology was employed. The incorporation of PV solar panels into HRES enhances their operational flexibility by allowing their output to be complemented by other renewable sources and managed through energy storage.

In addition to energy efficiency, user satisfaction, and accessibility are crucial factors in evaluating solar energy systems. Gaspar-Figueiredo et al. (2023) emphasized that intuitive user interfaces and real-time performance tracking enhance user experience and adoption rates. Studies suggest that incorporating data visualization tools and mobile-based controls increases engagement and system usability, a perspective supported by Boubakr et al. (2022). Intuitive interfaces and actionable insights, data visualization and mobile controls help users to make informed decisions about their energy consumption and optimize the benefits of their renewable energy. SolMate will be evaluated based on two key factors: energy output improvements compared to fixed panels and user accessibility and ease of use. By integrating a user-friendly mobile interface, SolMate aims to simplify solar energy system management, helping users maximize energy efficiency with minimal effort.

Conceptual Framework

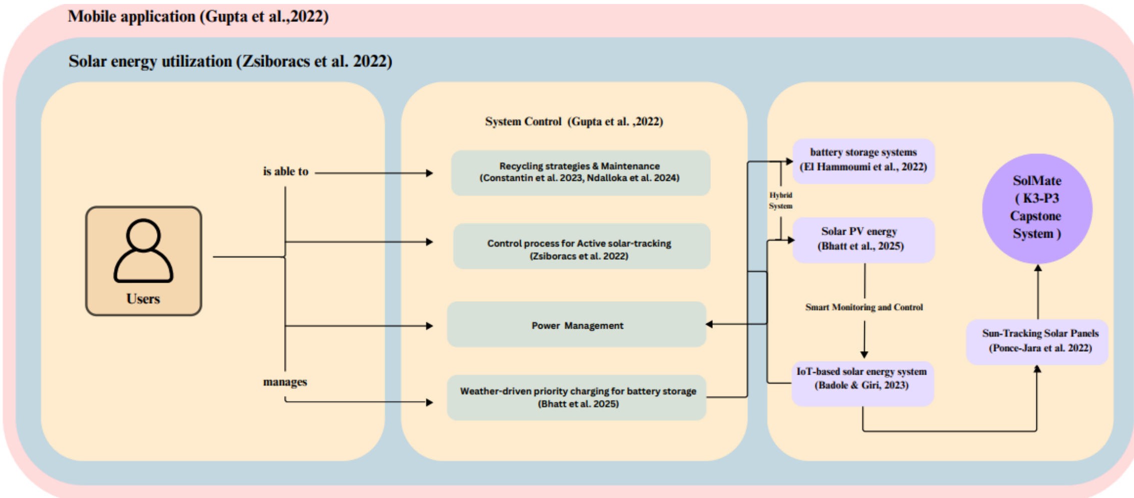

Figure 1: **Conceptual Framework of SolMate**

The conceptual framework illustrated in Figure 1 centers on the SolMate mobile application (Gupta et al., 2022), which functions as the primary user interface for managing a comprehensive solar energy utilization system (Zsiboracs et al., 2022). This system comprises several interrelated components designed to enhance energy efficiency and user interaction. At the core are sun-tracking solar panels (Ponce-Jara et al., 2022), which optimize solar energy capture by adjusting their orientation based on the sun's position. These panels are integrated into an IoT-based solar energy infrastructure (Babble & Giri, 2023), allowing for real-time remote monitoring and control.

To ensure energy availability beyond daylight hours, the system incorporates battery storage units (El Hammoumi et al., 2022), which store excess energy for later use. A centralized smart monitoring and control unit manages the communication between these hardware components and the SolMate application. This unit also facilitates key control functions such as active solar tracking (Zsiboracs et al., 2022). In addition to energy management, the framework emphasizes long-term sustainability through integrated recycling strategies and maintenance protocols (Constantin et al., 2023; Ndalloka et al., 2024), also governed via the SolMate interface. By seamlessly integrating these features, the system empowers users to actively monitor, control, and optimize their solar energy systems, promoting both efficiency and environmental responsibility.

Related Studies

The following section presents a review of existing systems and studies that share similar functionalities with SolMate: IoT Sun-Tracking Solar Panel System with Mobile Monitoring. These existing systems serve as useful references and inspiration as we develop our own innovative approach to energy optimization, renewable storage of energy and real-time solar monitoring.

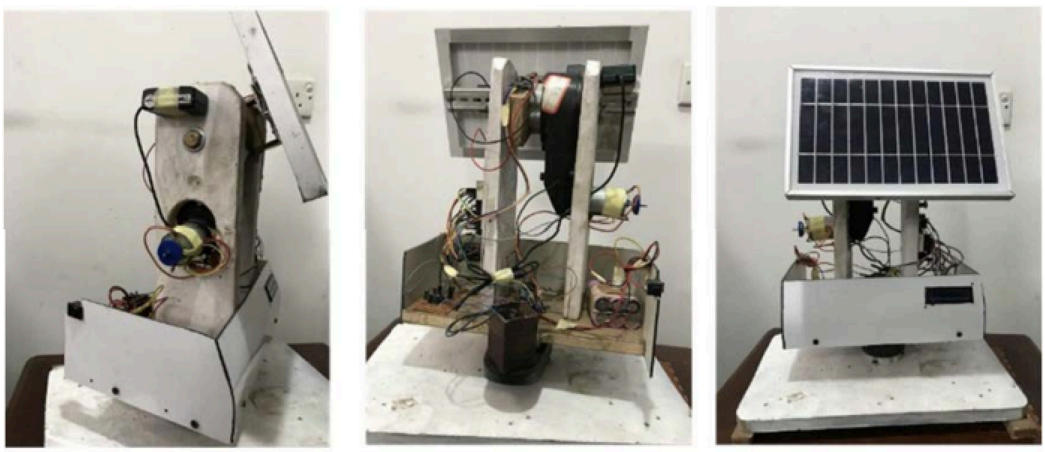

Figure 2: **Smart Solar Tracker**

Figure 2 illustrates an IoT-based smart solar tracker monitoring system developed by Al-Saadi et al. (2022), who introduced a smart, self-orienting solar tracking system designed for mobile PV power generation. The system utilizes a dual-axis tracker to optimize the orientation of PV panels, ensuring they remain perpendicular to the sun's rays and thereby maximize energy capture. The system is designed to be autonomous and efficient, capable of operating with a minimal power budget, making it suitable for mobile applications like recreational vehicles and camping equipment.

Both SolMate and Smart Solar Tracker System share several fundamental similarities. A core similarity lies in the use of dual-axis solar tracking to maximize energy output; Al-Saadi et al. (2022) developed a system that adjusts solar panels in both elevations to maintain perpendicularity with the sun's rays. Both systems prioritize maximizing energy output from solar panels. However, the study primarily focuses on the technical implementation of the tracking system; it incorporates an LCD for displaying system status, indicating a different degree of monitoring, but does not detail a user-friendly interface for easy real-time monitoring. In contrast, SolMate offers mobile monitoring, indicating a focus on providing a user-friendly interface for convenient and easy monitoring. Additionally, SolMate distinguishes itself by prioritizing sustainability through the use of recycled materials in its construction.

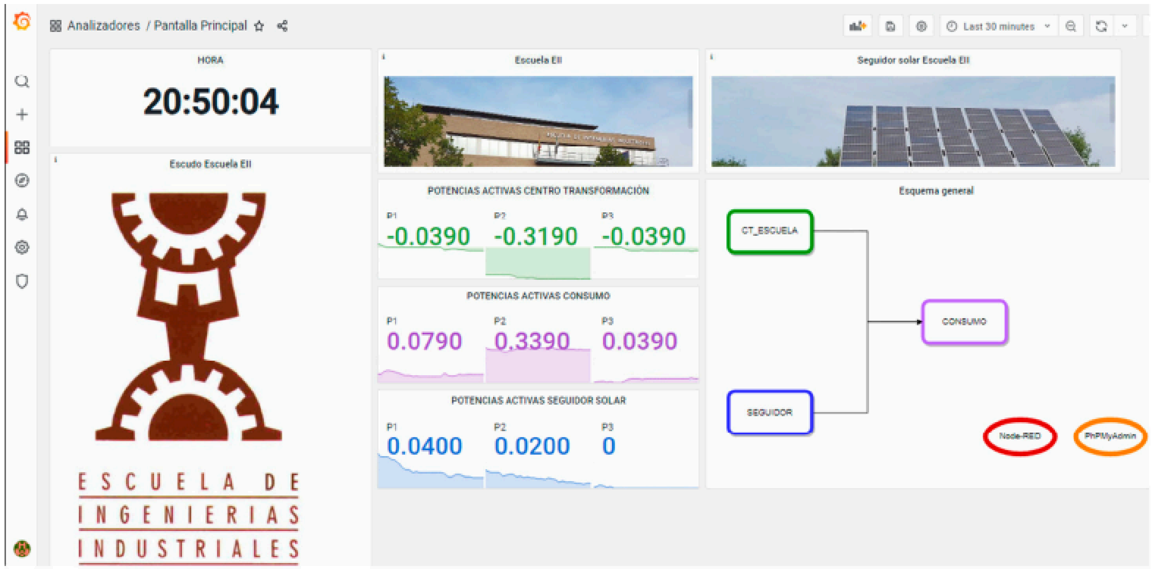

Figure 3: **Middle-Scale Grid Powered Tracker System**

According to Folgado et al. (2023), the system details the development and implementation of an IoT based monitoring system for a medium-scale power grid. The grid integrates a 60 kW photovoltaic (PV) solar tracker comprising 56 panels. The system focuses on data acquisition, management, and monitoring from the solar tracker, transformation center, and the energy consumption of the respondents of the study. Its modular and adaptable architecture supports future improvements, including the development of a digital twin model for system validation.

Both SolMate and Middle-Scale Grid Powered Tracker uses sensors to provide real-time data visualization and analysis, enhancing the efficiency and oversight of the energy system. Both of the systems have intuitive monitoring of metrics like voltage, current, power factor, and frequency, and presented them using user-friendly dashboards. The two systems have features that were made and were designed to be modular and adaptable to users, supporting future upgrades including digital twin modeling of the solar tracker system for performance validation.

Although monitoring of energy is visible, the system lacks the capability of having hybrid sun-tracking mechanisms. This medium-scale grid monitoring system utilizes fixed solar panels, which limits its potential for optimized energy capture compared to systems with dynamic tracking. Despite its robust real-time data visualization and user-friendly dashboards for metrics like voltage and current, the physical orientation of the panels remains static. This fixed design contrasts with our proposed system, SolMate. By incorporating advanced sun-tracking technology, SolMate aims to significantly enhance energy yield by continuously aligning the solar panels with the sun's position, effectively maximizing solar energy capture.

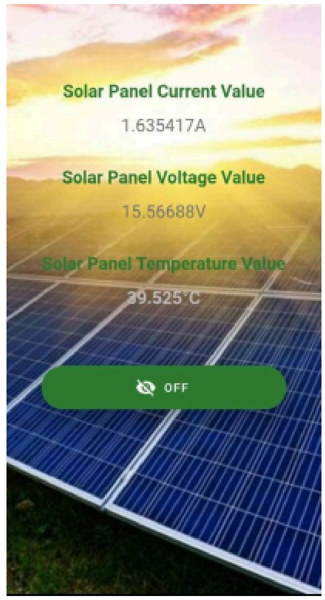

Figure 4: **Stand-Alone Solar Photovoltaic Plant and Power Estimation System**

According to Demir (2023), the increasing demand for solar photovoltaic (PV) systems, which produce electricity from sunlight, is growing because they are a clean and renewable energy source. The system presents a cost-effective product for real-time monitoring and predictive maintenance of stand-alone solar PV plants. This enables the user to monitor the critical parameters such as current, voltage and temperature from both the solar generator and the battery. The system uses machine learning techniques that are utilized to estimate power output and detect early issues, enhancing the system's reliability and performance.

Both SolMate and the Stand-Alone Solar Photovoltaic Plant and Power Estimation System emphasize the use of IoT technology. Furthermore, both systems prioritize the monitoring of solar energy parameters. Demir (2023) focuses on real-time data acquisition and monitoring key parameters like voltage, current, temperature, and environmental conditions. This is mirrored in SolMate's inclusion of mobile monitoring as a core feature, highlighting a common interest in providing accessible and timely information on system performance. Energy efficiency is another point of convergence.

However, due to its focus on machine learning, it lacks direct energy optimization as it focuses more on maintenance optimization. The SolMate, on the other hand, emphasizes energy optimization through efficient power management strategies. Another key difference would be the sun-tracking capability. SolMate integrates a sun-tracking solar panel system, a mechanism designed to actively adjust the orientation of solar panels to maximize sunlight capture as the sun moves across the sky, a feature absent in the Stand-Alone Solar Photovoltaic Plant and Power Estimation System.

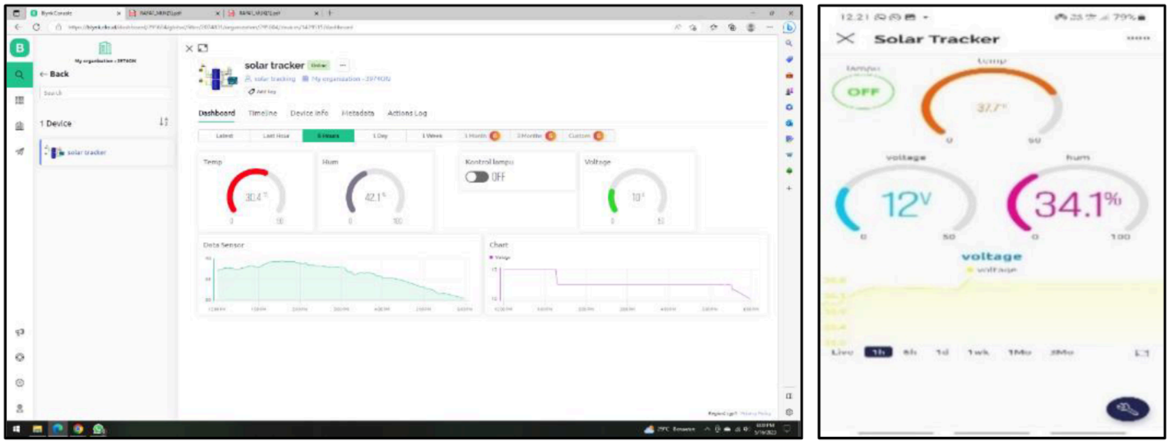

Figure 5: **<u>IoT Solar Panel Monitoring and Solar Tracking System</u>**

According to Nugraha et al. (2023), this study on IoT Solar Panel Monitoring and Solar Tracking utilizes sensors to gather real-time data on parameters such as solar illumination, panel temperature, and energy output. The automated tracking mechanism adjusts the panels' orientation to optimize sunlight capture throughout the day. All collected data is forwarded to a cloud platform, enabling users to monitor system performance via a mobile application remotely.

In functionalities, the SolMate and the study of Nugraha et al. (2023) share fundamental similarities in their approach to solar energy technology. Notably, both systems incorporate solar tracking mechanisms to enhance energy capture. The IoT Solar Panel Monitoring and Solar Tracking System focuses on designing and building a solar panel monitoring and solar tracking system, a goal that aligns with SolMate's inclusion of a sun-tracking solar panel system. Additionally, both projects utilize Internet of Things (IoT) technology for monitoring purposes. Nugraha (2023) employs an IoT system to monitor solar panel parameters and display them on a smartphone application, mirroring SolMate's objective of mobile monitoring, which also implies the use of IoT for remote data access.

The key difference would be the system primarily focuses on the design and implementation of a system that integrates both monitoring and solar tracking. In contrast, SolMate's objective of hybrid power management suggests a broader scope, potentially encompassing the management and optimization of energy from multiple sources, adding a layer of complexity beyond basic tracking and monitoring. SolMate explores the integration of solar energy with other sources, primarily the hybrid type of energy storage. Finally, the IoT Solar Panel Monitoring and Solar Tracking System lacks sustainability, unlike SolMate which emphasizes the use of recycled materials in its construction to reduce the cost and promote environmental sustainability.

Comparative Matrix

The table below represents the comparative matrix that compares the proposed study's advantages with the existing applications. The proposed solution will offer a greater insight into the area of development in solar monitoring and energy optimization.

Table 1

COMPARATIVE MATRIX

Features	Smart Solar Tracker Al-Saadi et al. (2022)	Stand-Alone Solar Photovoltaic Plant and Power Estimation System Demir (2023)	Middle-Scale Grid Powered Tracker Folgado et al. (2023)	IoT Solar Panel Monitoring and Solar Tracking System Nugraha et al. (2023)	SolMate
Power Management El Hammoumi et al. (2022)	✗	✗	✓	✗	✓
Cost Effective Junnel (2024)	✗	✓	✗	✓	✓
Sun-Tracking Ponnalagarsamy (2022)	✓	✗	✗	✓	✓
Hybrid Renewable Energy Samedova (2025)	✗	✗	✓	✗	✓
Mobile-Based Monitoring Gupta et al. (2022)	✗	✓	✗	✓	✓
Panel's Performance and Reliability Lopez and Wang (2023)	✓	✓	✓	✓	✓

Table 1 presents a comparative matrix that offers valuable insight into the landscape of contemporary solar energy systems, positioning SolMate within a context of diverse approaches and technological focuses. An initial overview of the table reveals a significant characteristic of SolMate: its apparent comprehensiveness.

Notably, the Stand-Alone Solar Photovoltaic Plant and Power Estimation System by Demir (2023) and the Middle-Scale Grid Powered Tracker by Folgado et al. (2023), do not incorporate sun-tracking features. Consequently, their systems are likely highly dependent on PV panels being directly aligned with the sun, thereby minimizing the potential benefits of solar tracking for maximizing energy storage. In contrast, SolMate includes this feature.

SolMate is the only system that uniquely incorporates sun track-driven priority charging, signifying an advanced level of system optimization based on environmental conditions. This feature, along with the inclusion of both mobile and web-based monitoring, positions SolMate at the forefront of leveraging data and connectivity for enhanced solar energy management.

Unlike the other four systems, the Smart Solar Tracker by Al-Saadi et al. (2022), the Stand-Alone Solar Photovoltaic Plant by Demir (2023), the Middle-Scale Grid Powered Tracker by Folgado et al. (2023), and the IoT Solar Panel Monitoring and Solar Tracking System by Nugraha et al. (2023) – only SolMate incorporates all the listed features.

This comparative matrix underscores SolMate's potential as a comprehensive and user-centric solution for managing and optimizing solar energy systems. The integration of a wide array of features, from fundamental aspects like power management and cost-effectiveness to advanced functionalities like weather-driven priority charging and multi-platform monitoring, suggests a design aimed at maximizing efficiency, reliability, and user convenience. This analysis positions SolMate as a potentially more advanced and integrated platform compared to the other analyzed solar energy solutions, warranting further investigation into its specific implementation and performance benefits.

CHAPTER III

DESIGN AND METHODOLOGY

This chapter provides a comprehensive overview of the research design and methodology employed in this study. It encompasses the specific method used, the step-by-step study flow, the research environment, the characteristics of the respondents, the 5-point Likert scale instrument utilized for data collection, the detailed research procedure, the process of data collection and the statistical treatment involving weighted mean, and the ethical considerations that were evaluated and approved by the Research Ethics Committee.

Research Design

This study focuses on exploring the development and impact of SolMate, a smart IoT-enabled sun-tracking solar panel system with mobile monitoring and energy optimization. The chosen methodology is a descriptive research design, which enables the observation, documentation, and analysis of current solar energy challenges and user interactions with the system as they naturally occur, without manipulation (Shinija, 2024).

A descriptive research design is used to systematically observe, document, and interpret the current state of a phenomenon as it naturally occurs. It does not involve manipulation of variables but instead focuses on gathering detailed information that can help identify patterns, problems, and relationships (McCombes, 2023). In this study, it is applied to understand existing solar energy practices, user experiences, and system performance within real-world conditions.

According to Matellio Inc. (2023), selecting the appropriate research approach is critical in aligning the system objectives with user-centric feedback and performance evaluation, especially when dealing with IoT-integrated renewable energy technologies. The integration of IoT into solar power monitoring systems allows for real-time data collection, remote accessibility, and improved decision-making processes, all of which demand a thorough understanding of both technological and human-centric variables. This underscores the importance of adopting a methodology that not only captures technical performance metrics but also reflects user experiences and operational ease. Consequently, this supports the study's reliance on a descriptive methodology, which is instrumental in gathering comprehensive and unbiased data relevant to the performance, usability, and overall impact of the SolMate system. By employing descriptive research, the study ensures a holistic assessment that bridges the gap between system functionality and end-user satisfaction.

Method. This research will adopt a quantitative approach, which involves the collection and analysis of numerical data to explain and describe the processes being observed. The primary objective of this method is to present factual and objective insights, focusing on what is happening rather than why it is happening. According to Taherdoost (2022), quantitative research emphasizes straightforward interpretations of data, avoiding subjective reasoning or the exploration of multiple methodologies. By utilizing this approach, the study seeks to produce clear, precise, and measurable findings that contribute to a reliable understanding of the system's performance and behavior.

Flow of the Study. Figure 6 depicts a descriptive flow of the study addressing the new way of . The study aims to develop SolMate, a smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization. The flow starts with identifying the current problems and challenges in solar harvesting. To address these issues and enhance energy efficiency, the study proposes SolMate, a platform that optimizes solar energy capture through a sun-tracking mechanism and provides a reliable power supply with hybrid power management, all while enabling convenient real-time monitoring. In executing the research, a descriptive-quantitative methodology will be implemented, primarily relying on the administration of survey questionnaires. These questionnaires were distributed through both digital channels, specifically utilizing Google Forms, and traditional methods involving personally handed-out paper-based questionnaires. Complementing this data collection strategy, the study also embraced an Agile Software Methodology as its framework for development and project management. The outcome is SolMate, an IoT-based hybrid sun-tracking solar panel system with mobile monitoring designed to enhance solar energy efficiency and ensure a reliable power supply. This innovative system leverages advanced technology to address current challenges in solar energy usage, including existing practices and encountered problems.

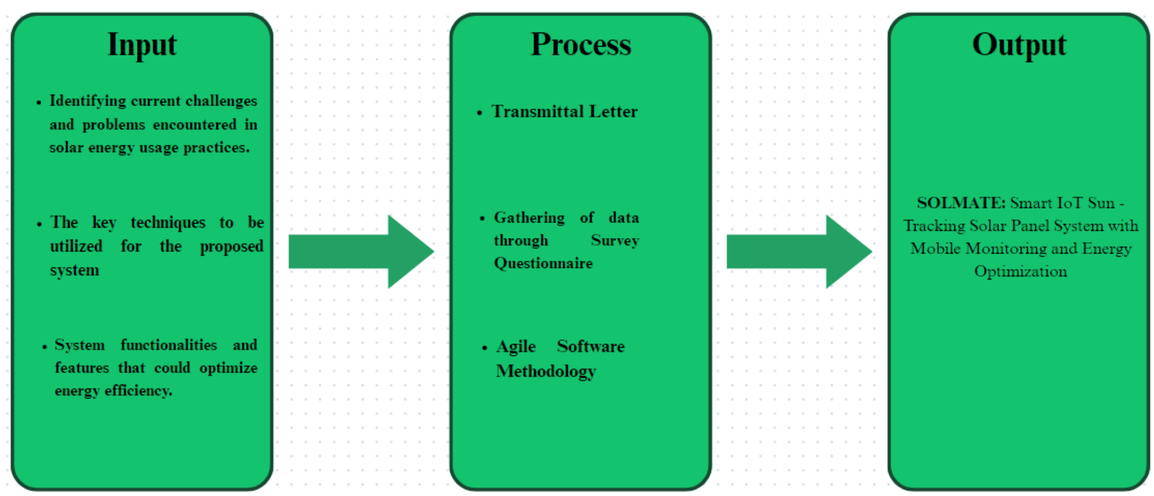

Figure 6: **Flow of the Study of Solmate**

Research Environment. The research was conducted in Gun-ob Lapu-Lapu City, Cebu. These locations were selected due to their residential nature and relevance to the study's focus on household-level solar energy usage. Data collection was carried out through survey distribution among local residents, particularly targeting households with existing or planned solar panel installations. This setting allowed the researchers to gather real-world insights on solar energy practices, challenges, and user perceptions of IoT-integrated solar technologies. By engaging directly with community members in their actual living environments, the study was able to assess the practical relevance, usability, and potential impact of the proposed SolMate system in addressing real-world energy needs.

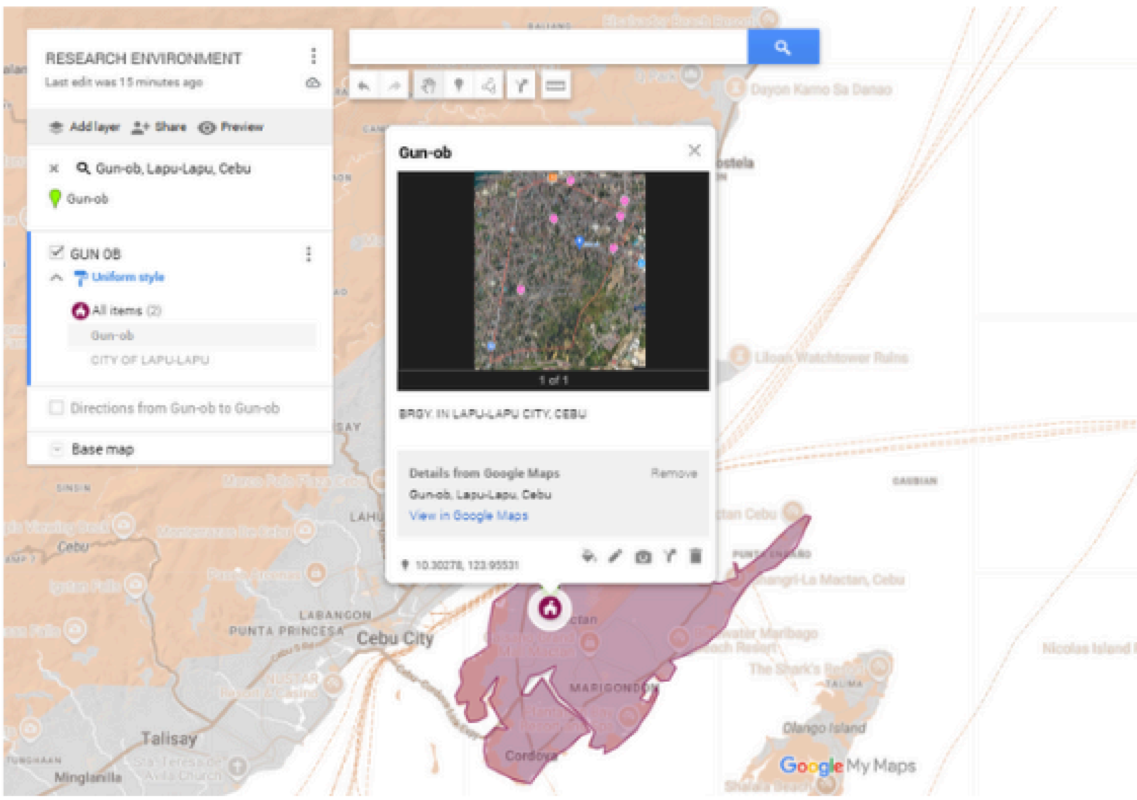

Figure 7: **<u>Local Map of Gun-ob Lapu-Lapu City</u>**

Respondents. The SolMate research involved collecting data from both solar panel owners and interested non-users in Lapu-Lapu City. A total of 525 individuals were surveyed, representing both groups. To ensure data quality, the responses were cleaned by applying sincerity checks, removing blank or incomplete submissions, and excluding inconsistent answers. After cleaning, 450 valid responses remained and were used for the analysis. This validation process ensured that the findings accurately reflected user needs and market readiness, supporting the development of SolMate as a reliable IoT-based energy solution.

Table 2

DISTRIBUTION OF RESPONDENTS

Respondents	No. of Respondents	Percentage %
Solar Panel Owners	284	63.1%
Customers or Potential Adopters (Non-users with Interest)	166	36.9%
TOTAL	**450**	**100%**

Research Instrument. This study's primary data collection tool is a researcher-designed questionnaire using a 5-point Likert scale to measure the level of agreement with statements related to solar energy usage, system performance, and user experience with the proposed SolMate system. The questionnaire is divided into five sections, each targeting a specific aspect of the study. The first section gathers demographic information to provide context on the respondents' backgrounds, such as age, employment status, and familiarity with solar energy systems. The second section explores the current practices and challenges in solar energy usage, capturing insights on issues such as power interruptions, inefficiencies of fixed panels, and the lack of real-time monitoring. The third section focuses on the development techniques used in SolMate, asking participants to assess the relevance and perceived effectiveness of components like sun-tracking mechanisms, hybrid battery storage, and IoT-based monitoring. The fourth section evaluates the key features of the proposed system, such as ease of use, mobile accessibility, energy optimization, and sustainability. Finally, the fifth section gathers respondents' recommendations, identifying potential improvements and their willingness to adopt or support the implementation of SolMate. The Likert scale is chosen for its reliability in quantifying attitudes, perceptions, and preferences, providing a structured approach to analyze the system's usability, functionality, and impact on its intended users.

Research Procedure. The following paragraphs detail the step-by-step process undertaken to investigate the research questions and achieve the objectives of this study.The comprehensive survey, using the procedural framework of the 5-point Likert scale model, was employed during the investigation, further enhancing the reliability of the findings.

Gathering of Data. Data gathering is a crucial phase in any research endeavor, as it provides the raw material for analysis, interpretation, and the drawing of meaningful conclusions. In this particular study, the data gathering process involved the preparation of a transmittal letter and survey questionnaire, which was addressed to the Deans of the College of Computer Studies, seeking for approval. Following this, the letter was sent to the Barangay Captain of Gun-ob Barangay Hall to facilitate the conduct of the survey. The survey questionnaires were then disseminated to the identified respondents through both accessible online forms and traditional paper-based format.

Statistical Treatment of Data. To gain a deeper understanding of the collected information, the researchers employed a range of statistical techniques to analyze the survey data. This involved calculating frequency and percentage distributions to illustrate the prevalence of different responses.

Frequency and Percentage. The use of frequency and percentage will play a vital role in analyzing and presenting data gathered from respondents, particularly solar panel owners and customers. Since one of our key objectives is to identify the current challenges in solar energy usage, specifically the practices and problems encountered. Frequency and percentage will allow us to quantify how often certain issues or behaviors occur among users. Frequency and percentage analysis will support our goal of determining user-preferred features and functionalities for energy optimization. By assessing how frequently certain features are requested or currently used, and calculating their relative prevalence, we can prioritize development areas such as real-time monitoring interfaces or hybrid energy management modules. Analyzing the frequency of user behaviors and preferences allows for a deeper understanding of practical needs and expectations, ultimately guiding more informed and user-centered system design (Li and Zhong 2022).

Weighted Mean. The weighted mean serves as an essential statistical tool for analyzing data collected through Likert-scale surveys. The objective of the study is to assess the importance of various solar panel features. The weighted mean helps to determine the average level of importance assigned by respondents to each feature. It functions as a tool for identifying key insights and is particularly effective in educational and applied research when interpreting ordinal data, such as Likert-scale responses. According to (Hassan et al., 2022), it provides a more nuanced understanding of central tendencies by accounting for the varying degrees of importance or agreement expressed by respondents, thus offering a more accurate reflection of collective sentiments.

Scoring Procedure. The Feedback on the proposed features and functionalities of the relevance, usability, and potential impact, particularly in enhancing energy efficiency and reliability through the integration of IoT technology and hybrid solar tracking systems was collected using a Likert scale, enabling systematic evaluation.

Table 3

SCORING POINTS

Scale	Description	Description
5	Strongly Agree (SA)	The system's functionality fully exceeds expectations.
4	Agree (A)	The system's functionality meets expectations well.
3	Neutral (N)	The system's functionality neither meets nor fails expectations significantly.
2	Disagree (D)	The system's functionality does not quite meet expectations.
1	Strongly Disagree (SD)	The system's functionality fails to meet expectations entirely.

Scale	Range	Description
5	4.21-5.00	Very Important
4	3.41-4.20	Important
3	2.61-3.40	Neutral or undecided
2	1.81-2.60	Not Important
1	1.00-1.80	Not at all Important

Ethical Considerations. To ensure ethical research practices, the researchers followed a formal ethics approval. The process started with contacting the University Research Office and Ethics Committee. Signatures were secured from the key stakeholders, including the project chairman and adviser, through signed Proposal Hearing Forms, and all associated fees needed. A comprehensive review submission was then compiled and presented to Dr. Juanito N. Zuasula, chair of the UC Research System Ethics Committee. This submission included the detailed research protocol, informed consent evaluation materials, curriculum vitae of the researchers, and proof of payment. Following a thorough review, the University Research Office officially granted ethical clearance for the study, evidenced by an email containing Dr. Zuasula's signed Protocol Approval.

Software Engineering Methodology

The Agile development methodology is a software methodology that breaks the project down into several phases known as sprints. This methodology has already been proven effective and is a substantial upgrade to the traditional Waterfall model. Throughout the project's lifetime, it emphasizes teamwork, adaptability, and continuous improvement, allowing teams to respond quickly to feedback and unexpected challenges. Agile has become the standard for many companies and start-ups because it promotes flexibility and faster development cycles. Additionally, user feedback is consistently integrated during each phase, ensuring that the final product aligns closely with the needs of its target users.

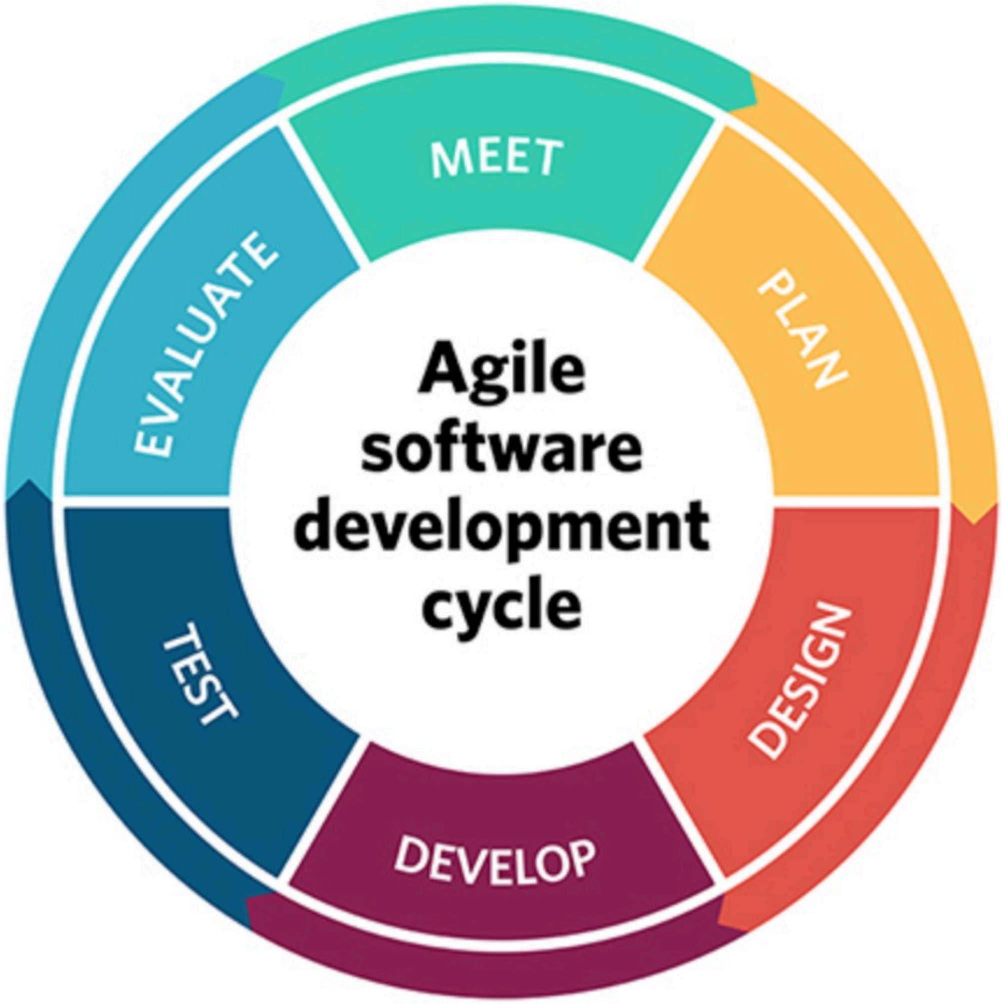

Figure 8: **Agile Methodology Diagram**

To effectively develop *SolMate*, the team will adopt the **Agile methodology**, an iterative and flexible software development approach. This methodology suits the project's complexity and need for continuous user feedback, as it enables the team to deliver functional system components in incremental sprints. Agile ensures responsiveness to changes in requirements, especially those driven by end-user feedback or real-world testing conditions, such as varying solar output, IoT data inconsistencies, or battery behavior. Agile is ideal for the SolMate project, given its focus on real-time system monitoring, sun-tracking precision, and mobile accessibility, all of which benefit from ongoing refinements and adaptive planning.

Meeting Phase. In this initial phase, the research team brainstormed and aligned on the scope of the *SolMate* system. They reviewed pressing issues in residential solar energy use—such as energy inefficiency, lack of real-time monitoring, and unreliable electricity during outages.

This phase included consultations and literature review to validate the feasibility of integrating IoT-based monitoring, sun-tracking mechanisms, and hybrid battery storage. The team finalized the system's title and concept and presented it for panel approval. Roles and responsibilities were assigned among members, ensuring a collaborative and well-organized project workflow.

Planning Phase. During this phase, the team created foundational planning documents such as the Business Model Canvas to evaluate how *SolMate* delivers and captures value for residential users, particularly in underserved areas like Lapu-Lapu. They mapped the Program Workflow, identifying user interactions with the mobile app and solar system. Tools such as the Validation Board helped assess assumptions around user needs (like uninterrupted power during brownouts), while the Business Road Map outlined development milestones. A Gantt Chart was produced to manage timelines and identify potential project risks. User surveys were distributed to validate the relevance of system features, such as real-time data access and energy optimization. Continuous documentation updates ensured a traceable and organized record of progress.

Designing Phase. During this phase, the team established the structural and theoretical design of *SolMate*. The team conducted a Review of Related Literature and Studies to benchmark best practices and identify gaps in current systems. A Conceptual Framework was built, highlighting the integration of sun-tracking PV panels, IoT monitoring, and hybrid storage. Tools like the Comparative Matrix and Entity Relationship Diagram (ERD) guided system design decisions. Database Design and a Data Dictionary were prepared to organize user and performance data efficiently. Documentation was updated to reflect design iterations, and survey instruments were finalized for deployment.

Development Phase. In the Development Phase, the team began building the technical core of the SolMate system. They first identified the required Technology Stack, selecting microcontrollers, cloud platforms, and frameworks suitable for IoT integration and mobile monitoring. Next, they established the Software Specifications, defining how the app would track solar energy output, battery status, and panel positioning. Hardware Specifications included the selection of servo motors, sensors like LDRs, and battery storage units. Wireframing helped visualize the mobile interface for users to view and manage real-time data. The Initial Backbone Development involved assembling the sun-tracking mechanism, implementing hybrid switching logic, and configuring cloud-based data handling. Continuous documentation ensure traceability of development changes.

Testing Phase. In this phase, the team rigorously evaluated SolMate's performance, reliability, and system responsiveness. Using tools like Selenium, they tested the mobile app's ability to display real-time monitoring data under various network conditions. Program Functionality Testing ensured that tracking, battery switching, and alerts performed as expected. Network Testing examined system stability when uploading data to the cloud. Bug Testing identified any flaws in system operation, and Program Debugging addressed these issues to ensure seamless functionality. All test scenarios and results were recorded and analyzed to support final refinements.

Evaluation Phase. In this final phase, the team assessed the overall effectiveness of the system before full deployment. A final round of validation was performed to confirm that all system features—from sun-tracking and hybrid energy management to mobile monitoring—met user expectations and performed under real-world conditions. Feedback from test users in Lapu-Lapu was gathered, focusing on usability, reliability, and responsiveness. The findings confirmed SolMate's potential as a practical solution for power interruptions and solar inefficiencies. Final documentation, including testing outcomes and user feedback, was completed to conclude the development lifecycle.

Planning/Conception–Initiation Phase. In this phase, the researchers accomplished a series of foundational tasks crucial to the successful development of *SolMate*. They began by creating a Business Model Canvas to define the system's core value—providing efficient, real-time monitored solar energy for households experiencing frequent power interruptions. To visualize how users would interact with the technology, they designed a Program Workflow, outlining the key system processes from solar tracking to mobile monitoring. To validate early ideas, the team built a Validation Board, which helped them collect insights and feedback from potential users about energy efficiency, monitoring concerns, and solar storage needs. Using these insights, they crafted a clear Business Roadmap that aligned their technical goals with user expectations. On the technical side, a Functional Decomposition Diagram was developed to break the system into core components—sun-tracking modules, IoT integrations, battery management, and cloud connectivity—ensuring a strong structure for implementation. To keep the project organized and on schedule, they created a detailed Gantt Chart mapping each task, deadline, and dependency.

Business Model Canvas. The Business Model Canvas is a visual tool illustrating how a business generates, provides, and extracts value, highlighting its strengths, weaknesses, and potential for change.

Figure 9: **Business Model Canvas of SolMate**

The Business Model Canvas above outlines SolMate's core operations, focusing on value creation through smart solar technology and real-time monitoring. It highlights key partners, resources, and strategies, offering insight into system strengths and guiding innovation for effective implementation.

Program Workflow. The figure below illustrates the complete workflow involving users and admin processes. It demonstrates how the system is designed to configure, execute, and monitor a particular course of action.

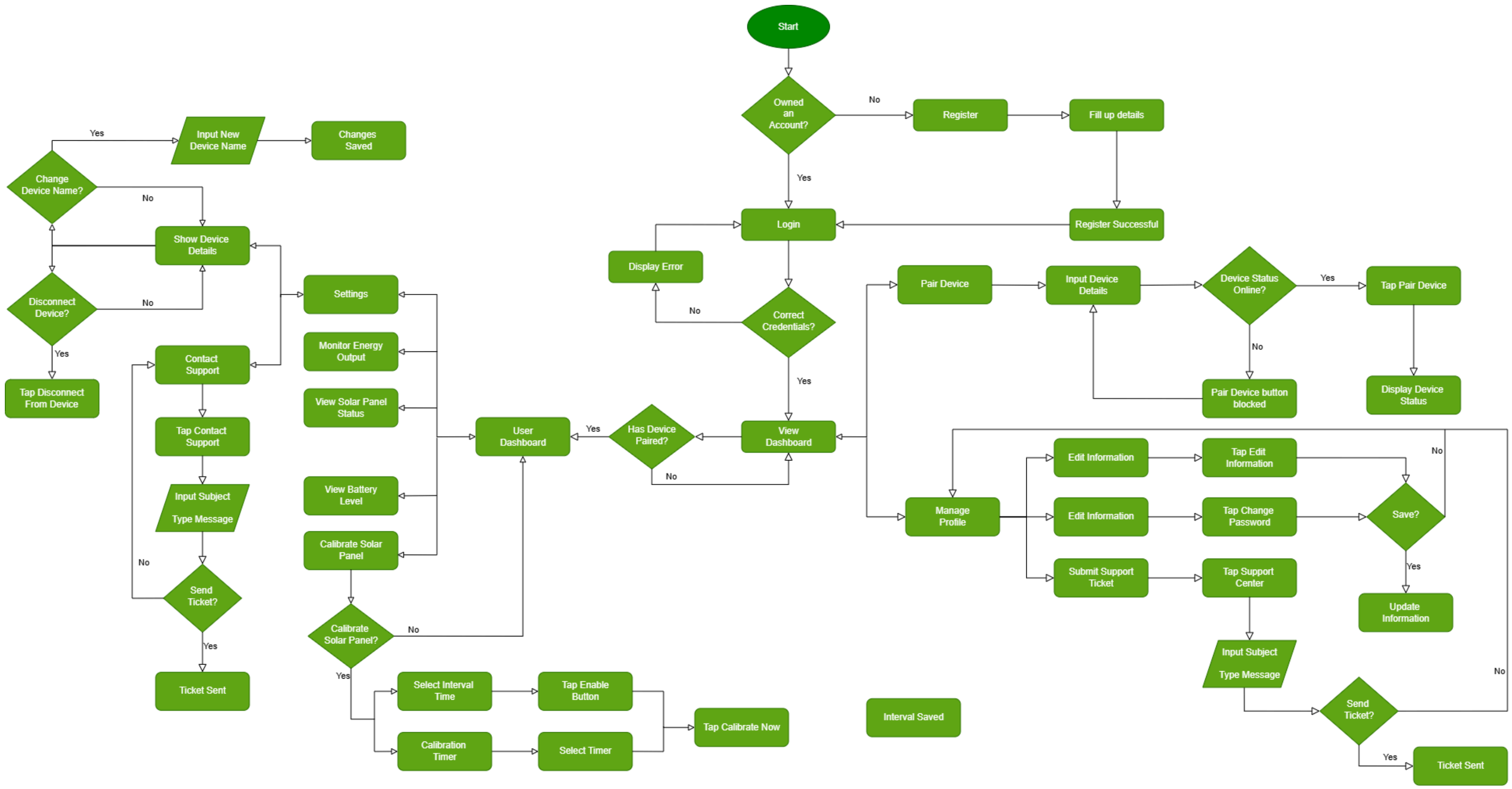

Figure 10: **<u>Program Workflow - User</u>**

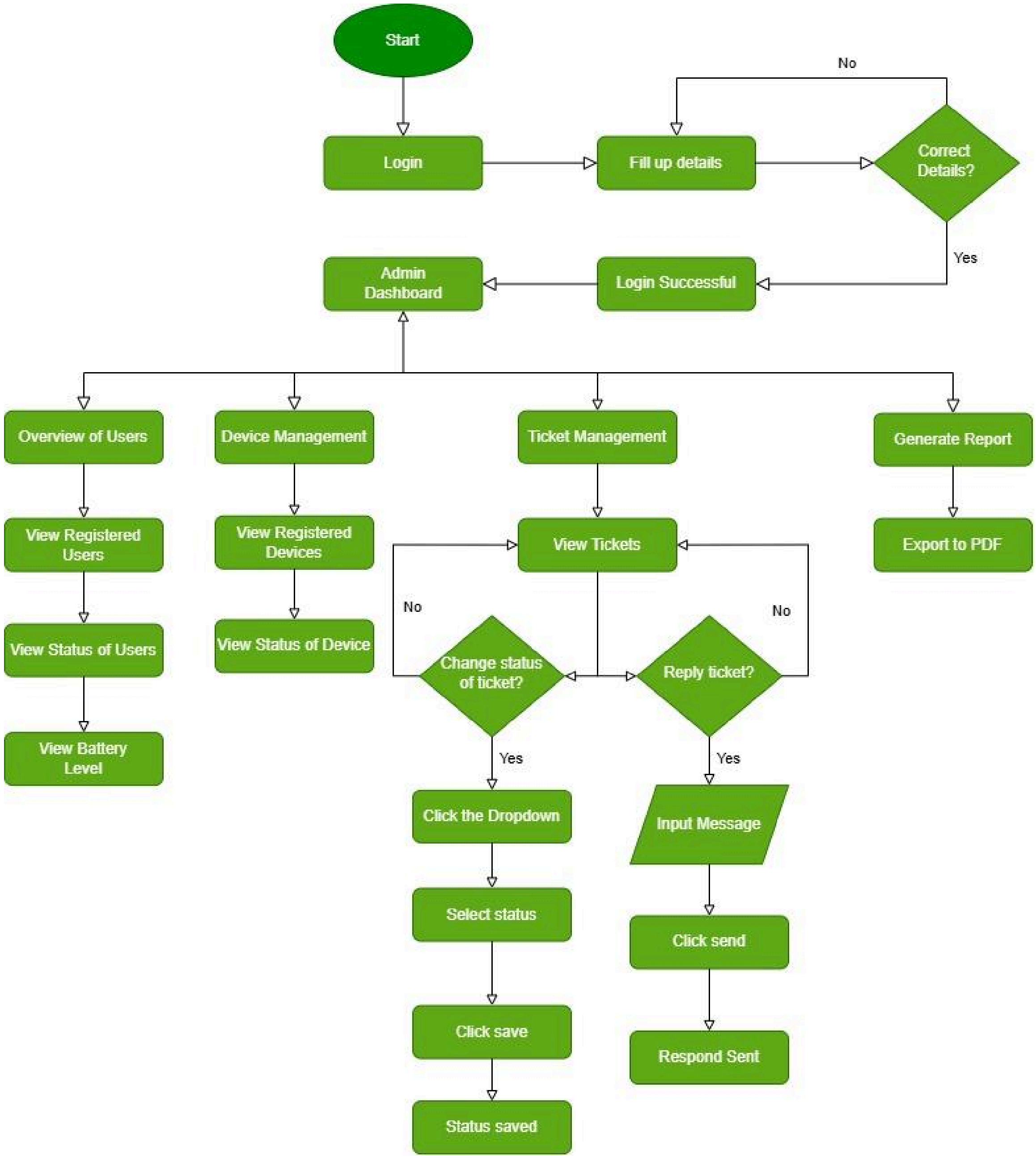

Figure 11: **<u>Program Workflow - Admin</u>**

Validation Board

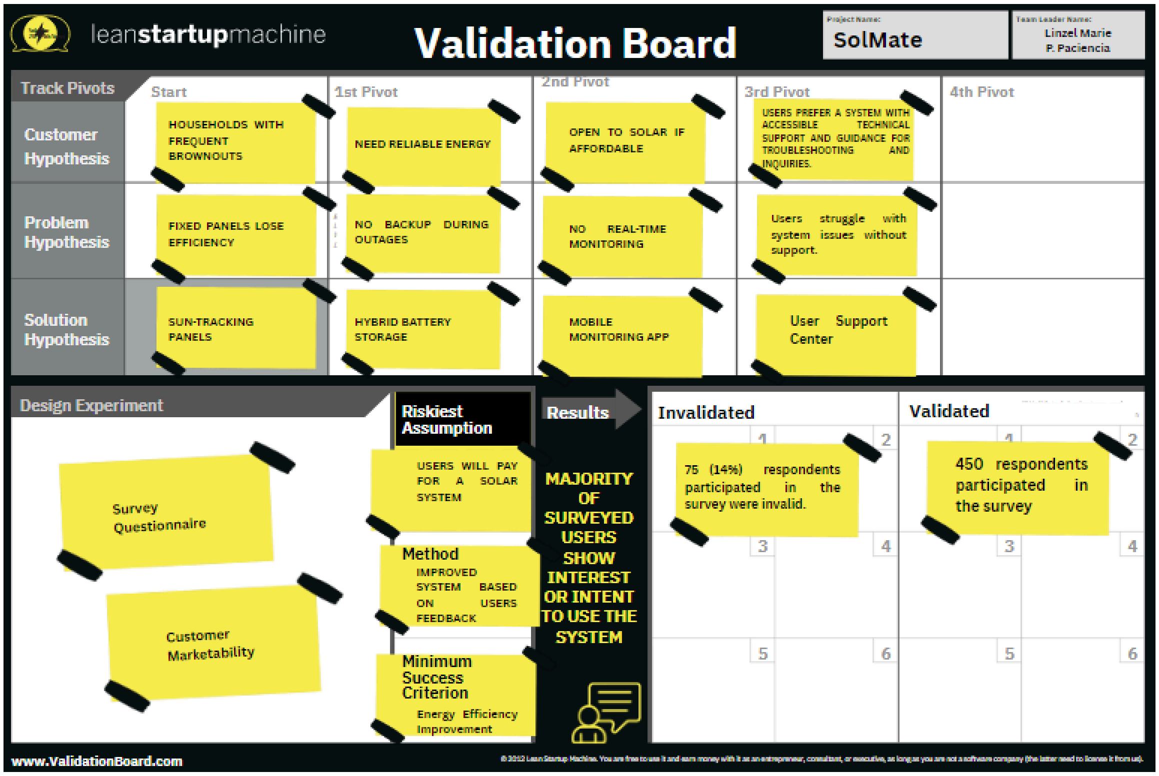

Figure 12: <u>Validation Board of SolMate</u>

Startup Idea: Solmate: Smart Iot Sun- Tracking Solar Panel System With Mobile Monitoring And Energy Optimization

The Validation Board presents a structured, step-by-step approach to testing and refining the key assumptions behind the SolMate system. The process began by identifying households experiencing frequent brownouts and hypothesizing their need for a reliable energy source. Initial challenges, such as the inefficiency of fixed solar panels and the absence of backup power, led to the introduction of sun-tracking panels and hybrid battery storage. Customer feedback gathered through surveys guided further pivots—shifting focus toward affordability and real-time mobile monitoring. As development progressed, users expressed the need for accessible technical support, leading to the addition of a User Support Center to assist with troubleshooting and inquiries. The riskiest assumption—that users would be willing to invest in a solar system—was tested, with energy efficiency improvement as the minimum success criterion. Out of 525 total survey responses, 450 were validated, while 75 were invalid due to incomplete data. Results showed that the majority of valid respondents expressed strong interest in adopting SolMate, validating its potential as a reliable, affordable, and user-friendly smart solar energy solution.

Business Road Map. A business roadmap is a strategic guide that outlines a specific goal or desired outcome and maps out the key steps or milestones required to achieve it. It acts as a communication tool that provides a clear overview of the plan, aligning the team's efforts and illustrating the reasoning behind both the objectives and the strategies designed to reach them.

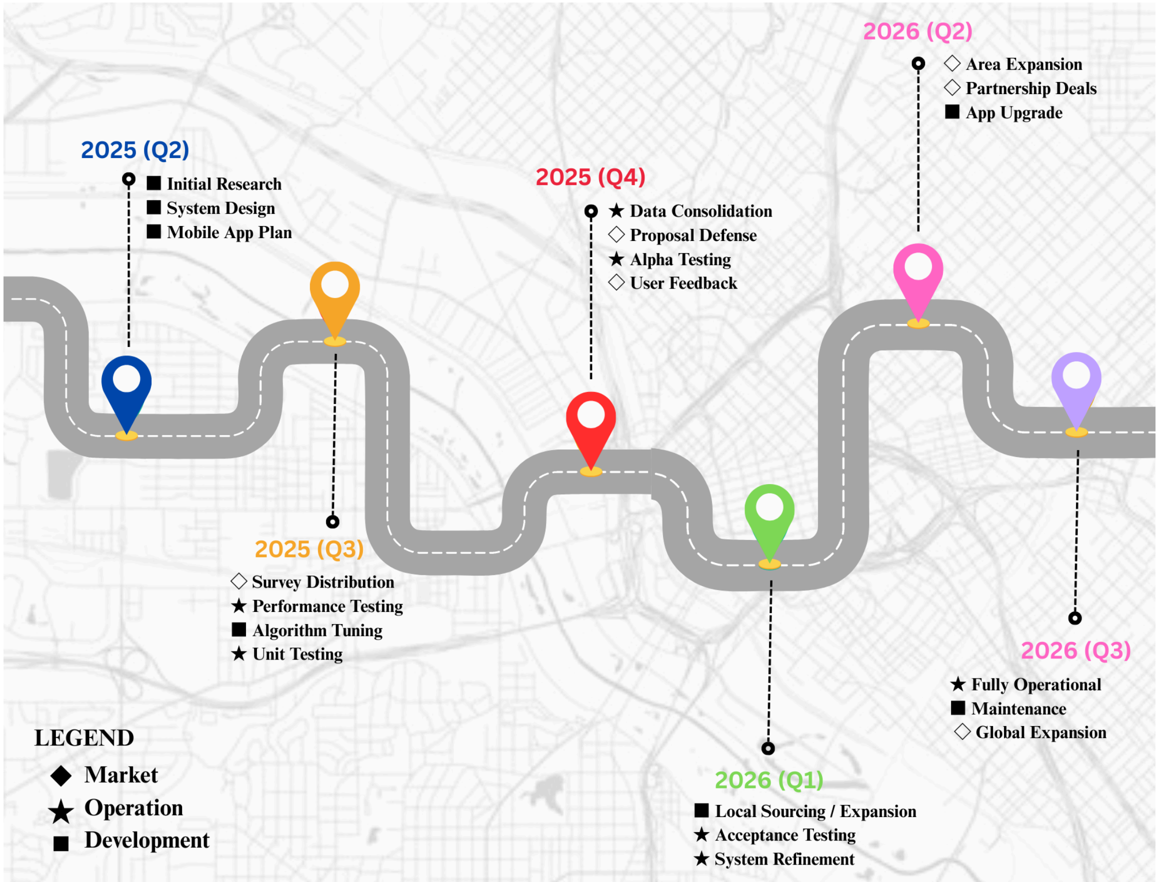

Figure 13: **Project Roadmap Diagram**

The figure above illustrates the project roadmap of the SolMate platform, detailing its key operational milestones, software development activities, and strategic market expansion plans from 2025 through global deployment in 2026. The roadmap begins with initial research, system design, and mobile app planning (Q2 2025), followed by survey distribution, algorithm tuning, and unit testing during development (Q3 2025). Proposal defense, alpha testing, and user feedback are conducted in Q4 2025 to validate the system before moving to acceptance testing and refinement in Q1 2026. Subsequent phases focus on local sourcing, area expansion, partnership deals, and system upgrades leading to full operational deployment and global expansion by Q3 2026. According to Rahman and Theel (2022), open innovation facilitates the structured flow of knowledge across organizational boundaries, accelerating innovation and maximizing value creation. Within this framework, Business Process Innovation (BPI) enhances internal efficiency, while Business Process Management (BPM) supports data-driven decision-making, ensuring that each phase of the roadmap contributes to improved organizational performance.

Functional Decomposition Diagram. This Functional Decomposition Diagram illustrates the proposed application's capabilities for problem-solving and development.

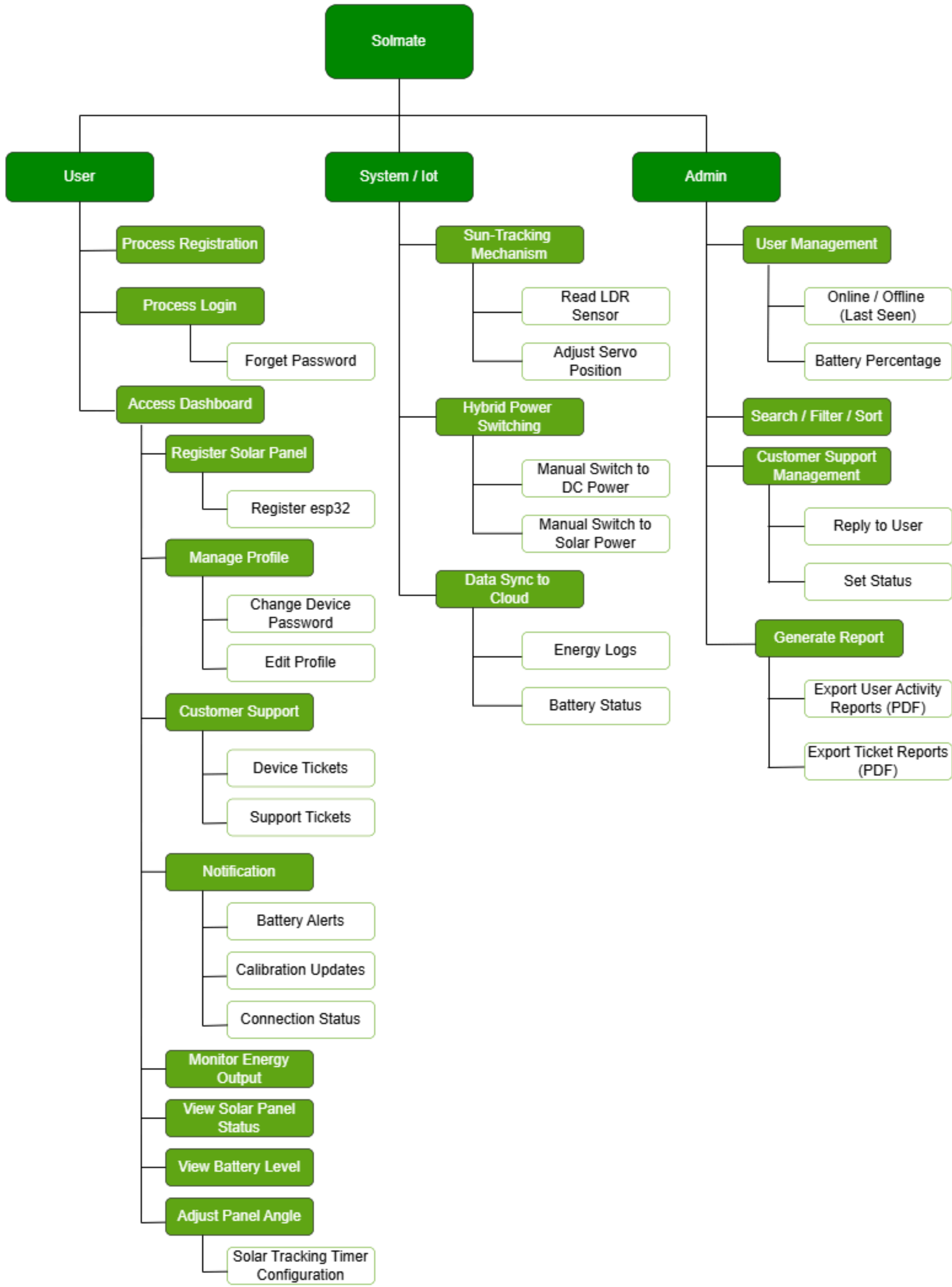

Figure 14: **Functional Decomposition Diagram**

Gantt Chart. The Gantt chart is a powerful and prevalent tool in project management, considered essential for both foresight and oversight. It empowers project teams to create and adapt their plans by specifying activities, their durations, interconnections, necessary resources, and potential risks Krcheva et al. (2023).

Table 4

GANTT CHART

TASK ID	TASK TITLE	TASK LEAD	START DATE	END DATE
1	**MEETING PHASE**			
1.1	Assigning Team Roles	ALL	5/1/25	5/2/25
1.2	Formulating Research Titles	ALL	5/2/25	5/10/25
1.3	Drafting Initial Chapters	ALL	5/2/25	5/10/25
1.4	Title Proposal	ALL	5/12/25	5/12/25
2	**PLANNING / CONCEPTION INITIATION PHASE**			
2.1	Justifying the Rationale	PROJECT MANAGER	5/10/25	5/21/25
2.2	Identifying the Study Objectives	PROJECT MANAGER	5/10/25	5/21/25
2.3	Mapping Scope and Limitations	PROJECT MANAGER	5/10/25	5/21/25
2.4	Emphasizing the Significance	PROJECT MANAGER	5/10/25	5/21/25
2.5	Defining Key Terms	PROJECT MANAGER	5/10/25	5/21/25
2.6	Updating the Documentation	HIPSTER	5/10/25	5/21/25
3	**ANALYSIS AND DESIGN PHASE**			
3.1	Gathering of Related Literature	HIPSTER	5/12/25	5/22/25
3.2	Formulating the Conceptual Framework	PROJECT MANAGER	5/12/25	5/22/25
3.3	Searching of Related Studies	HIPSTER	5/12/25	5/22/25
3.4	Establishing the Comparative Matrix	HIPSTER	5/12/25	5/22/25
3.5	Developing the Gantt Chart	HIPSTER / PROJECT MANAGER	5/13/25	5/22/25
3.6	Structuring the Program Workflow	TESTER	5/13/25	5/23/25
3.7	Mapping the System Use Case	HACKER	5/13/25	5/23/25
3.8	Desigining of Database	TESTER	5/13/25	5/23/25
3.9	Modeling the Entity Relationship Diagram	HUSTLER	5/14/25	5/23/25
4.0	Organizing the Data Dictionary	HIPSTER	5/14/25	5/23/25
4.2	Conducting the Survey Questionnaire	ALL	5/14/25	5/23/25
4.3	Updating the Documentation	PROJECT MANAGER	5/14/25	5/23/25
5	**DEVELOPMENT / CONSTRUCTION PHASE**			
5.1	Technology Stack Diagram	PROJECT MANAGER	5/15/25	5/24/25
5.2	Developing Software Specification	HUSTLER	5/15/25	5/24/25
5.3	Establishing Hardware Specification	TESTER	5/15/25	5/24/25
5.4	Listing of Program Specifications	PROJECT MANAGER	5/15/25	5/24/25
5.5	Creating of Wireframes	HIPSTER	5/15/25	5/30/25
5.6	Building of Prototype	HACKER	5/15/25	6/18/25
5.7	Updating the Documentation	PROJECT MANAGER	5/15/25	6/18/25
6	**TESTING / QUALITY ASSURANCE PHASE**			
6.1	Executing Alpha Testing	ALL	6/23/25	9/29/25
6.2	Conducting Unit Testing	ALL	6/23/25	9/29/25
6.3	Detecting System Bugs	ALL	7/8/25	11/15/25
6.4	Debugging the Product	ALL	7/8/25	11/15/25
6.5	Updating the Documentation	ALL	7/8/25	12/14/25
7	**EVALUATION PHASE**			
7.1	System Evaluation Assessment	ALL	9/2/25	12/14/25
7.2	Implement Necessary Revisions	ALL	9/19/25	12/15/25
7.3	Checking System Requirements	ALL	9/2/25	12/15/25
TEAM MEMBERS	Project Manager: Linzel Marie P. Paciencia			
	Hacker: Rigil Kent Y. Payo			
	Hipster: Hubert Harold P. Plarisan			
	Hustler: Kent Jyls P. Noel			
	Tester: Kent Jerard B. Sepra			

MAY				JUNE				JULY				AUGUST				SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

LEGEND

- Done
- Progress
- Target

The Gantt chart presents a structured overview of the project across six key phases, beginning with the Meeting Phase (May 1 – May 12), where the team conducted initial discussions, assigned roles, held brainstorming sessions, and proposed the project title. This phase laid the groundwork for team alignment and project direction.

Following that is the Planning Phase (May 10 – May 21) which involved defining the study's purpose, drafting the rationale, formulating objectives, and documenting the scope, limitations, significance of the study, the flow of the system, and the definition of terms. This phase served as the foundation for understanding the problem and outlining the research framework.

The Designing Phase (May 12 – May 23) focused on the research and technical structure of the system. Activities included reviewing related literature and studies, developing the conceptual framework, constructing a comparative matrix, designing the database, drafting the Entity Relationship Diagram (ERD), compiling the data dictionary, and conducting a survey. Updates to the documentation were made continuously to reflect progress.

The Development / Construction Phase (May 15 – June 18) focused on the initial implementation of the system. Activities during this phase included identifying the appropriate technology stack, drafting software and hardware specifications, listing program requirements, and designing wireframes. The team also worked on building the prototype and continuously updated the documentation to reflect technical progress. This phase marked the transition from design to execution, laying the foundation for system functionality and usability.

The next stages—Testing, and Evaluation Phases—are currently without specified dates in the Gantt chart. The Testing Phase will emphasize validating the system's functionality through unit testing, bug detection, and debugging procedures to ensure reliability and performance. Following this, the Evaluation Phase will involve assessing the overall system, verifying its alignment with the specified requirements, and implementing final revisions to prepare for project completion and presentation.

Analysis-Design Phase

During the Agile development of SolMate, the Analysis-Design phase was essential in shaping the system's functional and visual structure. This phase focused on translating the concept of a hybrid, IoT-enabled solar panel system into a comprehensive design through iterative planning and prototyping. The team developed wireframes, use case diagrams, and UI/UX layouts for the mobile based monitoring system, ensuring that energy data visualization, sun-tracking interfaces, and system controls were both intuitive and user-friendly. Continuous collaboration and feedback allowed for refinements that aligned with user needs, technical requirements, and the project's sustainability goals. By balancing smart functionality with clean design, this phase provided a strong foundation for the system's implementation and ensured that SolMate would be both efficient and accessible for its intended users.

Use Case Diagrams. Use case diagrams are a type of behavioral diagram that illustrate the interactions between a system and its external users, known as actors. These diagrams represent a collection of actions or functions the system can perform in response to user interactions. They highlight how each actor is connected to specific use cases, indicating which parts of the system's functionality are accessible to them. Essentially, use case diagrams provide a visual representation of user-system relationships and help define the scope of system behavior from a user's perspective.

Figure 15: **Use Case Diagram**

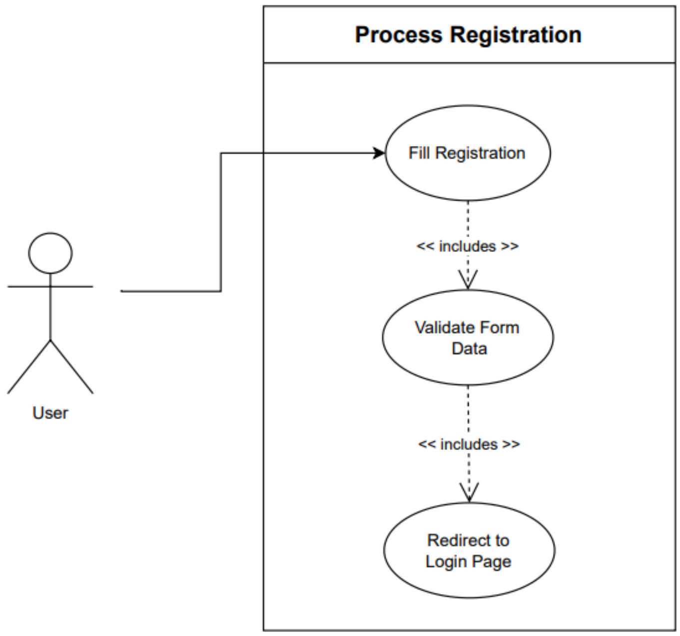

Figure 16: **Process Registration**

Use Case Name	Process Registration	
Actor(s)	User	
Purpose	To register the User Accounts.	
Benefiting Actor	User	
Pre-Conditions	User has not previously registered; Registration interface is accessible.	
Post-Conditions	User is ready to log in and access the application.	
Flow of Activity	**Actor**	**System**
	1. Tap on the "Register" Button. 3. Input the necessary details and tap "Register".	2. Redirect to the "Registration" page. 4. Verify Details 4.1. If valid, Display success message, redirect to "Login" page 4.2. Else, Display error message, redirect to "Registration" page.

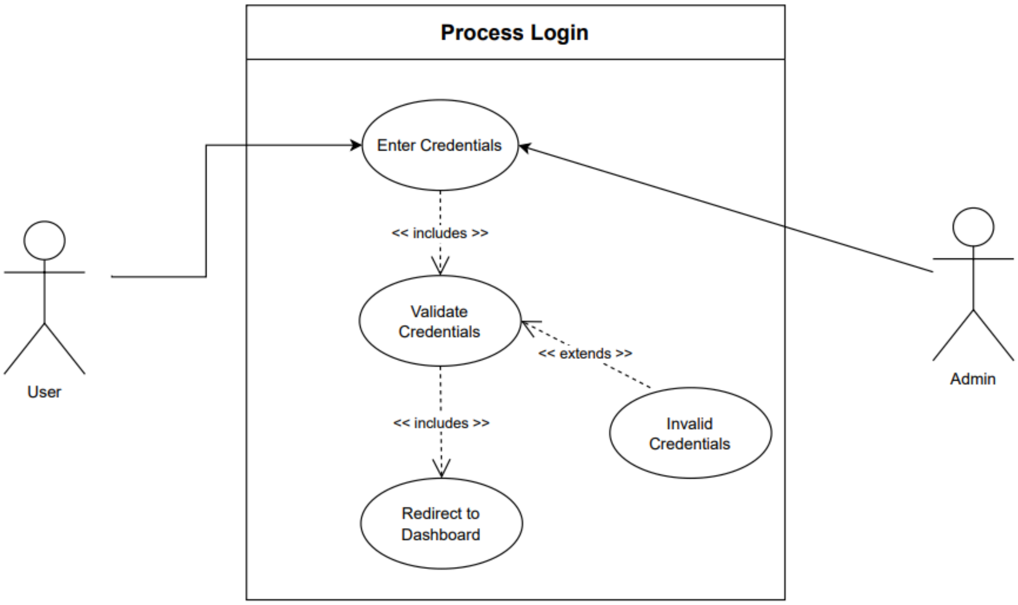

Figure 17: **Process Login**

Use Case Name	Process Login	
Actor(s)	User, Admin	
Purpose	The user can access the system.	
Benefiting Actor	User, Admin	
Pre-Conditions	User and Admin has already successfully registered an account.	
Post-Conditions	User and Admin gains access to their respective dashboards.	
Flow of Activity	**Actor**	**System**
	1. Input credentials. 3. Tap on the “Login” button.	2. Verify Credentials 2.1. If valid, redirect to Dashboard. 2.2. Else, display error message and redirect to “Login” page.

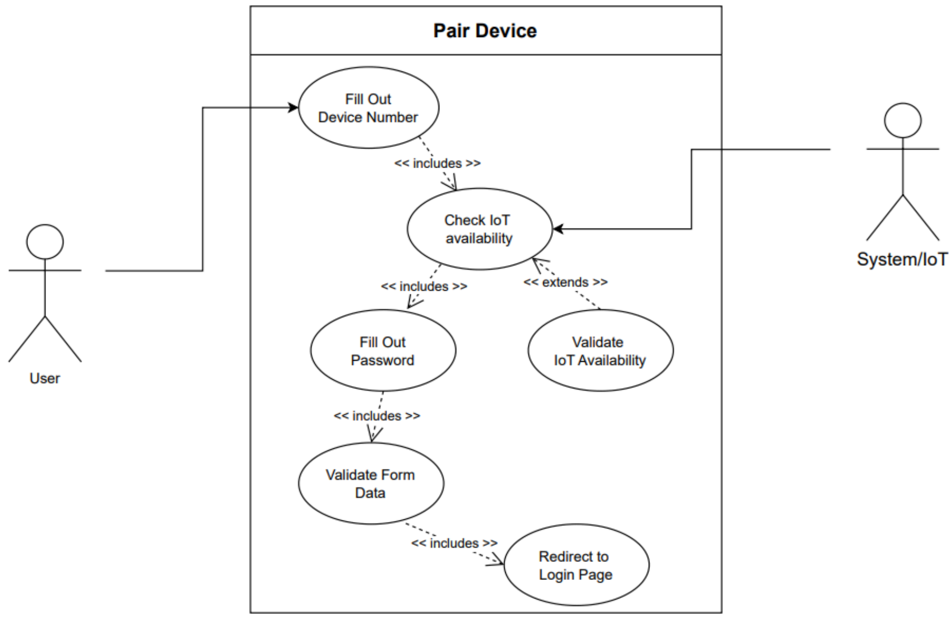

Figure 18: **Pair Device**

Use Case Name	Pair Device	
Actor(s)	User, System /IoT	
Purpose	The user can pair their solar panel device.	
Benefiting Actor	User	
Pre-Conditions	User already has an account.	
Post-Conditions	User pairs the solar panel to the mobile app.	
Flow of Activity	**Actor**	**System**
	1. Tap on "Pair Device" button 3. Input Serial Number, Password	2. Redirect to "Pair Device" Page 4. Verify IoT Availability 4.1. If valid, Display device found, can enter device password. 4.2. Else, Display device not found, cannot enter device password.

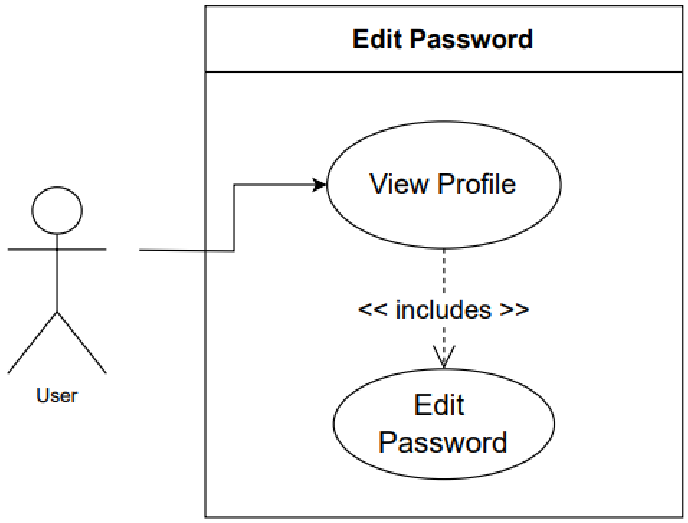

Figure 19: **Edit Password**

Use Case Name	Edit Password	
Actor(s)	User	
Purpose	The user can update their password.	
Benefiting Actor	User	
Pre-Conditions	User has access to their profile.	
Post-Conditions	User is able to change the Login credentials.	
Flow of Activity	**Actor**	**System**
	1. Tap on the "Profile" Logo. 3. Press "Change Password". 4. Enter new password 6. Tap on the "Save Changes" button and redirect back to "User Profile" page.	2. Redirect to the "User Profile" page. 5. Validate Credentials 5.1. If correct, display success. 5.2. Else, display error message and redirect back to "Edit Profile"

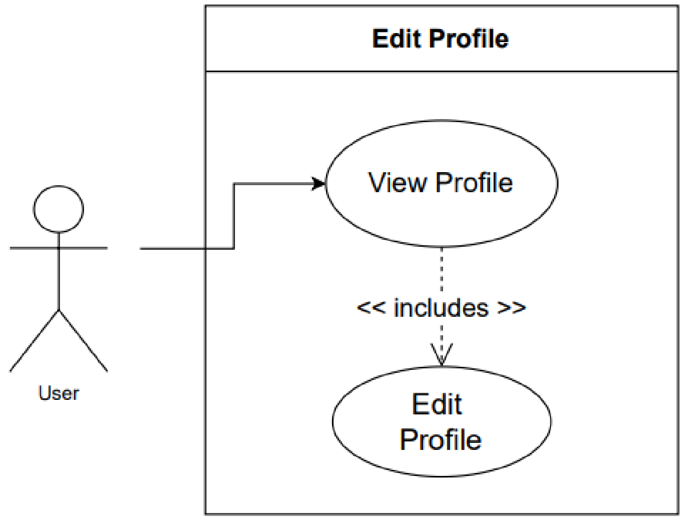

Figure 20: **Edit Profile**

Use Case Name	Edit Profile	
Actor(s)	User	
Purpose	The user can update their profile.	
Benefiting Actor	User	
Pre-Conditions	User has access to their profile.	
Post-Conditions	User is able to change their Profile credentials.	
Flow of Activity	**Actor**	**System**
	1. Tap on the "Profile" Logo. 3. Press "Change Password". 4. Enter new password 6. Tap on the "Save Changes" button and redirect back to "User Profile" page.	2. Redirect to the "Edit Password" page. 5. Validate Credentials 5.1. If correct, display success. 5.2. Else, display error message and redirect back to "Edit Profile"

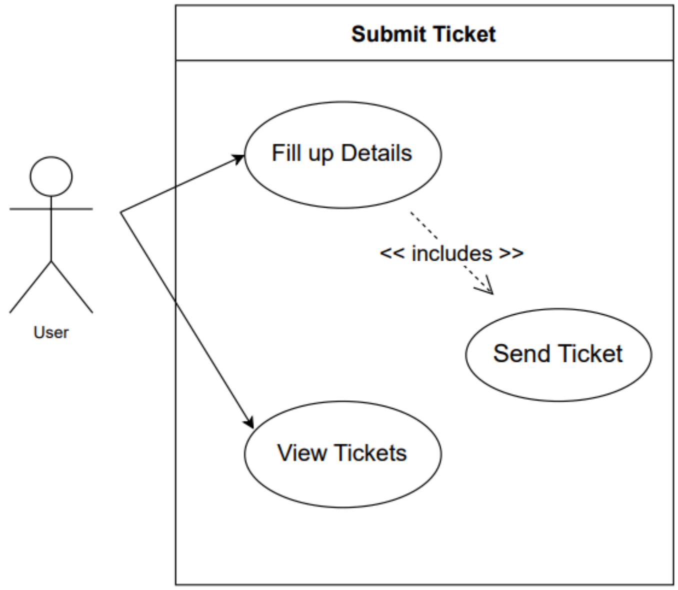

Figure 21: **Submit Ticket**

Use Case Name	Submit Ticket	
Actor(s)	User	
Purpose	User can submit a ticket, if ever the have queries regarding their account and device.	
Benefiting Actor	User	
Pre-Conditions	User has logged in to their account.	
Post-Conditions	User is able to submit a ticket.	
Flow of Activity	**Actor**	**System**
	1. Tap the “Support Center” 2. Fill in “Subject” and “Message” fields. 3. Tap “Send to Support”	4. Ticket being sent to Admin.

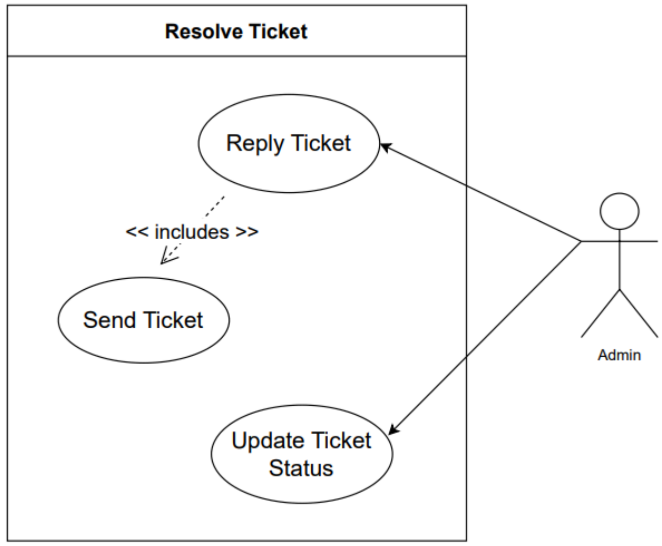

Figure 22: **Resolve Ticket**

Use Case Name	Resolve Ticket	
Actor(s)	Admin	
Purpose	Admin can view, set status, and reply to User tickets.	
Benefiting Actor	User, Admin	
Pre-Conditions	Admin is logged into the system.	
Post-Conditions	Admin can resolve a ticket.	
Flow of Activity	**Actor**	**System**
	1. Navigate to the Ticket Management in Admin Dashboard. 2. Update Ticket Status 3. Type in the Textbox to reply a ticket. 4. Click the "Send" button, to send the ticket.	5. System sends ticket reply through email.

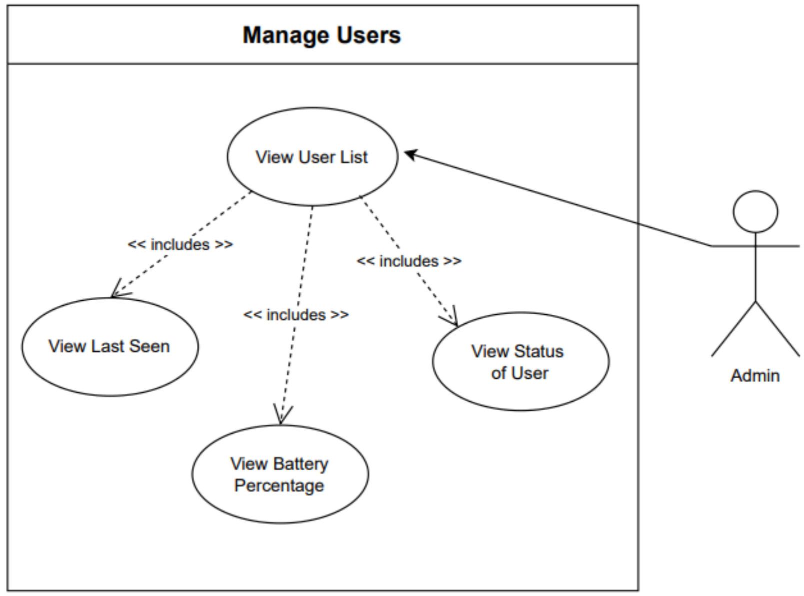

Figure 23: **Manage Users**

Use Case Name	Manage Users	
Actor(s)	Admin	
Purpose	Admin can Manage Accounts.	
Benefiting Actor	User, Admin	
Pre-Conditions	Admin is logged into the system.	
Post-Conditions	Admin can manage user	
Flow of Activity	**Actor**	**System**
	1. Admin overviews the account of its users, and its device status.	2. Sends data from user devices, to be monitored by the Admin.

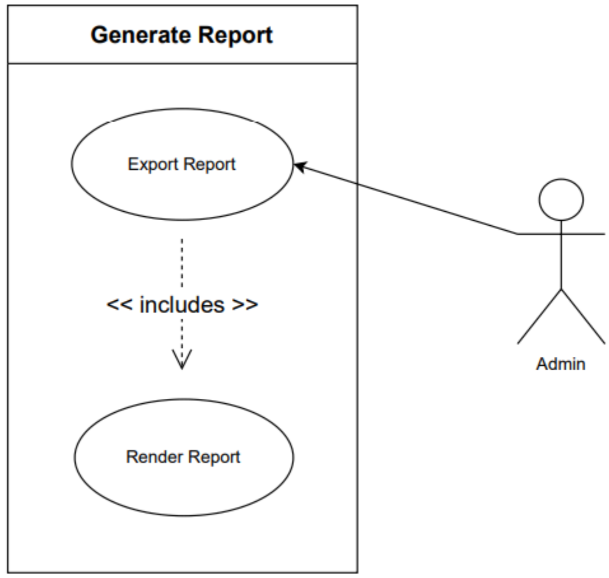

Figure 24: **Generate Report**

Use Case Name	Generate Report	
Actor(s)	Admin	
Purpose	Admin generates user report.	
Benefiting Actor	User, Admin	
Pre-Conditions	Admin is logged into the account.	
Post-Conditions	Admin can generate Report in pdf	
Flow of Activity	**Actor**	**System**
	1. Navigate the “Export PDF” button.	2. Generate User Report in PDF format.

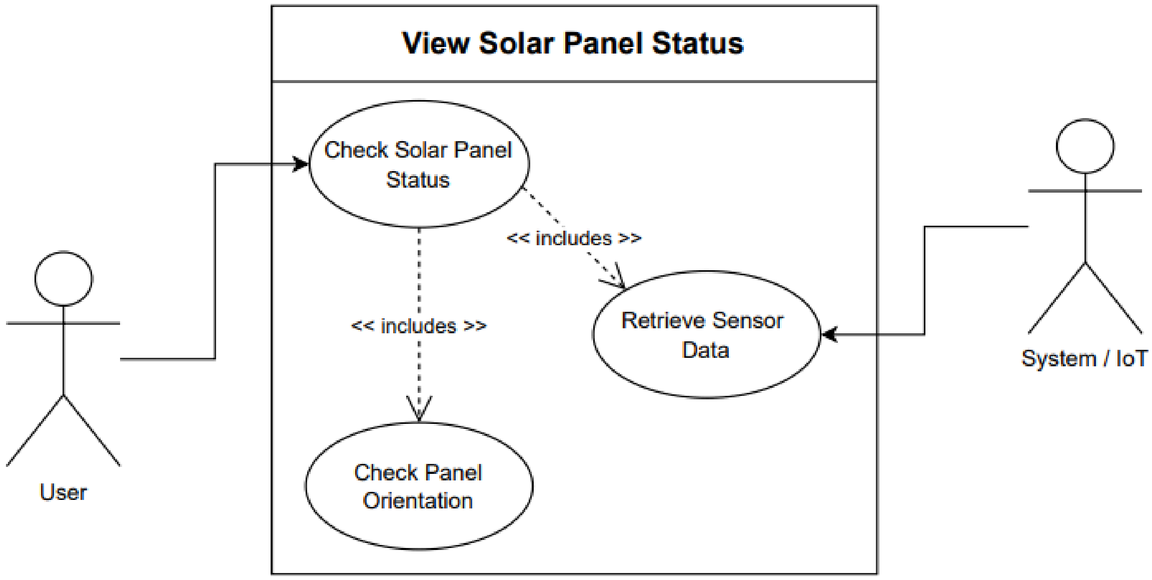

Figure 25: **View Solar Panel Status**

Use Case Name	View Solar Panel Status	
Actor(s)	User, System/IoT	
Purpose	User can view the status of the Solar Panel	
Benefiting Actor	User	
Pre-Conditions	User is logged into the application.	
Post-Conditions	User Views Solar Panel Status	
Flow of Activity	**Actor**	**System**
	1. Navigate to the Live Snapshot in Dashboard.	2. Supplies Realtime data from the Solar Panel

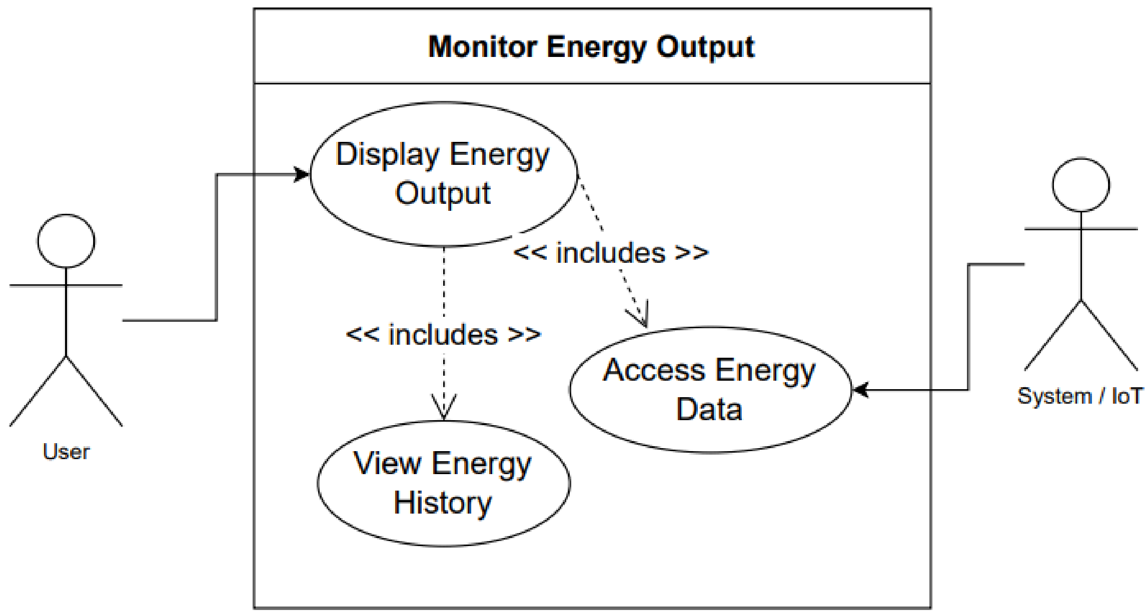

Figure 26: **Monitor Energy Output**

Use Case Name	Monitor Energy Output	
Actor(s)	User, System/IoT	
Purpose	To monitor real-time solar energy output of the system.	
Benefiting Actor	User	
Pre-Conditions	User is logged in to the system.	
Post-Conditions	User can view current and historical energy output data.	
Flow of Activity	**Actor**	**System**
	1. Navigate to “Energy Graph” in the User Dashboard.	2. Displays real-time energy output graph 3. Loads past energy data (daily/weekly/monthly)

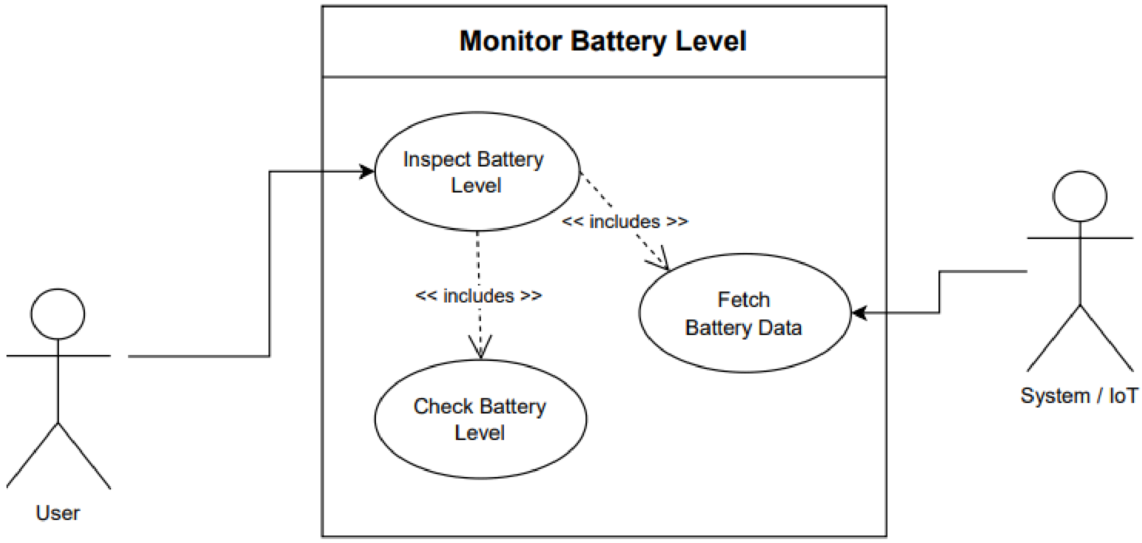

Figure 27: **Monitor Battery Level**

Use Case Name	Monitor Battery Level	
Actor(s)	User, System/IoT	
Purpose	To monitor the battery level the solar panel is producing.	
Benefiting Actor	User	
Pre-Conditions	User is logged into the system.	
Post-Conditions	User can view current battery energy output.	
Flow of Activity	**Actor**	**System**
	1. Navigate on “Battery Level” in User Dashboard	2. Displays battery energy.

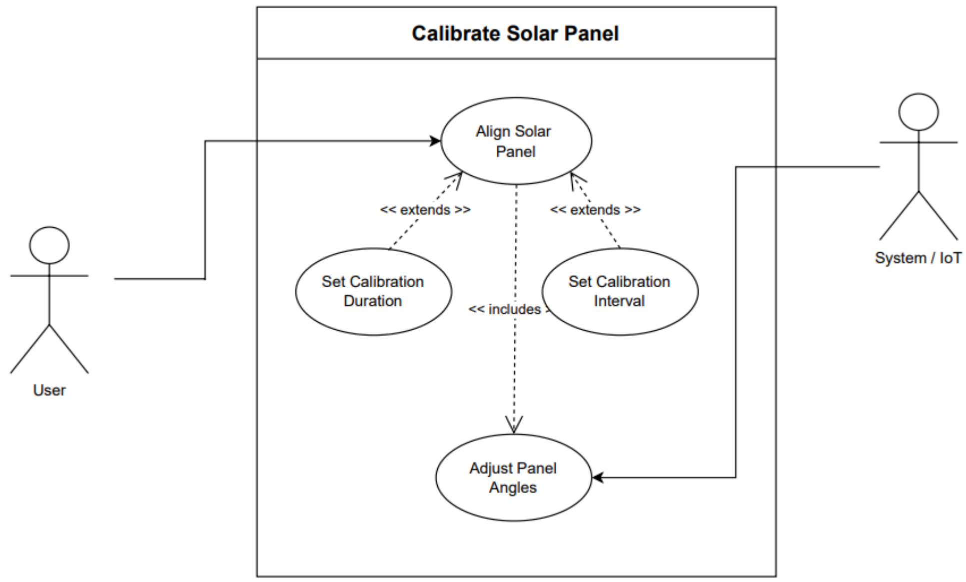

Figure 28: **Calibrate Solar Panel**

Use Case Name	Calibrate Solar Panel	
Actor(s)	User, System/IoT	
Purpose	User can calibrate their Solar Panel	
Benefiting Actor	User	
Pre-Conditions	User is logged into the system and displays panel calibration options. Applies and saves the new optimization configurations access.	
Post-Conditions	System updates and applies the user's panel calibration preferences.	
Flow of Activity	**Actor**	**System**
	1. Tap the "+" or "-" symbol to calibrate the panel to the desired time interval. 2. Press the desired time to calibrate duration	3. Calibrates the Solar Panel remotely.

Storyboard. The storyboard presents a visual narrative that captures the user's journey as they interact with the system. Through a sequence of thoughtfully designed panels, it illustrates how the platform guides users step by step—from initial interaction to successful completion of key tasks. The storyboard emphasizes system functionality, user engagement, and seamless process flow. While originally designed to showcase user interaction in a general context, its structure can later be adapted to reflect SolMate's features—such as monitoring solar energy usage, sun-tracking system, and responding to power-related events.

Screen No: 1

Screen Name: Process Login

Description: The user will input the registered credentials.

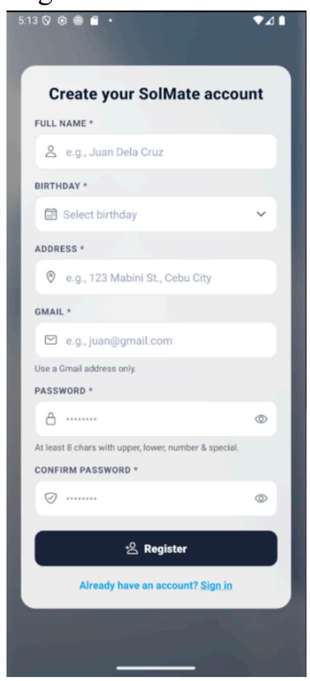

Figure 29: **Registration Page**

ITEMS	Type	Required?	Data Type	Sample Data
Full Name	TextBox	Yes	Object	Juan Dela Cruz
Birthday	TextBox	Yes	Object	2025/06/17
Address	TextBox	Yes	Object	testaddress
Gmail	TextBox	Yes	Object	juan@yahoo.com
Password	TextBox	Yes	Object	p@ssword
Confirm Password	TextBox	Yes	Object	p@ssword

Logic

1. Input the required credentials: fullname, birthdate, address, email, password and confirm password.
2. Tap the "Register" button
   2.1. If one of the input fields is empty, password and confirm password does not match, an error message will appear.
   2.2. Else, redirect to "Dashboard" page.

Screen No: 2

Screen Name: Process Login

Description: The user can log in to their accounts in "Login" page..

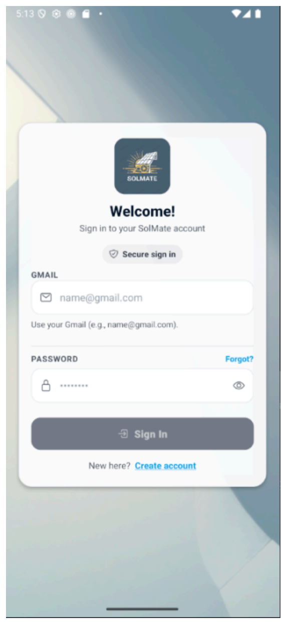

Figure 30: **Process Login**

ITEMS	Type	Required?	Data Type	Sample Data
Gmail	TextBox	Yes	Object	rigilkentpayo@gmail.com
Password	TextBox	Yes	Object	rigilkent123

Logic

1. The user inputs the Login Credentials; email and password.
2. Tap the "Login" button.
   2.1. If one of the inputs is incorrect, displays an error message.
   2.2. Else, redirect to the "Dashboard" page.

Screen No: 3

Screen Name: Forget Password

Description: The user can reset their password in the "Forget Password" page.

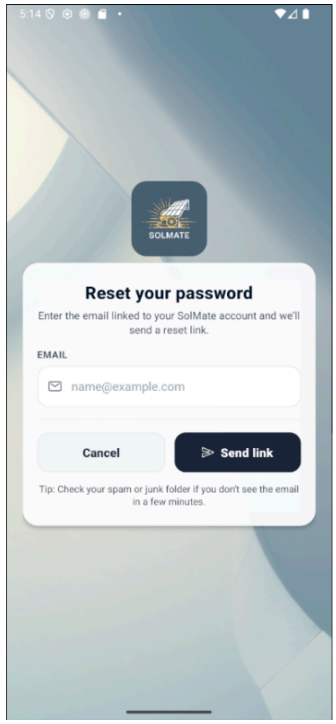

Figure 31: **Forget Password**

ITEMS	Type	Required?	Data Type	Sample Data
Email	TextBox	Yes	Object	name@example.com
Send Link	Button	Yes	Object	"Send link"

Logic

1. The user inputs their email.
2. Tap the "Send link" button.
    2.1. After clicking, an email will be received.
    2.2. Clicking the link in the email will lead to the changing of password.

Screen No: 4

Screen Name: Add Device

Description: The user can add multiple Devices in the “Dashboard” page.

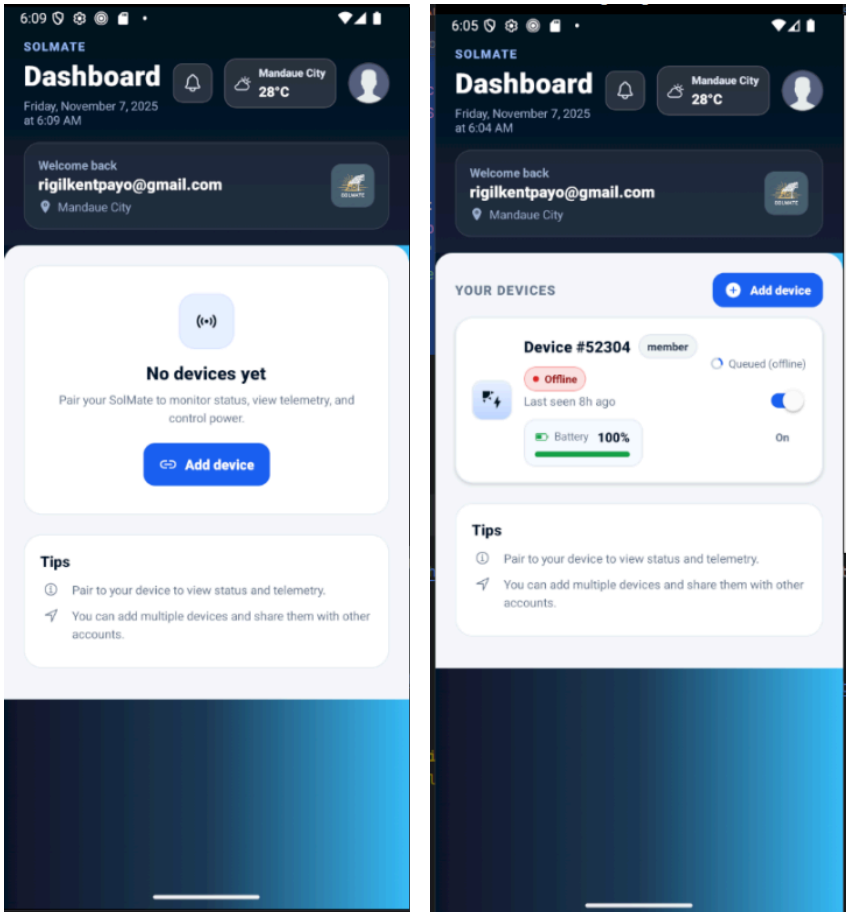

Figure 32: **Dashboard**

ITEMS	Type	Required?	Data Type	Sample Data
Add Device	Button	Yes	Object	N/A
Power	Button	Yes	Object	N/A

Logic

1. The user can link their device by tapping the “Add device” button, redirecting to the “Pair Device” page.
2. Tapping the “On” button, will activate the Solar Panel device.
3. If the user wants to connect multiple devices, click the “Add device” button.

Screen No: 5

Screen Name: Notification

Description: The user can view their notifications in the "Notification" page.

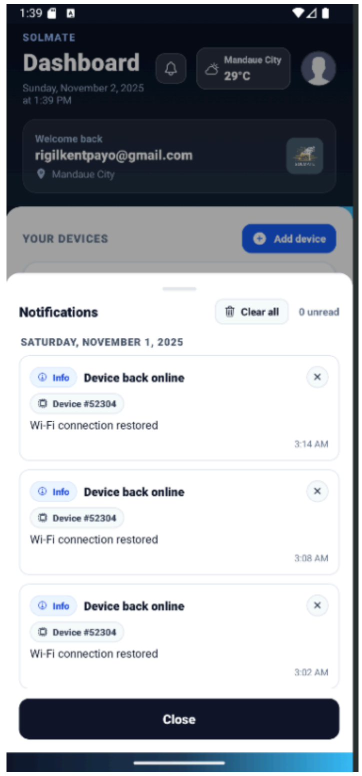

Figure 33: **Notification**

ITEMS	Type	Required?	Data Type	Sample Data
Notification Title	Text	Yes	String	Device back online
Device Number	Text	Yes	String	Device #52304
Description	Text	Yes	String	Wi-Fi connection restored
Date Header	Label	Yes	String	Saturday, November 1, 2025
Time Stamp	Label	Yes	String	3:14 AM
Clear All	Button	No	Object	"Clear all" button

Logic

1. The user can view their notifications in the "Notification" button.
2. If the user wants to clear their notification.
   2.1. Tap the "close (x)" button.
   2.2. To clear all notifications, Tap the "Clear all" button

Screen No: 6

Screen Name: User Profile

Description: The user can view their profile in the “User Profile” page.

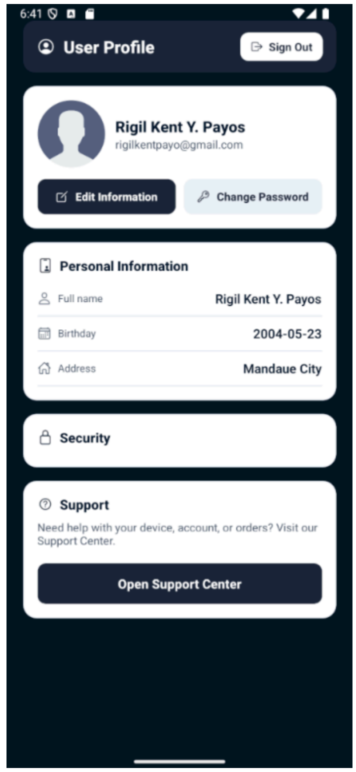

Figure 34: **User Profile**

ITEMS	Type	Required?	Data Type	Sample Data
Edit Information	Button	No	Object	N/A
Change Password	Button	No	Object	N/A
Open Support Center	Button	No	Object	N/A

Logic

3. The user can view their profile in the “User Profile” button.
4. If the user wants to edit their profile or change their password.
   4.1. Tap the “Edit Information” button
   4.2. Tap the “Change Password” button
5. “Open Support Center” button to contact support.

Screen No: 7

Screen Name: Edit Password

Description: The user can edit their “Password” credentials.

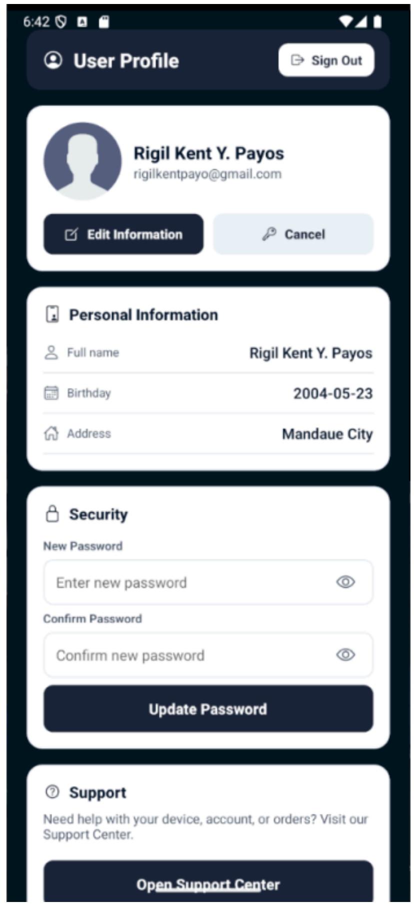

Figure 35: **Edit Password**

ITEMS	Type	Required?	Data Type	Sample Data
New Password	TextBox	Yes	Object	NewP@ssword
Confirm Password	TextBox	Yes	Object	NewP@ssword

Logic

1. If user seeks to change password
   1.1. Input new password
   1.2. Input new password again, to confirm new password
2. Tap the “Update Password” button
   2.1. If success, display success message
   2.2. Else, display error message

Screen No: 8

Screen Name: Edit Profile

Description: The user can edit their profile in the "User Profile" page.

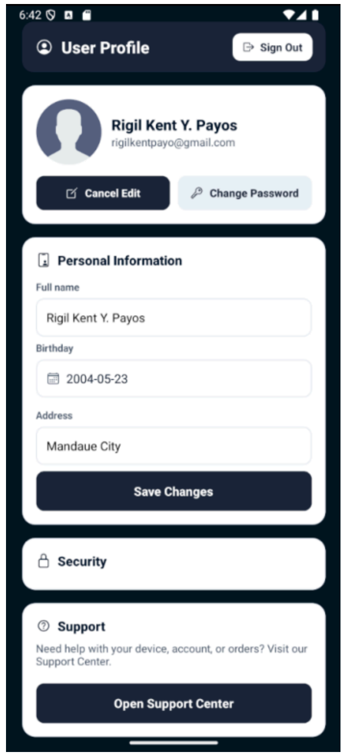

Figure 36: **Edit Profile**

ITEMS	**Type**	**Required?**	**Data Type**	**Sample Data**
Full Name	TextBox	Yes	Object	TestName
Birthday	Date	Yes	Object	2004-05-23
Address	TextBox	Yes	Object	Test Address
Save Changes	Button	Yes	Object	N/A

Logic

1. The user can change their profile, by providing the needed credentials.
2. Tap the "Save Changes" button, to save new changes.

Screen No: 9

Screen Name: User Support

Description: Users can submit a ticket regarding their accounts in “User Support” page.

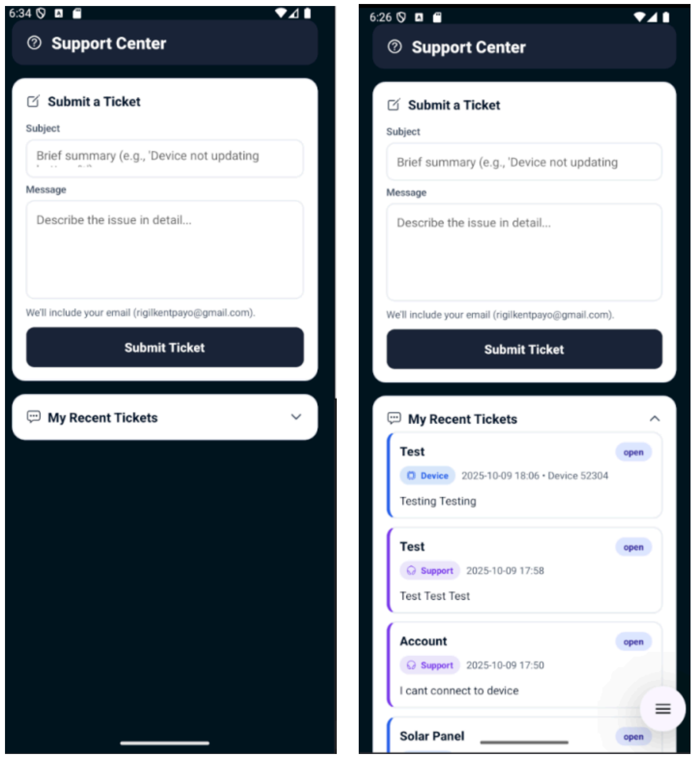

Figure 37: **User Support**

ITEMS	Type	Required?	Data Type	Sample Data
Subject	TextBox	Yes	Object	N/A
Message	Textbox	Yes	Object	N/A
Submit Ticket	Button	Yes	Object	N/A
My Recent Tickets	Dropdown	No	Object	N/A

Logic

1. When the user has queries about their profile, they can submit a ticket by filling in the “Subject” and the “Message” textboxes
   1.1. Tap the “Submit Ticket” button to continue..
2. User can view their submitted tickets in the “Show my tickets” button.

Screen No: 10

Screen Name: Pair Device

Description: The user can pair their Solar Panel in the "Pair Device" page.

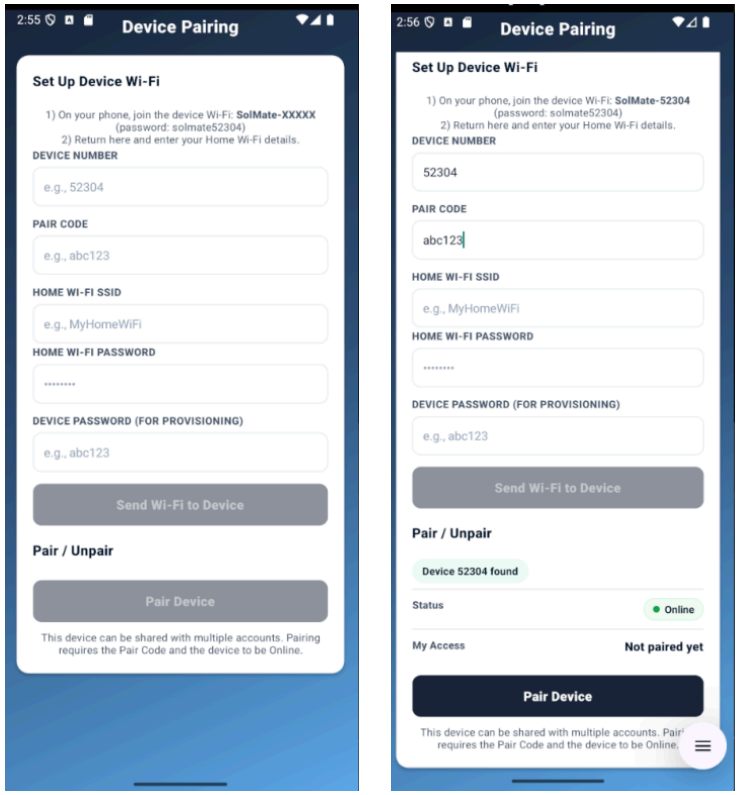

Figure 38: **Pair Device**

ITEMS	Type	Required?	Data Type	Sample Data
Device Number	TextBox	Yes	Object	52304
Pair Code	TextBox	Yes	Object	abc123
Home WI-FI SSID	TextBox	Yes	Object	MyHomeWifi
Home WI-FI Password	TextBox	Yes	Object	wifiP@ssword
Device Password	TextBox	Yes	Object	abc123

Logic

1. To register the Solar Panel, Enter the "Device Number" and "Pair Code".
    1.1. If the device is online, "Pair Device" button can be tapped,
    1.2. Else, button cannot be tapped.
2. The Home Wi-Fi SSID, Home Wi-Fi Password, and the Device Password, can be used to connect the Solar Panel for Provisioning Offline features.

Screen No: 11

Screen Name: Dashboard

Description: The user can monitor their Solar Panel in the “Dashboard” page.

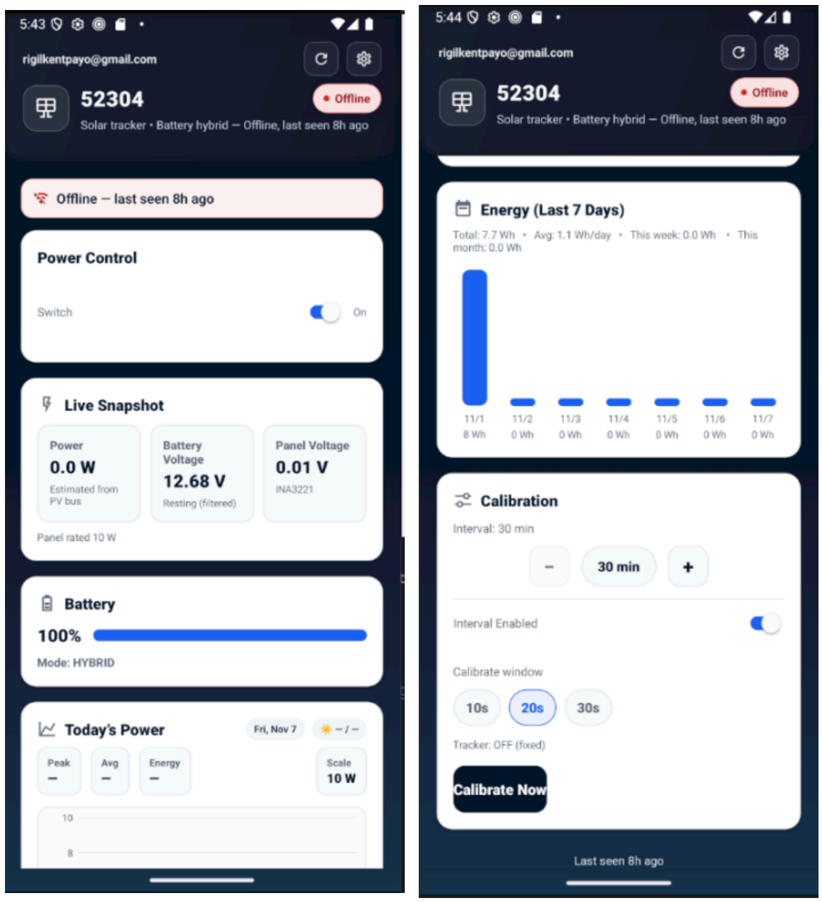

Figure 39: **User Dashboard**

ITEMS	Type	Required?	Data Type	Sample Data
Switch	Button	Yes	Object	N/A
Panel Voltage	Card	Yes	Object	0.0 W
Battery Voltage	Card	Yes	Object	12.94 V
Battery	Card	Yes	Object	100%
Power Curve Graph	Card	Yes	Object	Time Graph
Energy Graph	Card	Yes	Object	Weekly Graph
Calibration Interval	Button	No	Object	“-” , “+”

Interval Enabled	Button	No	Object	N/A
Calibration Window	Button	No	Object	“10s”, “20s”,”30s”
Calibrate Now	Button	Yes	Object	N/A

Logic

1. To turn on the monitoring, Tap the “On” button.
2. The Battery, Power, Battery Voltage, Panel Voltage, Power Curve Graph, and Energy Graph will be monitored in the “Dashboard” page.
3. To calibrate the Solar Panel
   3.1. If the user wants to set the calibration by interval, Tap the “+” or “-” button to set the interval of the calibration, tap the “Interval Enabled” button, to turn it on.
   3.2. Else, to calibrate the Solar Panel at the exact moment, Tap the desired duration.

Screen No: 12

Screen Name: Device Settings

Description: The user can edit their device details in “Device Settings”

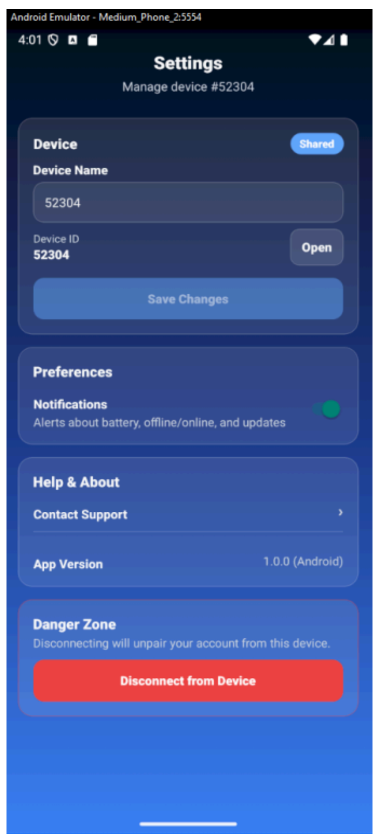

Figure 40: **Device Settings**

ITEMS	Type	Required?	Data Type	Sample Data
Device Name	TextBox	No	Object	New Name
Notifications	Button	No	Object	N/A
Contact Support	Hyperlink	No	Object	N/A
Disconnect from Device	Button	No	Object	N/A

Screen No: 13

Screen Name: Device Support Center

Description: The user can submit a query through the Device Support Center.

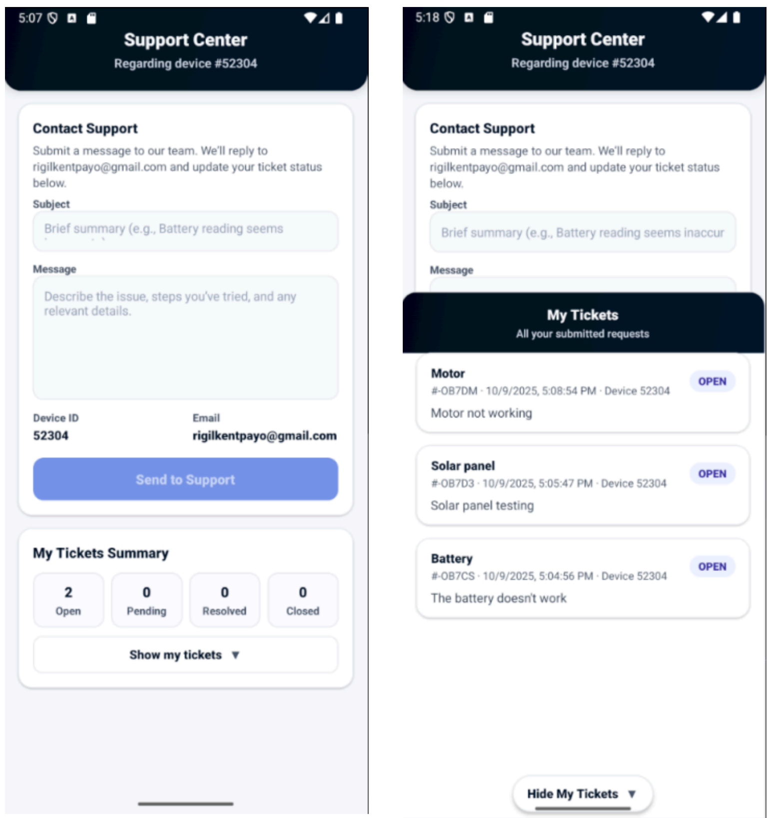

Figure 41: **Device Support Center**

ITEMS	Type	Required?	Data Type	Sample Data
Subject	TextBox	Yes	Object	testSubject
Message	TextBox	Yes	Object	"I can't connect"
Send to Support	Button	Yes	Object	N/A

Show my tickets	Dropdown	No	Object	N/A
Open	Button	No	Object	N/A

Logic

1. When the user has queries about their devices, they can submit a ticket by filling in the "Subject" and the "Message" textboxes.
   1.1. Tap the "Submit Ticket" button to continue.
2. User can view their submitted tickets in the "Show my tickets" button.

Screen No: 14

Screen Name: Process Admin Login

Description: The Admin Login feature allows administrators to securely access the web-based dashboard using their registered email and password to manage users, devices, and support tickets.

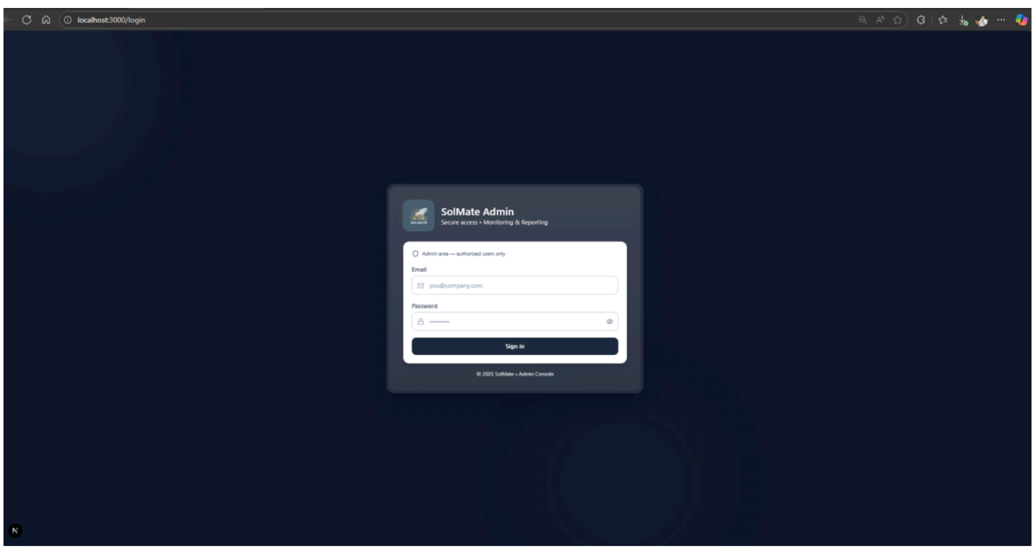

Figure 42: **Process Admin Login**

ITEMS	Type	Required?	Data Type	Sample Data
Email	TextBox	Yes	Object	you@company.com
Password	TextBox	Yes	Object	adminP@ssword

Logic

1. The admin inputs the Login Credentials; email and password.
2. If one of the inputs is incorrect,
   2.1. displays an error message.
   2.2. Else, redirect to the "Dashboard" page.

Screen No: 15

Screen Name: Admin Dashboard

Description: The Admin Dashboard provides administrators with a comprehensive management tool. Its key metrics highlight the total users and devices in the system, and a detailed table allows for the real-time monitoring of each user's data, including their paired device, last activity, and current battery level.

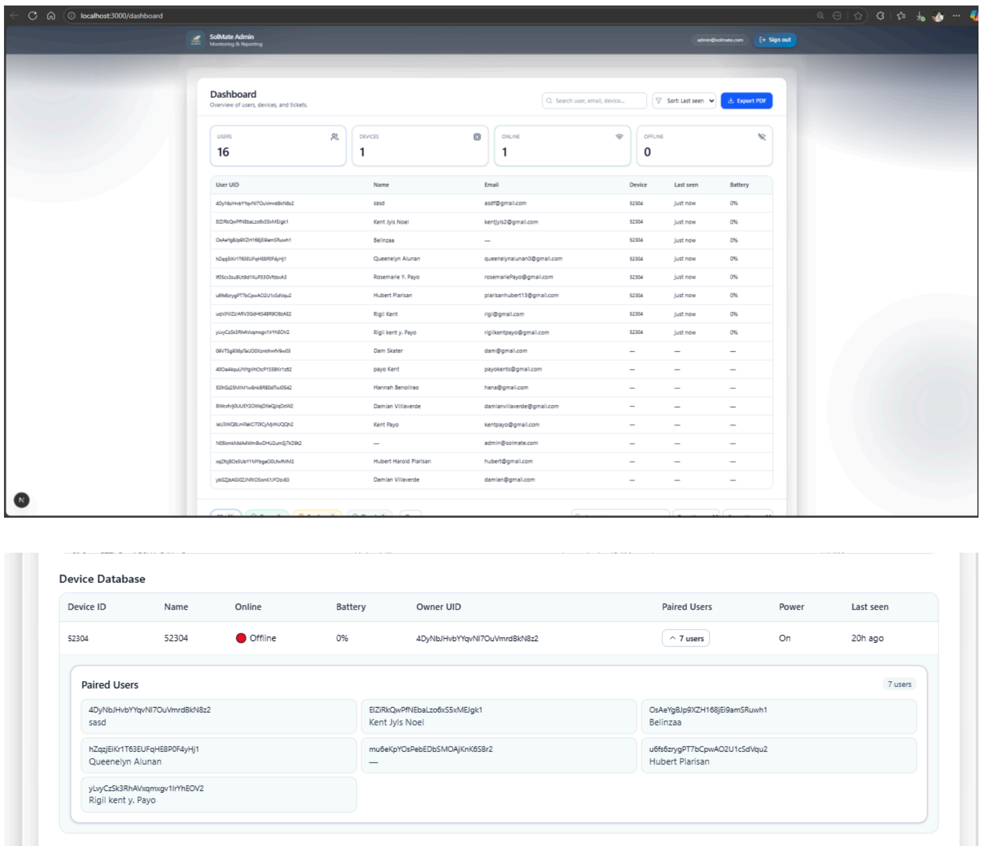

Figure 43: **Admin Dashboard**.

Screen No: 16

Screen Name: Process Ticket Management

Description: The Ticket Management process is a feature within the Admin Dashboard that allows the administrator to reply to user tickets and update their status accordingly.

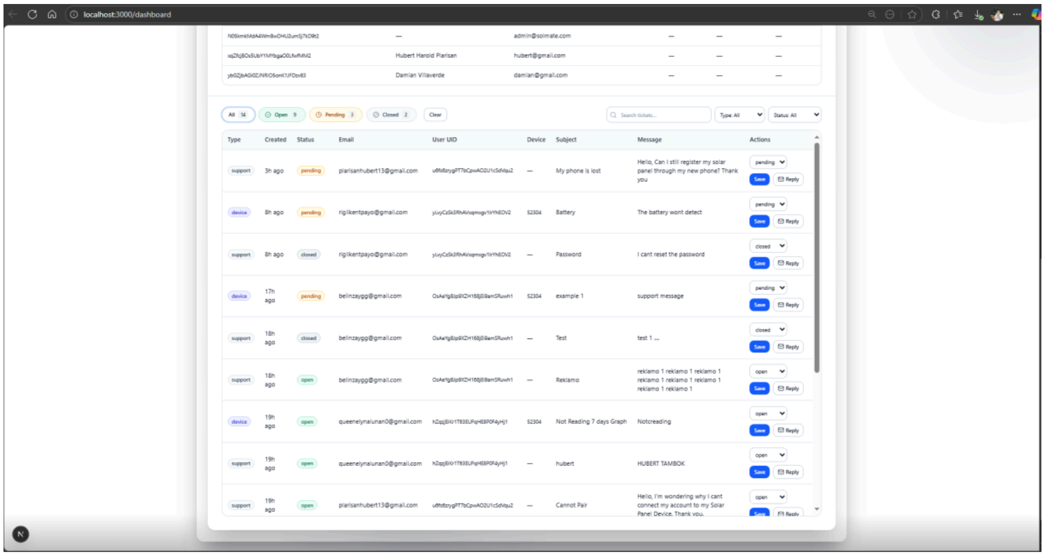

Figure 44: **Process Ticket Management**

ITEMS	Type	Required?	Data Type	Sample Data
Ticket Type	Text	Yes	Object	“support”
Status	Text	Yes	Object	“pending”
Email	Text	Yes	Object	testmail@yahoo.com
User ID	Int	Yes	Object	“Unique ID”
Device ID	Int	Yes	Object	52304
Subject	Text	Yes	Object	“My phone is lost”
Message	Text	Yes	Object	“Device problem”
Actions	Dropdown	Yes	Object	“pending”
Reply	Button	Yes	Object	adminP@ssword

Logic

1. The admin can change the status of the ticket, by clicking the “Actions” dropdown.
2. To reply a message through email,
   2.1. Click the “Reply” button,
   2.2. A message modal will appear, type the message,
   2.3. After click the “Send” button.

Database Design. This includes all logical and physical design decisions, as well as physical storage elements like the Entity Relationship Diagram and Data Dictionary.

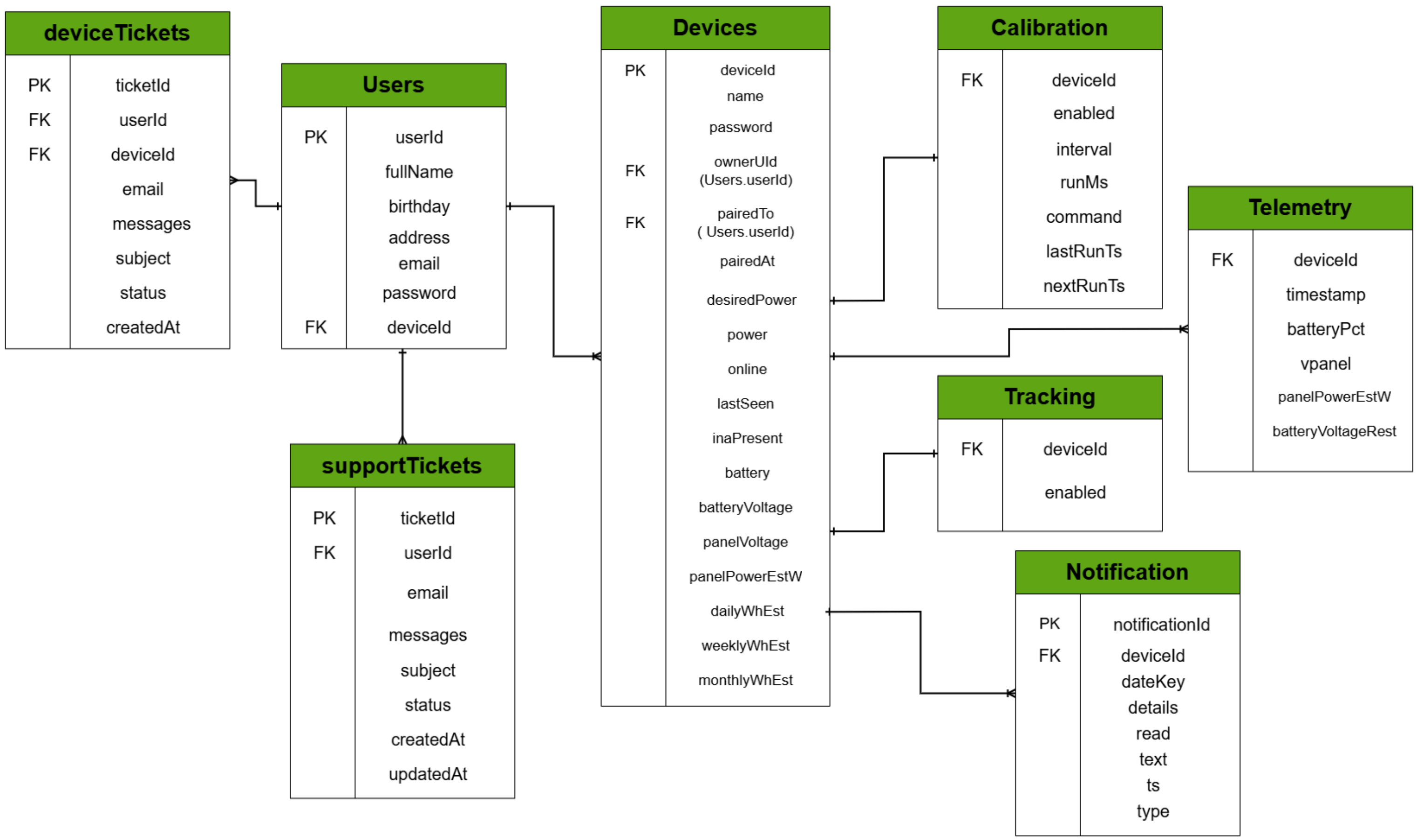

Figure 45: **Database Design of SolMate**

Entity Relationship Diagram. The figure below illustrates a segment of the Firebase database structure, showcasing a database design process that integrates a comprehensive data model. This method combines a data description language with the necessary logical and physical architectural decisions and parameters to construct the database. It establishes a fully attributed data model by defining specific attributes for each element within the Firebase environment.

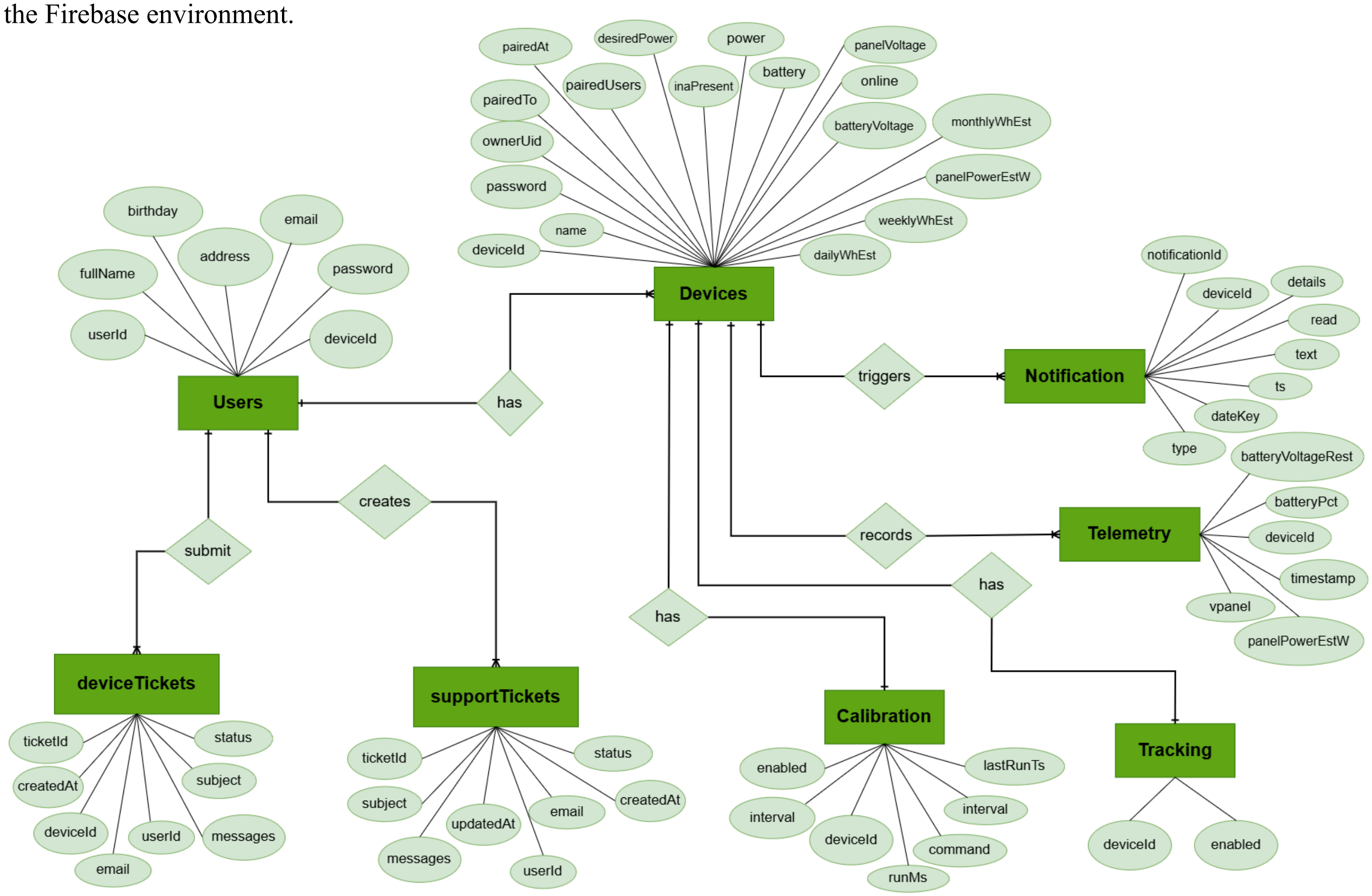

Figure 46: **Entity Relationship Diagram of SolMate**

Data Dictionary. Below is the description of the user data dictionary, including the fields' index, data type, and charts. It provides a detailed overview of the type of data the database collects, along with its format, structure, and intended use.

Table 5

DATA DICTIONARY OF USER

Column	Data Type	Constraints	Description
userId	Int	PK	Unique identifier for each user. Serves as the main reference in the system.
fullName	String	NOT NULL	Stores the complete name of the user.
birthday	String	NOT NULL	Records the user’s date of birth.
address	String	NOT NULL	Stores the residential or contact address of the user.
email	Nvarchar	NOT NULL	Stores the user’s email address. Used for communication and login reference.
password	String	NOT NULL	Stores the user’s login password
pairedDevice	Int	FK	Refers to the device paired with the user, linked to the Devices table.

The table 5 defines the structure of the system’s account information and stores the essential details required for user identification and authentication. It includes the userId as the primary key, which uniquely identifies each user within the system. The table also contains the fullName, birthday, and address fields that capture basic personal details of the user. The email field is mandatory and serves as a unique contact point for communication, while the password field stores the user’s login credentials to ensure account security. Together, these attributes form the foundation of the user account, enabling device pairing, secure access, and personalized interaction.

Table 6

DATA DICTIONARY OF DEVICES

Column	Data Type	Constraints	Description
deviceId	Int	PK	Unique device number of ESP32
name	String	NOT NULL	Readable device name
password	String	NOT NULL	Password required to pair the device.
ownerUserId	Nvarchar	FK	The account that owns the device.
pairedToUserId	Nvarchar	FK	The account currently paired/connected
pairedAt	Int	NOT NULL	Epoch ms when current pairing occurred.
desiredPower	Boolean	NOT NULL	Indicates whether the user has requested the device to turn on or off through the mobile app.
power	Boolean	NOT NULL	Reflects the actual power state of the device's system 'On' or 'Off' as reported by the ESP32 in real time.
online	Boolean	NOT NULL	Indicates the device's status: true if currently online, false if offline.
lastSeen	BigInt	NOT NULL	Timestamp of the device's most recent activity or communication with the system.
inaPresent	Boolean	NOT NULL	Shows whether the INA3221 power monitoring sensor is detected and functioning on the device, ensuring accurate voltage and current readings.
battery	Int	NOT NULL	Current battery percentage level of the device.
batteryVoltage	Float	NOT NULL	Real-time battery voltage reading of the device.
panelVoltage	Float	NOT NULL	Real-time panel voltage reading of the device.
panelPowerEstW	Double	NOT NULL	Estimated instantaneous panel power (watts).
dailyWhEst	Double	NOT NULL	Estimated energy for the current day (watt-hours).

weeklyWhEst	Double	NOT NULL	Estimated energy for the current week (watt-hours)
monthlyWhEst	Double	NOT NULL	References Users.userId, linking the device to its corresponding owner.

Table 7

DATA DICTIONARY OF CALIBRATION

Column	Data Type	Constraints	Description
deviceId	Int	FK	The device this calibration config belongs to.
enabled	Boolean	NOT NULL	Enables interval-based calibration.
interval	Int	NOT NULL	Minutes between automatic calibration runs.
runMs	Int	NOT NULL	Duration of each calibration window in milliseconds.
command	Nvarchar	NOT NULL	Latest command written by the app.
lastRunTs	Int	NOT NULL	Epoch ms when calibration last started.
nextRunTs	Int	NOT NULL	Epoch ms when the next interval run is due.

Table 8

DATA DICTIONARY OF TRACKING

Column	Data Type	Constraints	Description
deviceId	Int	FK	The device this tracking toggle belongs to.
enabled	Boolean	NOT NULL	Tracker state as reflected in the app.

Table 9

DATA DICTIONARY OF TELEMETRY

Column	Data Type	Constraints	Description
deviceId	Int	FK	Device that produced the sample.

timestamp	BigInt	NOT NULL	Epoch ms of the sample
batteryPct	Int	NOT NULL	Battery state of charge.
vpanel	Double	NOT NULL	Panel voltage at sample time, window in milliseconds.
panelPowerEstW	Double	NOT NULL	Estimated panel power at sample time .
batteryVoltageRest	Double	NOT NULL	Resting/filtered battery voltage , when available.

Table 10

DATA DICTIONARY OF NOTIFICATION

Column	Data Type	Constraints	Description
notificationId	Int	PK	Unique identifier for each notification entry.
deviceId	Int	FK	The device that generated this notification.
dateKey	Varchar	NOT NULL	Date grouping key in the date format used to organize notifications by day.
details	Nvarchar	NOT NULL	Detailed message describing the notification event.
read	Boolean	NOT NULL	Indicates if the notification has been viewed or not.
text	Nvarchar	NOT NULL	Short title of the notification.
ts	BigInt	NOT NULL	Epoch timestamp representing when the notification was created.
type	Varchar	NOT NULL	Category of notification.

The Devices, Calibration, Tracking, TelemetryDay, and Notification tables collectively manage and monitor each ESP32 solar tracking unit in the SolMate system. The Devices table stores key operational data such as battery level, voltage, last activity, connectivity status, and panel angle, while linking each device securely to its owner through a unique pairing password. The Calibration table controls automated sun-tracking parameters, including calibration intervals, run duration, and timing schedules. The Tracking table records whether the tracking function is enabled, allowing differentiation between manual and automatic modes. The TelemetryDay table logs time-based readings like battery percentage, panel voltage, and power output to analyze daily performance trends. Lastly, the Notification table stores system alerts and event-based updates such as battery warnings, calibration activities, shading alerts, and connectivity changes, providing users with real-time feedback on device conditions. Together, these tables provide accurate monitoring, synchronized automation, and efficient communication between the IoT hardware, user accounts, and the system's administrative dashboard.

Table 11

DATA DICTIONARY OF DEVICETICKETS

Column	Data Type	Constraints	Description
ticketId	Int	PK	Unique identifier for each device-related ticket.
userId	Int	FK	References the user who submitted the device ticket.
deviceId	Int	FK	References the device associated with the issue.
email	Nvarchar	NOT NULL	Email address of the user submitting the ticket.
messages	String	NOT NULL	Description or message content of the issue submitted.
subject	Nvarchar	NOT NULL	Brief summary of the issue (e.g., "Battery not charging").
status	Nvarchar	NOT NULL	Ticket's current state — values may include 'open', 'pending', 'closed'.
createdAt	DateTime	NOT NULL	Timestamp of when the ticket was created.

Table 12

DATA DICTIONARY OF SUPPORTTICKETS

Column	Data Type	Constraints	Description
ticketId	Int	PK	Unique identifier for each support-related ticket.
userId	Int	FK	References the user who submitted the support ticket.
email	Nvarchar	NOT NULL	Email of the user submitting the support request.
messages	String	NOT NULL	Description or content of the support inquiry.

subject	Nvarchar	NOT NULL	Title or topic of the support request.
status	Nvarchar	NOT NULL	Status of the ticket ('open', 'pending', 'closed').
createdAt	DateTime	NOT NULL	Timestamp of ticket creation.
updatedAt	DateTime	NOT NULL	Timestamp of last update.

The deviceTickets and supportTickets tables handle the user support and issue reporting system within SolMate. The deviceTickets table stores user-submitted concerns related to hardware or device performance, including the issue’s subject, detailed message, status, and creation date, while linking each ticket to a specific user and their corresponding device through foreign keys. Meanwhile, the supportTickets table manages general inquiries not tied to a device—such as account or system-related concerns—recording details like the subject, message, email, and timestamps for creation and updates. Both tables enable the administrator to track, respond to, and manage user issues efficiently, ensuring smooth communication and timely resolution between users and the support team.

Network Design. The network design of SolMate, a smart IoT-enabled solar panel system, is built on a secure and scalable architecture that supports real-time monitoring and efficient energy optimization. At its core is a robust cloud-based server that ensures seamless data transmission between solar panels, mobile applications, and storage systems. This infrastructure plays a key role in safeguarding user data and enabling critical system functionalities such as sun-tracking, battery switching, and performance analytics.

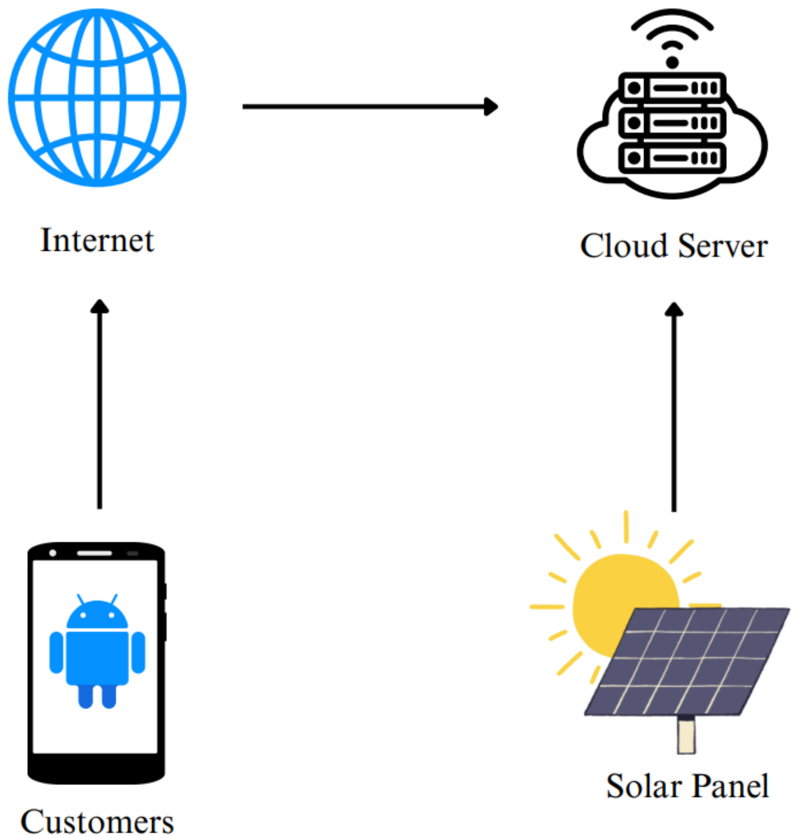

Figure 47: **Network Design**

The network design of SolMate shows how Customers connect to the Cloud Server to get access to the monitoring of the Solar Panel by the use of the Internet. The server processes and stores critical information from the solar panel, including sun-tracking status, energy production, and battery management metrics. This infrastructure ensures reliable operation of essential features such as sun-tracking, hybrid power management, and performance analytics, enhancing the system's overall efficiency, accessibility, and data security.

Network Model. The network model of SolMate illustrates the interaction between the end users, cloud infrastructure, and the system database to facilitate smart solar energy management. The cloud server acts as the central processing unit, handling requests from the mobile application and coordinating data exchange. It is directly linked to a dedicated database that stores essential system information, including solar panel performance metrics, sun-tracking data, battery status, and energy usage logs. This model ensures efficient, secure, and real-time data flow between components, enabling users to remotely monitor and manage solar energy operations through a reliable and responsive IoT framework.

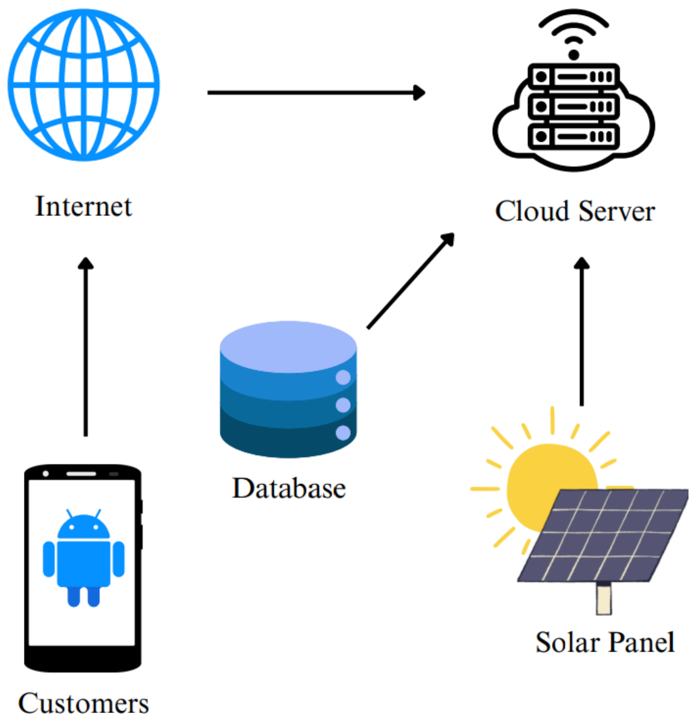

Figure 48: **<u>Network Model</u>**

The network model of SolMate connects customers to the cloud server and database via the Internet. Users access the system through a mobile application on their smartphones. The cloud server manages real-time operations and communications from the solar panel, while the database securely stores system data such as solar panel performance, energy usage, and monitoring logs. This structure ensures efficient interaction, remote accessibility, and reliable data management within the platform.

Network Topology. SolMate adopts a cloud-based client-server architecture that facilitates direct communication between end-users and the cloud server through the Internet. Customers access the system using a mobile application, which connects to the cloud server to send and receive real-time data.

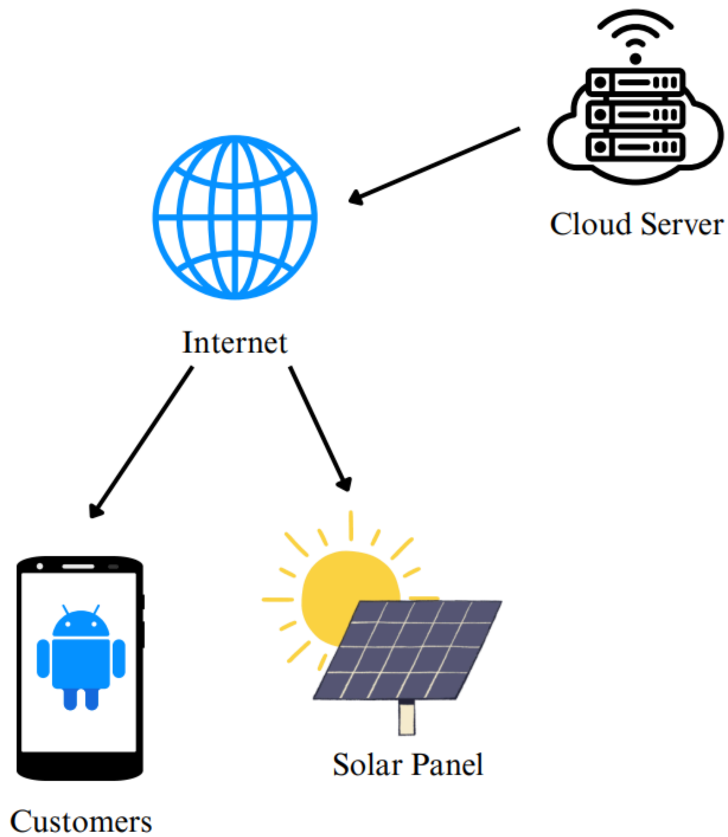

Figure 49: **Network Topology**

The network topology of SolMate follows a client-server configuration, connecting users via mobile devices and solar panels to a cloud server through the Internet. This structure enables centralized communication, smooth data transmission, and efficient system operations for real-time solar panel monitoring and control.

Development/Construction/Build Phase

In this phase, programmers and system analysts gain a comprehensive understanding of the application software, allowing them to effectively develop, install, and maintain the system.

Technology Stack Diagram. The Technology Stack Diagram provides a visual representation of the various technologies, tools, and platforms used in the development and deployment of the SolMate system. It outlines the layers of the system architecture, including the front-end, back-end, database, and hosting components, illustrating how each technology integrates to support the overall functionality. This diagram helps in understanding the role of each technological component and how they collectively contribute to achieving a scalable, efficient, and responsive solar energy monitoring solution.

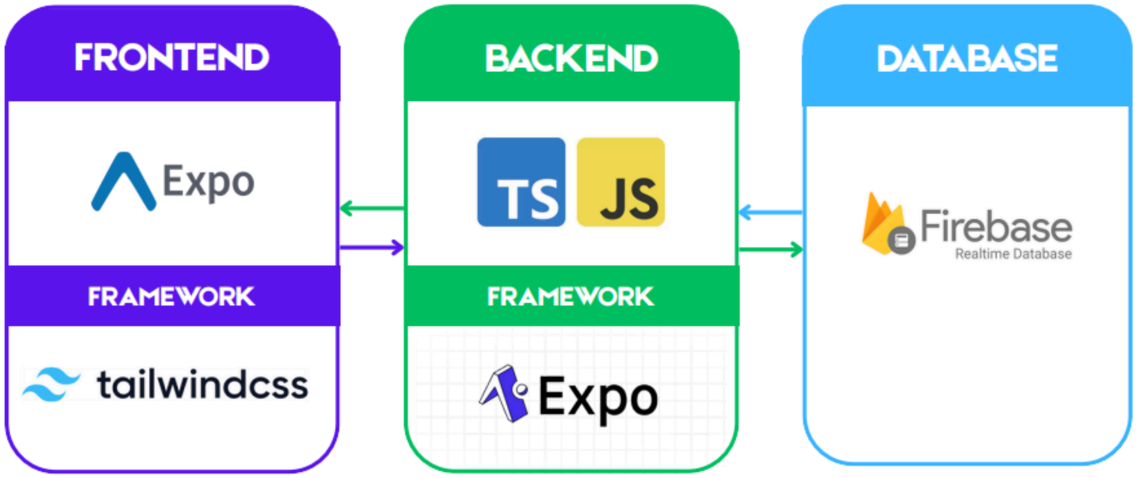

Figure 50: **Technology Stack Diagram**

The Technology Stack Diagram above shows the integration of various technologies used in the development and deployment of the SolMate system. The front end is built using Expo, a React Native framework that enables cross-platform mobile development, and is managed through Tailwind CSS for efficient navigation. The backend utilizes JavaScript and TypeScript, supported by Expo Go, to handle server-side logic and asynchronous operations. These components communicate through secure Internet protocols to facilitate seamless real-time interactions. For data storage, the system relies on Firebase Realtime Database, which ensures synchronized and scalable data management. This layered architecture promotes modularity, real-time responsiveness, and ease of maintenance across the entire system.

Software Development Specification. The system can be implemented with the following Software specification:

Table 13

SOFTWARE SPECIFICATION

SOLMATE: SMART IOT SUN- TRACKING SOLAR PANEL SYSTEM WITH MOBILE MONITORING AND ENERGY OPTIMIZATION	
Back End:	
Operating System	Windows 10
Database Management System	Firebase Realtime DB
Platform Technologies	WebStorm 2025
Programming Language	JavaScript/TypeScript
Framework	React Native (Expo Go)

Front End:	
Scripting Language	Javascript/TypeScript
Design Tools	Figma, Expo Go Preview, React Native Components
CSS Framework	Tailwind CSS (Native Wind)
Editors	WebStorm 2025

Hardware Specification. The system can be implemented with the following hardware specifications:

Table 14

HARDWARE SPECIFICATIONS

	Minimum Requirement	Recommended
1. Central Processing Unit (CPU)	Intel Core i3 (or equivalent AMD processor)	AMD Ryzen 5 5600G — 6-core, 12-thread processor used for software development, system simulation, and real-time data processing.
2. System Memory (RAM)	8 GB DDR4	16 GB DDR5 5600 MHz — provides efficient multitasking and smooth performance for development and testing.
3. Internal Storage	500 GB HDD	1 TB SSD — fast read/write storage for project files, databases, and backups.
4. Microcontroller	ESP32-WROOM-32 Dev Board	Dual-core 240 MHz MCU with built-in Wi-Fi + Bluetooth; controls sensors, motors, and Firebase communication.
5. Motor Drivers	TMC2209 Stepper Drivers (x2)	Silent, current-controlled steppers for azimuth & elevation motors; share an enable pin (GPIO 23 — active LOW).
6. Motors	Stepper Motors (x2)	Drive the solar panel mount on dual axes for sun tracking (horizontal and vertical).

7. Light Sensors	LDRs x 4	Detect light intensity from four directions (Top-Left 32, Top-Right 33, Bottom-Left 34, Bottom-Right 35) for calibration.
8. Power / Voltage Sensor	INA3221 Triple-Channel Current & Voltage Sensor	Monitors panel voltage, battery voltage, and load voltage via I2C (Addr 0x40-0x43, SDA 21, SCL 22).
9. Battery	12 V 7 Ah Sealed Lead-Acid Battery (TF7-12)	Energy storage for the system; powers ESP32 and motors during low-sunlight hours.
10. Solar Panel	12 V 10 W Monocrystalline Panel	Provides DC power input to the charge controller for battery charging.
11. Charge Controller	PWM Solar Charge Controller (10 A)	Regulates charging between solar panel and battery; integrated into hybrid system.
12. Relay Module	Single-Channel 5 V Relay	Optional hardware for switching motor/charger power
13. Resistor Divider / Voltage Tap	25 V Voltage Sensor Module (~5:1)	Converts high voltage (12 V battery line) to safe ADC input level for ESP32.
14. Wi-Fi Antenna (Internal)	Built-in ESP32 antenna	Handles all wireless communication to Firebase.
15. Force-AP Button / Boot Input	Tactile Switch (GPIO 0)	Forces Access Point provisioning mode when held LOW at startup.
16. Wiring / Connectors	Dupont jumpers, JST connectors	For sensor, driver, and power line connections.
17. Aluminum Electrolytic Capacitor	6.3 V 1500 µF 10x13 mm Capacitor	Used for power filtering and voltage stabilization on the PCB; smoothes sudden current surges from motors and prevents voltage drops or noise on the 5 V/3.3 V lines.

Program Specification. The program specification is designed in alignment with the capabilities and constraints of the underlying hardware components, which include microcontrollers, power regulation modules, sensors, and connectivity interfaces.

Functional Requirements. The system must provide the following functionalities:

A. **User Authentication -** the system shall provide secure user registration and login functionalities for customers.
B. **Login Process -** the system must let the user log in their accounts.
C. **Register Process-** the system lets the user register an account.
D. **Sun-Tracking Mechanism -** the system shall automatically adjust the orientation of the solar panel to track the sun's position throughout the day, maximizing solar energy absorption.
E. **Hybrid Power Management -** the system shall intelligently manage the switching between solar energy and backup battery power based on available solar input and stored energy levels.
F. **Data Logging and Historical Tracking -** the system shall record and store operational data such as energy production, consumption, battery usage, and system uptime. Users shall be able to access historical trends through the mobile application.
G. **Cloud Integration -** the system shall utilize cloud infrastructure to handle data synchronization between the IoT devices and the mobile application, ensuring reliability and scalability.
H. **Remote Access and Control -** users shall be able to configure system settings such as tracking sensitivity, energy usage preferences, and data reporting intervals through the mobile application.
I. **Data Visualization -** the mobile application shall present data through interactive charts and dashboards, offering users an intuitive understanding of energy performance metrics.

Nonfunctional Requirements

A. The app is only compatible with a Mobile app.
B. The app needs Internet connectivity to function.
C. Only registered users can login to the Mobile app.

List of Modules. The table, shown below, consists of modules that comprise the whole system, which will be divided among the members to ensure the successful development of the system.

Table 15

LIST OF MODULES

Programmer	List of Modules	User	System
Payo, Rigil Kent	**Account Registration**		
	Registration	*	
No. of point (1 point per module per user)		1	
Sepra, Kent Jerard	**Validation of Account**		
	Login	*	*
	Forget Password	*	*
No. of point (1 point per module per user)		2	2
Payo, Rigil Kent	**Device Registration**		
	Pair Device	*	
No. of point (1 point per module per user)		1	
Sepra, Kent Jerard	**Profile Management**		
	Edit Profile	*	
	Edit Password	*	
	User Support Center	*	*
No. of point (1 point per module per user)		3	1
Payo, Rigil Kent	**Solar Panel Management**		
	Battery Level Monitoring	*	*
	Energy Tracking	*	*
	Device Data Logging		*
	Calibration Management	*	*
No. of point (1 point per module per user)		3	4

Payo, Rigil Kent	**Device Settings**		
	Rename Device	*	
	Notification Preferences	*	
	Contact Support	*	
	Disconnect Device	*	*
No. of point (1 point per module per user)		4	1
Payo, Rigil Kent	**Ticket Management**		
	Submit Support Ticket	*	
	Submit Device Ticket	*	
No. of point (1 point per module per user)		2	
Payo, Rigil Kent	**Manage User**		
	View User Accounts		*
	Receive Tickets		*
	Ticket Status		*
	Report Ticket		*
No. of point (1 point per module per user)			4
Payo, Rigil Kent	**Reports Generation**		
	Export to PDF		*
No. of point (1 point per module per user)			1
Payo, Rigil Kent	**Notification**		
	Receive Notification	*	
No. of point (1 point per module per user)		1	

Testing Plan. The table below shows that the Testing Phase of the SolMate is critical for assessing hardware functionality, IoT communication, and overall system robustness. This inspects the clarity and performance of the sun-tracking mechanism, the mobile monitoring application, and the energy optimization features to ensure optimal system performance and dependability.

Unit Testing. In the implementation of SolMate: A Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization, unit testing was conducted to ensure the functionality, accuracy, and reliability of each individual component within the system. This testing phase focuses on verifying the correctness of core modules such as user authentication, device pairing, energy monitoring, calibration control, and data synchronization with the Firebase Realtime Database. Using the Jest testing framework, each function was independently tested to confirm that it performs as intended under various scenarios. The unit testing framework involved documenting module names, test case IDs, descriptions, expected results, actual results, and remarks. This systematic approach allowed early detection of logical errors and ensured that every unit of the SolMate system operates as designed before proceeding to integration and system-level testing.

Table 16

UNIT TESTING TABLE

Module Name	**Unit Name**	**Date Tested**	**Test Case ID**	**Test Case Description**	**Expected Results**	**Actual Results**	**Remark**
Account Registration	Signup	10/11/25	TC-001	Valid entries	Registration Successful	Performed as expected	Passed
Account Registration	Signup	10/11/25	TC-002	Invalid entries	Account will not be registered	Performed as expected	Passed
Account Validation	Login Account	10/11/25	TC-003	Valid entries	The user logged in successfully	Performed as expected	Passed
Account Validation	Login Account	10/11/25	TC-004	Invalid entries	User login failed	Performed as expected	Passed
Password Recovery	Forgot Password	10/11/25	TC-005	Submit valid email	Reset link sent	Performed as expected	Passed
Password Recovery	Forgot Password	10/11/25	TC-006	Unregistered email	Reset link sent failed	Performed as expected	Passed
Device Pairing	Pair Device	10/11/25	TC-007	Device Credentials	Device paired to user	Performed as expected	Passed
Device Pairing	Pair Device	10/11/25	TC-008	Invalid device credentials	Pairing blocked with error	Performed as expected	Passed
Profile Management	Edit Profile	10/11/25	TC-009	Change current profile details	Update profile details	Performed as expected	Passed

Profile Management	Edit Profile	10/11/25	TC-010	Change current password	Password updated	Performed as expected	Passed
Profile Management	Logout	10/11/25	TC-011	User logs out	Session cleared, back to login	Performed as expected	Passed
Support Center	User Ticket	10/11/25	TC-012	Submit account ticket	Ticket recorded	Performed as expected	Passed
Device Monitoring	Energy Tracking	10/11/25	TC-013	Show live energy tracking	Live values displayed	Performed as expected	Passed
Device Monitoring	Battery Level Monitoring	10/11/25	TC-014	Show battery	Live values displayed	Performed as expected	Passed
Device Monitoring	Device Data Logging	10/11/25	TC-015	Show graphs	Graphs displaying	Performed as expected	Passed
Calibration	Adjust Duration	10/11/25	TC-016	Increase/decrease duration	New duration reflected	Performed as expected	Passed
Calibration	Set Interval	10/11/25	TC-017	Save interval schedule	Interval saved and applied	Performed as expected	Passed
Calibration	Calibration Management	10/11/25	TC-018	Trigger one-tap calibration	Motors run then auto-stop	Performed as expected	Passed
Settings	Rename Device	10/11/25	TC-019	Change device name	Name updated across UI	Performed as expected	Passed
Settings	Notifications	10/11/25	TC-020	Toggle notifications	Preference saved	Performed as expected	Passed

Settings	Device Ticket	10/11/25	TC-021	Submit device ticket	Ticket recorded with device context	Performed as expected	Passed
Settings	Disconnect Device	10/11/25	TC-022	Disconnect device	Device removed from account	Performed as expected	Passed
User Management	Monitor User	10/11/25	TC-023	Monitor User Details	Admin can monitor User Accounts	Performed as expected	Passed
Ticket Management	Receive Ticket	10/11/25	TC-024	Monitor Tickets	Admin receive ticket	Performed as expected	Passed
Ticket Management	Ticket Status	10/11/25	TC-25	Status Ticket Management	Admin set ticket status	Performed as expected	Passed
Ticket Management	Reply Ticket	10/11/25	TC-026	Reply Management	Admin replies a ticket	Performed as expected	Passed
Reports Generation	View User Reports	10/11/25	TC-027	View history/previous activity	View all history	Performed as expected	Passed
Notification	Battery Alerts	11/2/25	TC-028	Display notification when battery ≤ 20%	Alert message appears	Performed as expected	Passed
Notification	Critical Battery	11/2/25	TC-029	Display “Battery Critical” if ≤ 10%	Critical alert appears with timestamp	Performed as expected	Passed
Notification	Calibration Updates	11/2/25	TC-030	Display start and finish messages	Notification shown with duration	Performed as expected	Passed
Notification	Wi-Fi Status	11/2/25	TC-031	Show connectivity status	Status updates display correctly	Performed as expected	Passed

Integration Testing. In the development of SolMate: A Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization, integration testing was conducted to evaluate the interaction and data flow between interconnected modules of the system. This testing phase ensured that the individual components—such as user authentication, dashboard interface, device pairing, calibration control, energy monitoring, and reporting—functioned seamlessly when combined. Using the Jest testing framework, integration tests simulated real-world processes across multiple modules with mocked Firebase Realtime Database interactions to verify logical consistency and data synchronization. Each test case focused on assessing whether dependent components communicated correctly and produced the expected results. This process validated the cohesion of the SolMate system's architecture and confirmed that all integrated features work harmoniously as a unified whole.

Table 17

INTEGRATION TESTING TABLE

Test Case ID	**Module 1**	**Integration Process**	**Module 2**	**Precondition**	**Expected Result**	**Result**	**Remarks**
TC-001	Account Registration	Complete signup for User	Login	Valid registration data	Newly created account can log in successfully.	Performed as expected	Passed
TC-002	Account Validation	Submit valid credentials.	Dashboard	Account is verified and active	Dashboard renders with user context after login	Performed as expected	Passed
TC-003	Password Recovery	Request reset link, set new password, then log in with the new password	Account Validation	Registered email exists; valid reset token not expired	Old password is rejected; new password accepted; login succeeds	Performed as expected	Passed

TC-004	Dashboard	Tap Add Device to open Pair Device screen with user context	Device Pairing	User is logged in	Pair Device screen loads with user ID preloaded	Performed as expected	Passed
TC-005	Device Pairing	Enter device number/password to bind	Security & Access	Device online; credentials valid	User–device binding is allowed and saved	Performed as expected	Passed
TC-006	Device Pairing	After pair/unpair, refresh device list and status on dashboard	Dashboard	Successful pair or unpair operation has been performed	Paired device appears or disappears and status reflects correctly	Performed as expected	Passed
TC-007	Profile Management	Update profile details	User Management	Authenticated user; valid fields	Profile changes are saved and reflected across the app	Performed as expected	Passed
TC-008	Profile Management	Change password credentials	Account Management	Current password verified	Credentials updated	Performed as expected	Passed
TC-009	Support Center	Submit support ticket	Tickets	Form inputs valid	Ticket is created with reference number; confirmation/acknowledgement issued	Performed as expected	Passed

TC-010	Device Monitoring	Fetch live telemetry and compute/display energy	Energy Tracking	Device is online and publishing power telemetry	Energy view shows current data consistent with telemetry	Performed as expected	Passed
TC-011	Device Monitoring	Computing Battery Energy	Battery Level Monitoring	Device is online and publishing Battery Output	Battery Level Shows	Performed as expected	Passed
TC-012	Device Monitoring	Fetch power graphs	Device Data Logging	Device is online and publishing power graphs	Energy view shows current data consistent with power graphs	Performed as expected	Passed
TC-013	Calibration	Save new calibration duration; apply on next/active calibration	Duration Adjusted	Authenticated owner	Duration is saved; Calibrate Now uses the updated value	Performed as expected	Passed
TC-014	Calibration	Save interval schedule	Interval Adjustment	Interval configured	Next calibration occurs on the configured interval	Performed as expected	Passed
TC-015	Settings	Rename device from settings	Account Management	Authenticated user; valid settings	Settings persist and reflect across the account	Performed as expected	Passed

TC-016	Settings	Disconnect device from settings	Device Management	Settings persist and reflect across the account	Disconnect removes device from account	Performed as expected	Passed
TC-017	Device Ticket	Submit device-scoped ticket with auto-attached device context	Tickets Creation	Logged-in user	Ticket created with device metadata; confirmation provided	Performed as expected	Passed
TC-018	User Management	Manage or view user accounts and privileges	Account Management	Admin account is logged in	Admin oversees User account	Performed as expected	Passed
TC-019	Receive Tickets	Admin views user-submitted tickets	Ticket Records	User has submitted a ticket	Admin receives tickets	Performed as expected	Passed
TC-20	Ticket Status	Admin set ticket status	Ticket Records	A ticket exists	Admin set ticket status	Performed as expected	Passed
TC-21	Reply Tickets	Admin replies tickets	Admin Dashboard	Ticket thread exists	Admin replies tickets	Performed as expected	Passed
TC-022	Reports Generation	Generate performance or activity reports	Dashboard / Database	System stores user activity	Admin generates user reports	Performed as expected	Passed

TC-023	Notification	User receive battery alerts	Device Monitoring	Device is online and publishing data	Battery and calibration alerts appears	Performed as expected	Passed
TC-024	Notification	Calibration confirmation displays notification	Calibration	Calibration is triggered manually or on interval	Start and finish messages appear with “number seconds” duration	Performed as expected	Passed
TC-025	Notification	Change of connectivity alerts the user	System / IoT	Wi-Fi connection changes state	“Device offline/online” notifications appear	Performed as expected	Passed
TC-026	Notification	Notification display and realtime storing and deletion of data in database	Dashboard	User logged in and viewing Notification tab	Notifications grouped by date, deletions and clear-all actions update Firebase in real time	Performed as expected	Passed

Alpha Testing. Individuals, alpha testing is conducted to evaluate the SolMate system's functionality and user experience, focusing on the mobile monitoring application (GUI) and system performance. Criteria such as consistency, simplicity, readability, clarity, and user-friendliness are assessed for the mobile interface that displays real-time data. At the same time, system performance is evaluated based on conformance to requirements, efficiency, and security. Each criterion is rated from "Poor" to "Very Good," providing a comprehensive evaluation of usability and reliability. This structured alpha testing helps identify issues and bottlenecks early, ensuring the system meets technical standards and the objective of enhancing solar energy efficiency before beta testing or release.

Table 18

ALPHA TESTING

Test Criteria	**Poor**	**Fair**	**Good**	**Very Good**
GRAPHICAL USER INTERFACE (GUI)				
Clarity (Ease with which users can understand the real-time data labels, graphs, and monitoring status)				
Readability (Ease with which text and numerical values like, font size, color contrast, and layout, can be visually processed by the user)				
Simplicity and Consistency (The Uniformity of design, navigation, and placement of controls, buttons and data fields across all screens)				
User-Friendly (Overall intuitive nature and ease of use of the mobile monitoring and control features)				
Forgiveness and Tolerance (The System's ability to handle user errors or unexpected inputs without crashing or irreversible data loss.)				
SYSTEM PERFORMANCE				

Conformance to Requirements (The system has met their technical specifications, like sun-tracking and hybrid charging)				
Conformance to the Objectives (The system objectives are fully achieved)				
Energy Efficiency (The effectiveness of the system in optimizing power output compared to a stationary panel under the same conditions without delay)				
Security (The system contains data integrity, reliability and accuracy of data transmission and storage)				
Responsiveness (The system succeed in reaction to changes like panel angle adjustment and mobile data refresh rate)				
Overall Impression (In general, the system is functional and practical)				

Acceptance Testing. During the user acceptance testing of SolMate: Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization, the system is critically evaluated to ensure it meets all predefined functional and performance requirements and is ready for real-world deployment. The key criteria for this assessment include Functionality, Performance/Reliability, and Mobile Monitoring Usability. This phase goes beyond basic checks to evaluate the system's performance under actual operating conditions, specifically verifying the proper function of the sun-tracking system, hybrid power management, and the mobile monitoring interface. Each attribute is rated on a scale from Poor to Excellent, with space for detailed comments, ensuring a thorough and objective evaluation of the system's operational readiness. This thorough assessment ensures that SolMate provides an effective, reliable, and user-friendly solution for optimizing solar energy efficiency.

Table 19

ACCEPTANCE TESTING

	Please check only one box per attribute.					
Attributes being evaluated	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**	**Comment**
Functionality: Does the system meet all key functionality requirements prescribed by the study objectives?						
Performance/Reliability: Is the system a stable and reliable source of consistent power?						
Mobile Monitoring/Usability: Is the mobile monitoring feature user-friendly and effective for managing and viewing system data?						
Overall: Based on all tests, is the system ready for full deployment and real world use?						

Implementation/Deployment Phase

User-Guide

Register

Step 1: Click the “Create account” button to get started.

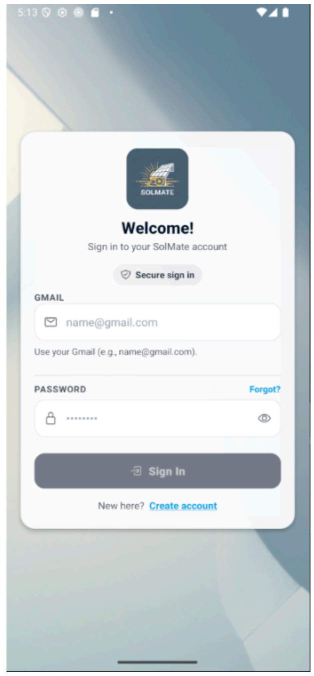

Figure 51: **Login Page**

Step 2: Fill out the necessary details, after click the “Register” button.

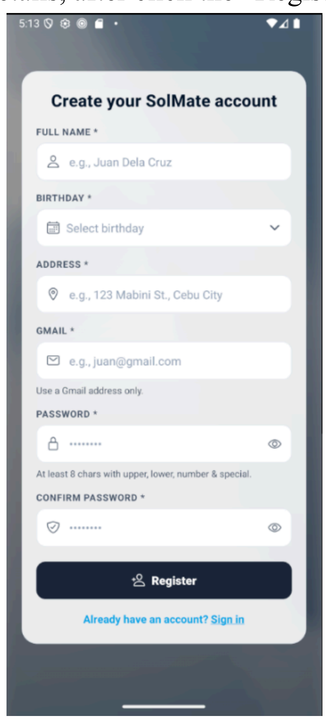

Figure 52: **Registration Page**

Forget Password

Step 3: If you Forgot your Password, On the Login Page, tap “Forgot?”. Enter your registered email address. Tap “Send Link”.

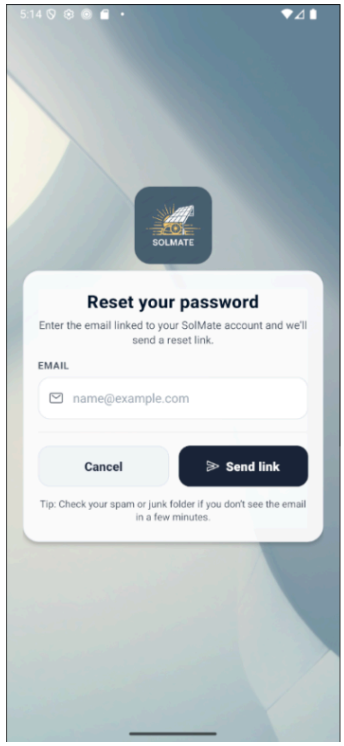

Figure 53: **Forgot Password Page**

Step 4: Check your email inbox for the password reset link.

Step 5: Open the link and set a new password.

Step 6: Return to the app and log in using your new credentials.

Dashboard

Step 7: You will be directed to the Dashboard. Here you will see if you have connected your Solar Panel to the Mobile Application. To connect one or more devices, click the "Add device" button.

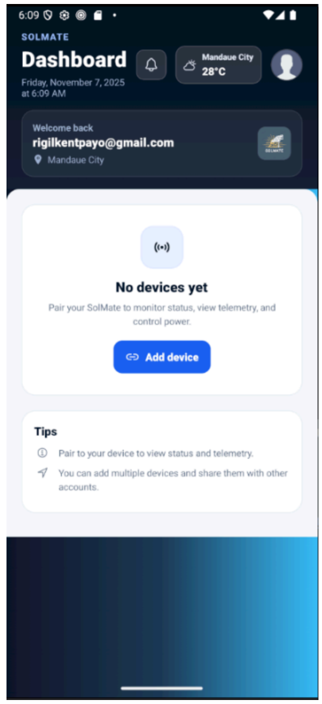

Figure 54: **User Dashboard Page**

Pair Device

Step 8: To pair a device, fulfill the necessary details, once the device is online, you can start pairing by clicking the "Pair Device" button. To provision the device offline, click the "Send Wi-Fi to Device" button.

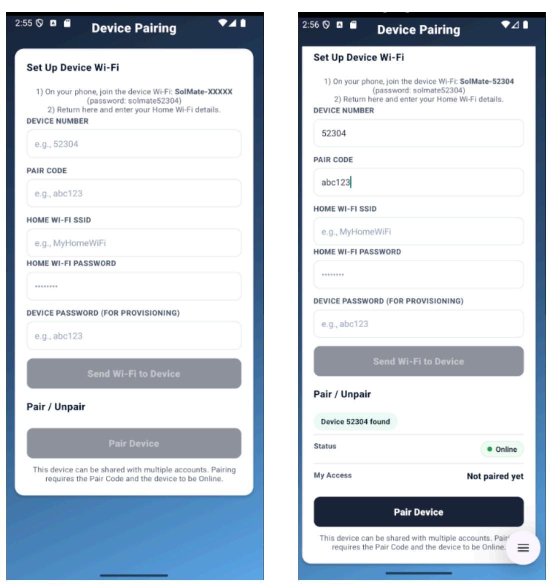

Figure 55: **Pair Device Page**

Notification

Step 9: To view your notification, click the “Notification” icon.

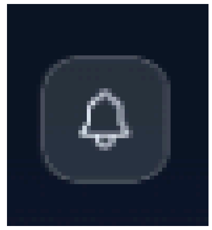

Figure 56: **Notification Button**

Step 10: In the Notification Page, the device info will be shown with exact dates. To clear the Notifications, tap the “Clear all” button.

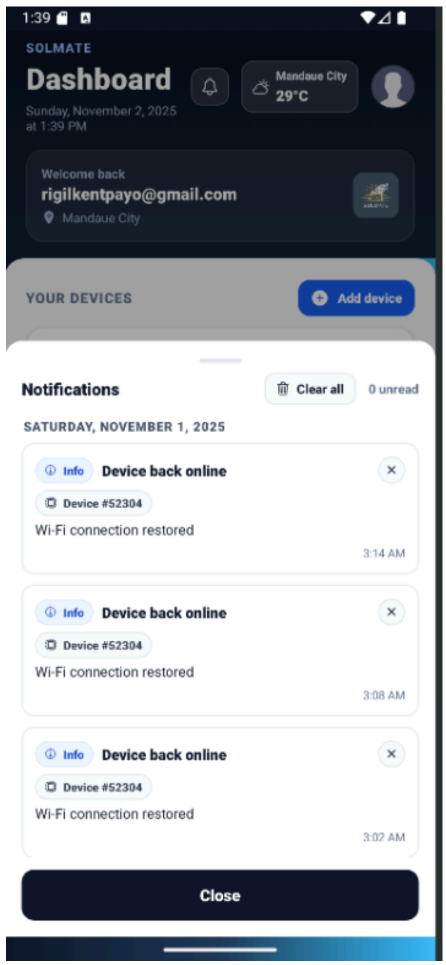

Figure 57:**Notification Page**

Edit Profile/Device

Step 11: To edit your profile and pair your device, click the "Profile" icon.

Figure 58: **Profile Button**

Step 12: To edit your profile details, click "Edit Information". To edit the security of your device, click the "Change Password" button.

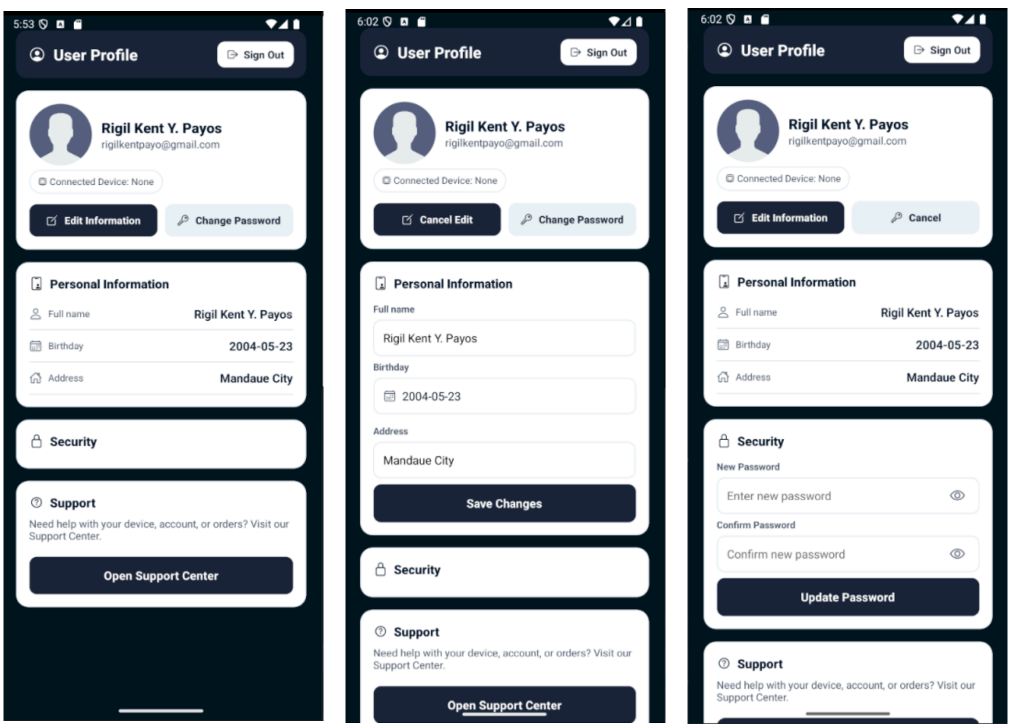

Figure 59: **Edit Profile/Device Page**

Step 13: If you have queries regarding your profile, you can submit a ticket, by clicking the "Open Support Center" button in the Edit Profile/Device page. Fill up the need necessary details, then click "Submit Ticket"

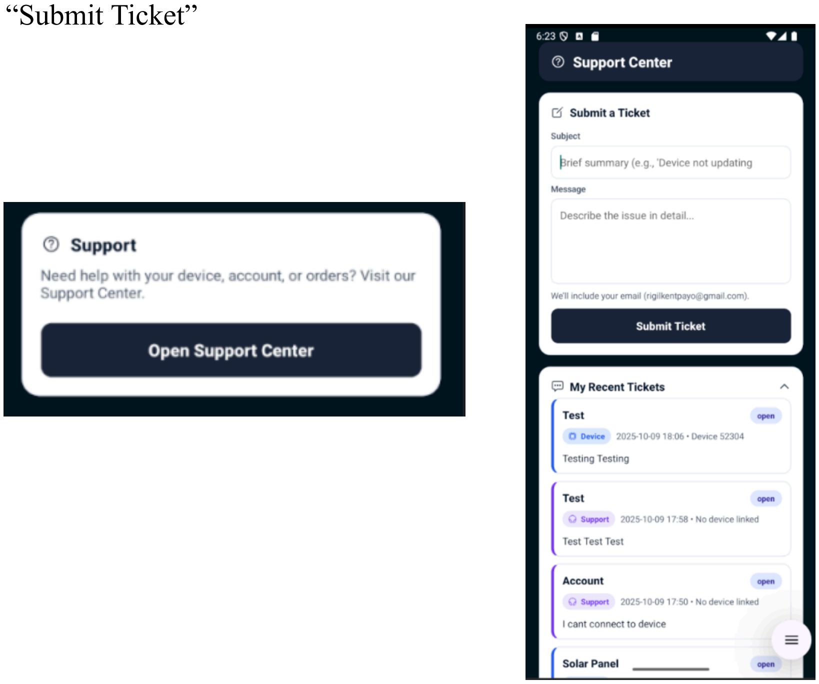

Figure 60: **<u>User Support Center Page</u>**

Device Page

Step 14: Once you have paired a device, you can fully monitor your panel in the "Device" page by turning the "On" button.

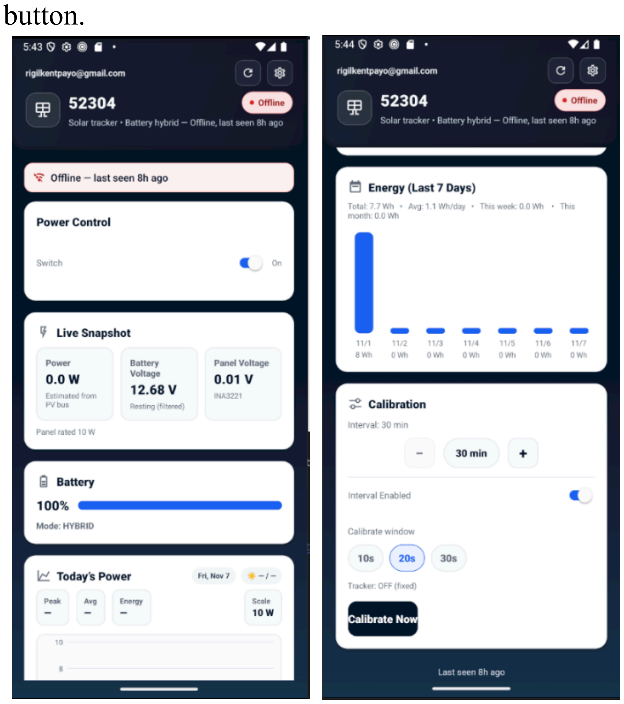

Figure 61: **<u>Device Page</u>**

Calibration

Step 15: To calibrate the Solar Panel to the desired duration, Click the "+" or "-" button. Click the "Interval window" button , to enable the calibration. If you want to calibrate the device at that exact time, select the desired time, then click "Calibrate Now" to start calibrating.

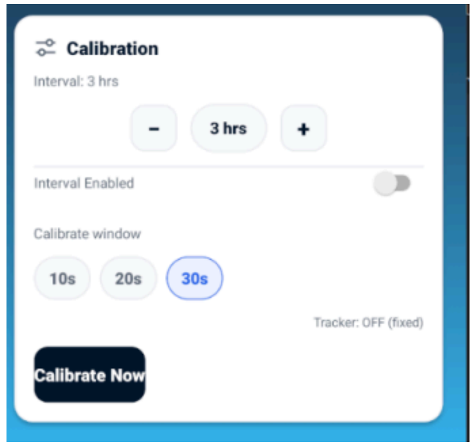

Figure 62: **Calibration Menu**

Settings

Step 16: To view the device setting, click the "Settings" button, near the "Refresh" button. In the Settings page, you can rename the device name, toggle the notifications, contact support regarding the device, and disconnect from your device.

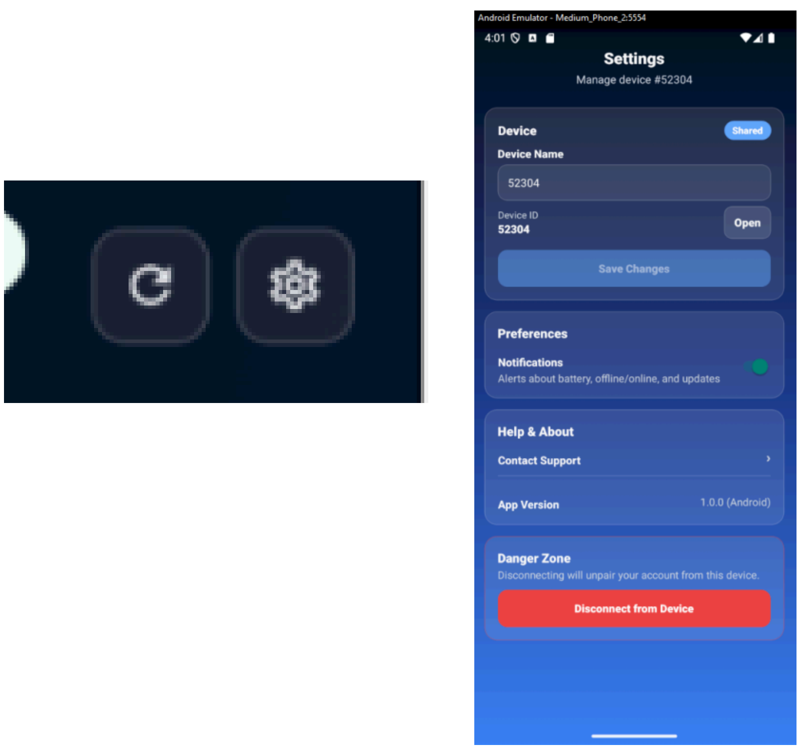

Figure 63: **Settings Page**

Device Support Center

Step 17: To submit a ticket regarding the device, click the “Contact Support” in the Settings page. Fill in the necessary details, Click “Send to Support” button to send. You can view your tickets in the “My Tickets” below.

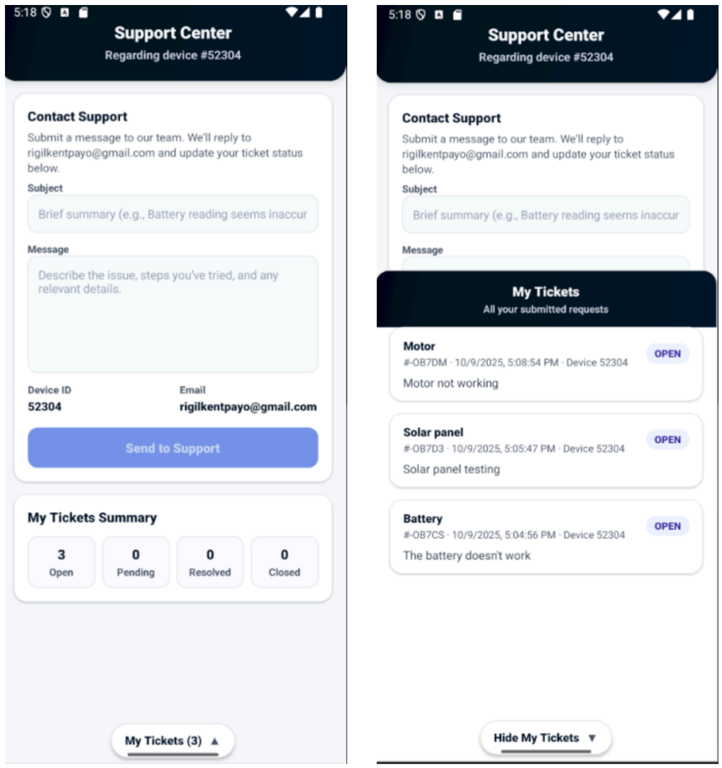

Figure 64: **Device Support Center Page**

Installation Guide

1. In order to successfully use the application, make sure your device meets these requirements:
    a. An Android phone.
    b. It has a stable internet connection for sign-in and syncing.
    c. Access to your device’s serial/device number.
2. Download the APK from the official link.
3. Open the downloaded SolMate.apk and tap Install.
4. Open SolMate.
5. You will be directed to the login page, choose to sign in or create an account.
6. Use your solar panel's serial number to register to the mobile application.
7. You’ll be redirected to the dashboard, where you can begin monitoring.

CHAPTER IV
PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

In this chapter, the researchers examine the findings of the study in-depth, giving a comprehensive review of the data collected and the reasoning behind it. The data is presented in tabular form for ease of interpretation, followed by straightforward discussion underscoring its importance and implications.

Profile of the respondents

The demographic profile of the respondents includes details for both users and non-users of solar panels. It captures their gender, age group, employment status, monthly household income, solar panel usage, duration of usage, purpose of usage, and maintenance practices for solar panel owners.

Gender of the Respondents

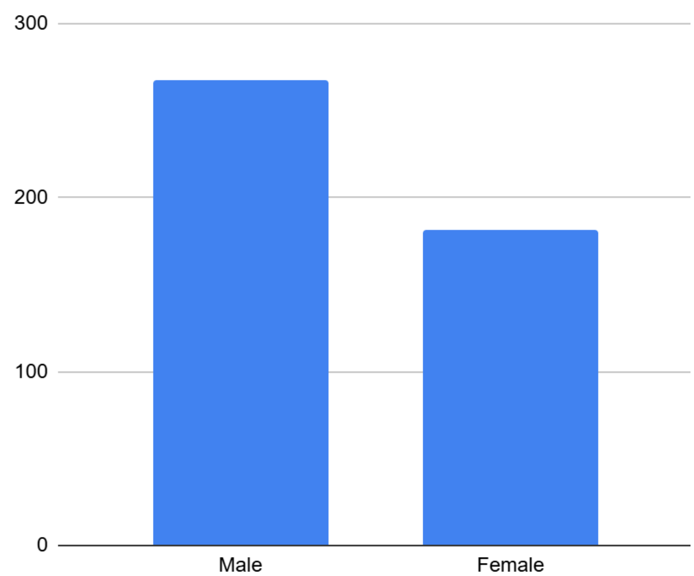

Figure 65: **<u>Respondents' Gender</u>**

The survey data in Figure 37 presents the gender distribution of 450 respondents. Among them, 40.2% are female while 59.8% are male, indicating a higher proportion of male participants in the survey. Research suggests that men and women play different but complementary roles in energy adoption, particularly in technology-based systems such as renewable energy (Aboitiz Power, 2024; Al-Saadi et al., 2022).

Age Group

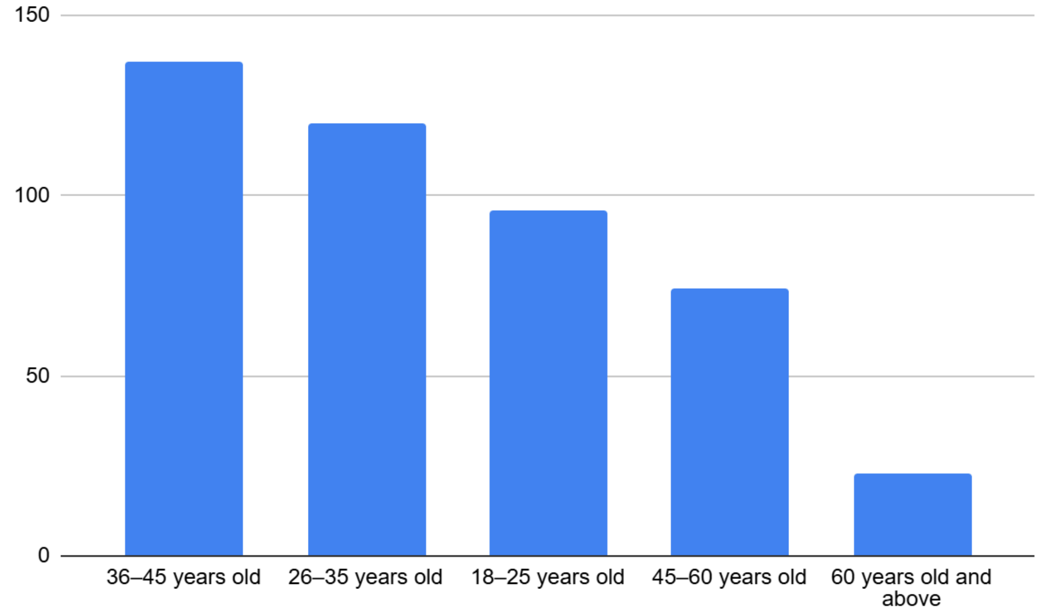

Figure 66: **Distribution of Respondents by Age Group**

The chart shows that the 36–45 years old group represents the largest portion of the population at 30.4%, followed by the 26–35 years old group at 26.7%, and the 18–25 years old group at 21.3%. The percentage then declines to 16.4% among those aged 46–60 years old, and is lowest among respondents aged 60 years old and above, who account for only 5.2% of the total. This age distribution suggests that a significant share of the respondents belong to the productive working-age population, which may influence their openness to investing in renewable energy solutions. In line with related studies, younger respondents are generally more receptive to adopting modern technologies such as IoT-enabled renewable systems, while older groups tend to be more conservative in their usage and adoption patterns (Ali & Salih, 2023; Gupta et al., 2022).

Current Employment Status

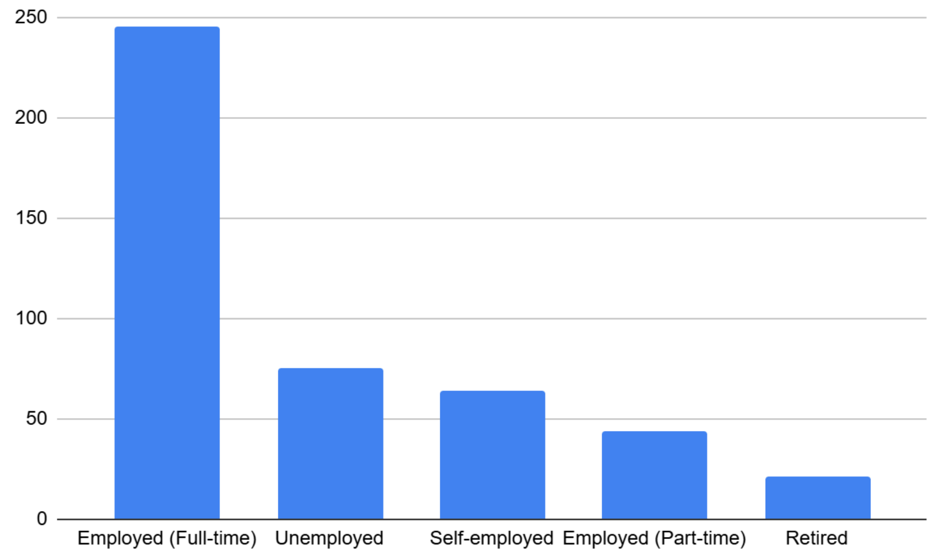

Figure 67: **Employment Status of Solar panel user or non-user**

The survey data in Figure 49 illustrates the employment status of respondents. A majority, 54.7%, are employed full-time, followed by 14.2% who are self-employed. Meanwhile, 16.7% reported being unemployed, 9.8% are working part-time, and a smaller portion, 4.7%, are retired—though this last category was only visible when hovering over the chart. Employment status is a key factor influencing the capacity to invest in solar technology, as stable income sources provide households with the financial means to adopt renewable energy systems (Junnel, 2024; Adeyinka et al., 2024). Overall, the results indicate that most respondents are actively engaged in the workforce, either through full-time employment or self-employment, which supports their potential readiness to consider renewable energy solutions.

Monthly Household Income

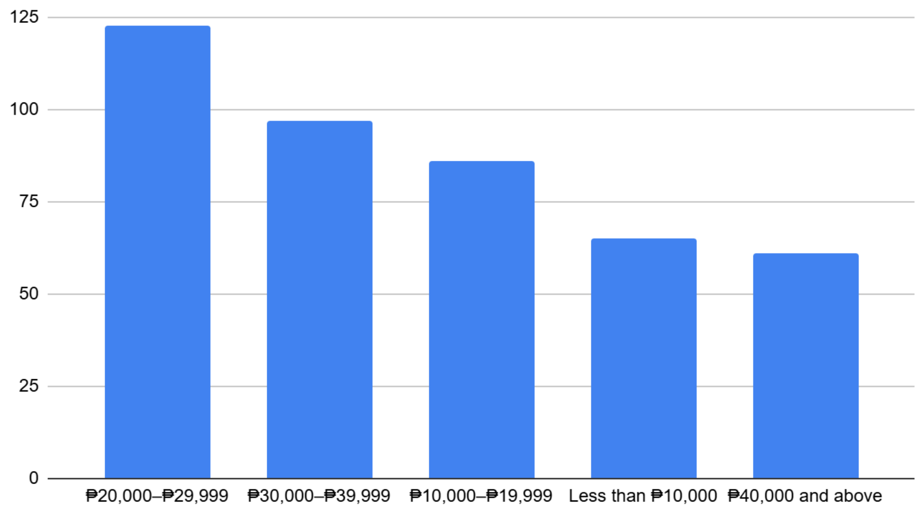

Figure 68: **Monthly Household Income Levels of Respondents**

The survey results revealed that respondents came from diverse income levels. The largest portion, 28.5%, reported earning between ₱20,000 and ₱29,999 monthly, followed by 22.5% within the ₱30,000–₱39,999 range. Meanwhile, 19.9% earned ₱10,000–₱19,999, and 15% reported earning less than ₱10,000. Only 14.1% of the respondents had a monthly household income of ₱40,000 and above. These findings indicate that the majority of respondents belong to low to moderate income groups. Consistent with previous studies, household income significantly influences the feasibility of adopting solar energy systems, as affordability remains one of the most critical barriers to renewable energy use in the Philippines (Aboitiz Power, 2024; Junnel, 2024).

Solar Panel Usage

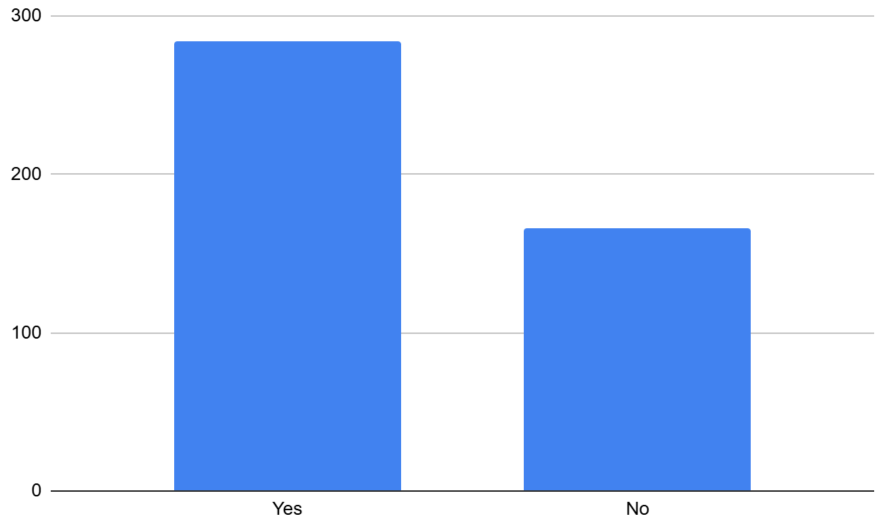

Figure 69: **<u>Respondents' Current Use of Solar Panels</u>**

When asked if they currently use solar panels in their home or business, 63.1% of the respondents answered "Yes," while 36.9% answered "No." This indicates that a majority already utilize solar panels, reflecting the growing adoption of renewable energy in the community. However, the significant portion of non-users highlights a strong potential market for affordable and efficient solar solutions such as *SolMate*, particularly for those interested but not yet able to install their own systems. Among those who own solar panels, the duration of usage ranged from less than a year to several years. Longer usage was often associated with greater satisfaction and familiarity with the system's benefits, consistent with previous findings on renewable adoption (Ali & Salih, 2023; Luis et al., 2023).

Duration of Solar Panel Usage (for owners only)

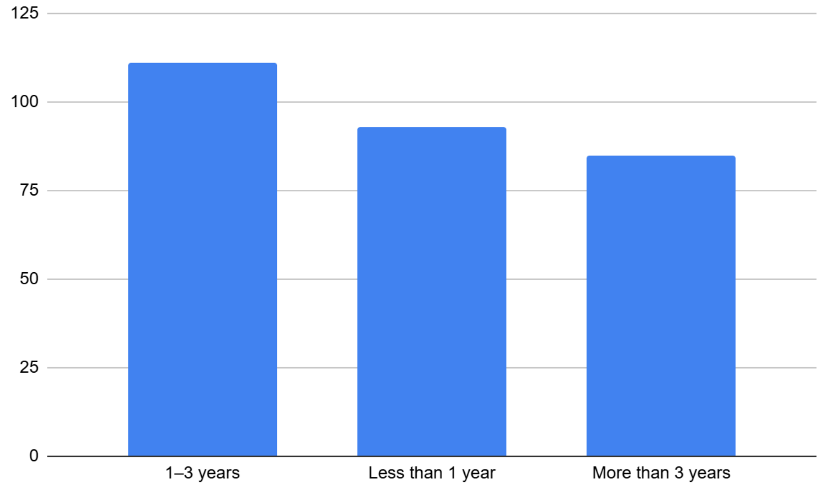

Figure 70: **Respondents' Usage of Solar Panel**

Among current users, the majority (38.4%) reported using solar panels for 1–3 years, while 32.2% had used them for less than 1 year, and 29.4% for more than 3 years. This indicates that solar adoption in the area is relatively recent and reflects a growing awareness of renewable energy solutions. The data also showed variation in the extent of solar panel usage, with some households relying on solar panels as their primary energy source, while others used them as supplementary support. This trend highlights the increasing adoption of smart renewable technologies across different household contexts (Al-Saadi et al., 2022; Gupta et al., 2022).

Purpose of Usage

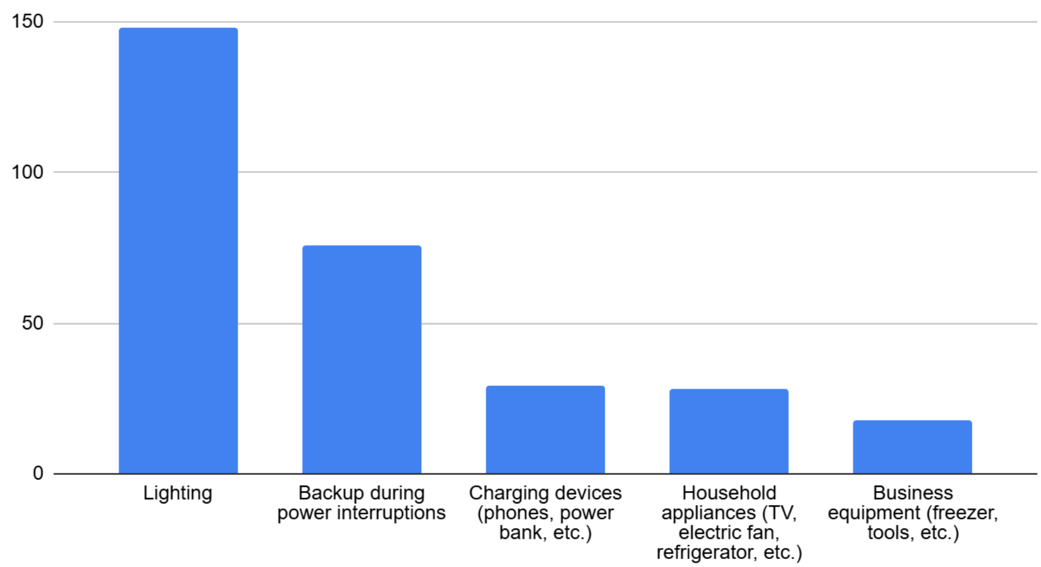

Figure 71: **Reported Uses of Solar Panels**

The survey revealed that solar panels are most commonly used for lighting, with 49.5% of respondents identifying this as their primary purpose. This was followed by 25.4% who use them as backup during power interruptions, highlighting the community's need for reliable alternatives during brownouts. Smaller portions of respondents reported using solar panels for charging devices (9.7%), household appliances such as televisions and refrigerators (9.4%), and business equipment like freezers and tools (6%). These results indicate that while solar energy is primarily viewed as a practical and cost-saving solution for essential needs, it also plays a critical role in addressing power interruptions and supporting both household and business operations. Overall, respondents primarily rely on solar panels for lighting, powering appliances, and serving as backup energy during outages. This finding supports earlier studies that emphasize the role of solar systems in meeting essential electricity demands and providing alternative power sources during shortages (Samedova, 2025; Adeyinka et al., 2024).

Maintenance Practices

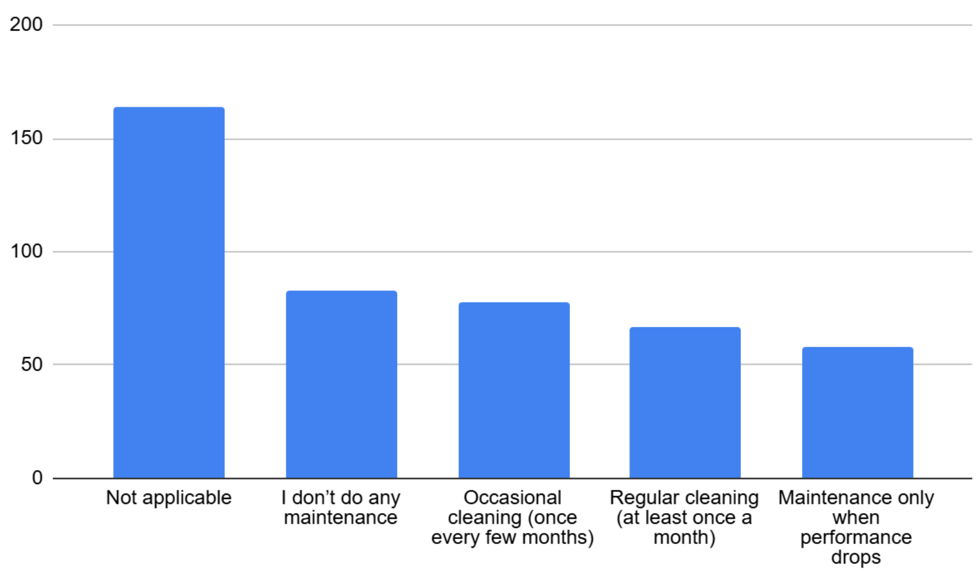

Figure 72: **<u>Solar Panel Maintenance Practices</u>**

Survey results show that 36.4% of respondents marked maintenance as not applicable, reflecting non-users of solar panels. Among those who do maintain their panels, 17.3% perform occasional cleaning once every few months, while 14.9% carry out regular cleaning at least once a month. Additionally, 12.9% indicated that they only conduct maintenance when performance declines, and 18.4% admitted they do not perform any maintenance at all. These findings highlight that while some households consistently care for their panels, many either neglect upkeep or act only reactively, which can reduce system efficiency and lifespan. This underscores the value of smart monitoring systems like SolMate, which encourage proper and timely maintenance. Respondents also reported conducting routine practices such as panel cleaning and wiring checks, which aligns with studies emphasizing the importance of monitoring systems in extending solar panel lifespan and ensuring efficiency (Luis et al., 2023; Gupta et al., 2022).

Solar Energy Usage Practices and Challenges

This study utilized a Likert scale to perform a comparative analysis. The survey was designed to first capture respondents' perceptions of existing solar panel systems and their processes. This data will be used to identify key areas of dissatisfaction and need, which our proposed system aims to address.

Table 20

SOLAR ENERGY USAGE PRACTICES AND CHALLENGES

Solar Energy Usage Practices and Challenges	Mean	Qualitative Description
1. Traditional solar panel systems are difficult to maintain without technical knowledge.	4.49	Strongly Agree
2. The performance of conventional solar panels is greatly affected by weather conditions like rain, dust, or cloud cover.	4.56	Strongly Agree
3. I am concerned about the long-term durability and lifespan of solar energy system.	4.50	Strongly Agree
4. Power output from traditional solar panels is often inconsistent throughout the day	4.35	Strongly Agree
5. Conventional solar systems may not be reliable for continuous power supply without backup sources.	4.42	Strongly Agree
6. Hybrid systems that combine solar with other power sources offer more reliable energy than solar alone.	4.51	Strongly Agree
7. Many traditional solar panel systems do not include features like sun-tracking.	4.47	Strongly Agree
8. There is no need for backup power sources when using a traditional solar panel system.	1.64	Strongly Disagree
9. Sun-tracking technology is completely useless and makes no difference in solar energy production.	1.63	Strongly Disagree

10. To what extend do you agree or disagree with the statement: It is easy for most people to repair or adjust solar panel systems without any knowledge.	1.61	Strongly Disagree
11. The addition of IoT or mobile monitoring features only complicates the use of solar panels.	1.66	Strongly Disagree
12. Manual adjustments to solar panels are just as effective as automated sun-tracking systems	1.74	Strongly Disagree
13. Mobile monitoring apps for solar energy systems are purely decorative and serve no functional purpose at all.	1.55	Strongly Disagree
14. Solar panel systems do not require any cleaning or maintenance after installation.	1.51	Strongly Disagree
GRAND MEAN	3.04	Neutral

Survey results revealed that the majority of respondents recognized that weather conditions significantly affect solar panel performance, with a mean score of 4.56 (Strongly Agree), while challenges such as durability concerns (4.50) and traditional solar panels is often inconsistent throughout the day (4.35) were also emphasized. This supports earlier findings that fixed solar panels lose 25–40% of energy efficiency due to shading, dust accumulation, and the sun's shifting position throughout the day (Ponce-Jara et al., 2022; Ali & Al-Juboury, 2023). Similarly, respondents strongly agreed that the absence of sun-tracking mechanisms reduces efficiency (4.47), aligning with studies showing that dual-axis tracking improves energy capture by up to 40% (Muthukumar et al., 2023). On the other hand, misconceptions such as "no maintenance required" (1.51) and "mobile monitoring complicates usage" (1.66) received the lowest ratings, underscoring the need for user education and practical IoT integration. These findings reinforce existing literature that poor maintenance, weather dependency, and lack of smart tracking remain major obstacles to efficient solar energy utilization, and they highlight the importance of hybrid systems and real-time monitoring in addressing these challenges (Samedova, 2025; Gupta et al., 2022).

Solar System Development Techniques

Using the same scale, the respondents' evaluation of the proposed system's development techniques shows whether they Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree with the effectiveness of integrating sun-tracking mechanisms, hybrid power management, and real-time monitoring.

Table 21

SOLAR SYSTEM DEVELOPMENT TECHNIQUES

Solar System Development Techniques	Mean	Qualitative Description
1. I believe that solar panels should adjust their position to follow the sun throughout the day to store more sun energy.	4.66	Strongly Agree
2. Monitoring solar energy performance as it happens allows for smarter decision-making than waiting for monthly reports.	4.62	Strongly Agree
3. A solar system should be able to automatically switch to backup power when sunlight is insufficient (hybrid power).	4.66	Strongly Agree
4. I want to monitor my solar panel's performance (energy generation/consumption) through a mobile phone or app.	4.67	Strongly Agree
5. The weight and size of the solar panels significantly influence the design requirements of the base structure.	4.59	Strongly Agree
6. The environmental impact of the materials and construction methods used for the solar panel base should be taken into account.	4.63	Strongly Agree
7. The system should be able to handle changes in power demand without interrupting the power supply.	4.63	Strongly Agree
8. Delayed or occasional monitoring is more useful than real-time tracking because energy data doesn't need constant updates	2.02	Disagree
9. A well-designed solar power can contribute to a more sustainable energy future.	4.68	Strongly Agree
10. I believe that solar power has no potential for practical use.	1.49	Strongly Disagree
11. Having both solar and battery storage makes a system more reliable.	4.70	Strongly Agree
12. Having both solar and battery storage makes a system less reliable.	1.56	Strongly Disagree

13. Real-time monitoring often leads to confusion and inaccurate results, making it unreliable for managing energy use.	1.57	Strongly Disagree
14. Real-time monitoring provides accurate energy data, helping users detect issues early and manage consumption better.	4.70	Strongly Agree
GRAND MEAN	3.79	Agree

The survey results revealed strong agreement among respondents regarding the importance of advanced techniques in developing solar systems, with sun-tracking mechanisms, hybrid automatic backup, real-time monitoring, and mobile-based applications all receiving mean scores above 4.60 (Strongly Agree). This indicates clear support for integrating intelligent features that maximize efficiency and reliability. These findings align with existing literature emphasizing that sun-tracking systems can boost energy capture by 30–40% compared to static panels (Muthukumar et al., 2023; Shakeel et al., 2023), while hybrid power management ensures stable supply even under cloudy conditions or outages (Giedraityte et al., 2025; Adeyinka et al., 2024). Likewise, IoT-enabled platforms provide users with real-time access to performance data, reducing maintenance costs and improving system reliability (Gupta et al., 2022; Luis et al., 2023). The low rating for delayed monitoring 2.02 (Disagree) further underscores users' preference for real-time tracking and automation, consistent with Fernandez et al. (2022), who highlighted that immediate feedback enhances decision-making in solar management. Overall, the survey validates the necessity of incorporating sun-tracking, hybrid storage, and IoT monitoring as critical development techniques for effective solar energy systems.

Key Features of the Proposed System

Using the same scale, the respondents' assessment of the proposed system's key features reflects whether they Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree with the inclusion of mobile-based monitoring, automated sun-tracking, hybrid storage, and sustainability-focused design.

Table 22

KEY FEATURES OF THE PROPOSED SYSTEM

Key Features of the Proposed System	Mean	Qualitative Description
1. A sun-tracking feature that follows the sun will help the solar panels produce more energy.	4.67	Strongly Agree

2. It's important to include recycling and easy maintenance to make the system last longer and stay eco-friendly.	4.61	Strongly Agree
3. Saving system data online is useful for checking past performance.	4.63	Strongly Agree
4. Automatically adjusting the panels to follow the sun is better than doing it manually.	4.64	Strongly Agree
5. A back-up battery that works even when there's no sunlight can make the system more reliable.	4.63	Strongly Agree
6. The system's energy storage capacity should be sufficient to provide power during periods of low sunlight.	4.66	Strongly Agree
7. A reliable and efficient solar power system is important for the widespread adoption of renewable energy.	4.68	Strongly Agree
8. The features of a solar power system have no impact on its overall usefulness.	1.62	Strongly Disagree
9. This system uses solar energy, not gasoline, to create electricity.	4.68	Strongly Agree
10. This system relies on gasoline, not solar energy, to generate electricity	1.49	Strongly Disagree
11. A solar panel should be placed where there is a lot of sunlight, not in a dark room.	4.75	Strongly Agree
12. A solar panel should be placed in a dark room, not where there is a lot of sunlight.	1.44	Strongly Disagree
GRAND MEAN	3.32	Neutral

The results showed strong support for the system's core features, with the highest ratings given to reliable and efficient solar adoption mean of 4.68, the use of solar energy instead of gasoline 4.68, and the sun-tracking mechanism 4.67. Other highly rated features included automatic adjustment 4.64, online data storage 4.63, The mean for the backup battery and energy storage feature ranges from 4.63 to 4.66, and eco-friendly maintenance such as recycling 4.61. In contrast, negatively framed items—such as reliance on gasoline 1.49, placement of solar panels in dark rooms 1.44, and the claim that features would have no impact 1.62—were strongly rejected. While these very low scores lowered the grand mean to 3.32 (Neutral), the overall findings confirm that respondents value practical, innovative, and sustainable features while rejecting unrealistic system attributes. These results align with prior studies emphasizing that sun-tracking can increase solar efficiency by up to 40% (Muthukumar et al., 2023; Shakeel et al., 2023), hybrid storage ensures stable power during low sunlight (Adeyinka et al., 2024), and IoT-enabled monitoring improves reliability and user decision-making (Gupta et al., 2022; Luis et al., 2023).

Recommendations

Using the same scale, the respondents' feedback on the system's recommendations indicates whether they Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree with the suggested improvements and priorities for further system development and adoption.

Table 23

RECOMMENDATIONS

Recommendations	**Mean**	**Qualitative Description**
1. SolMate should be used in homes to help save more solar energy.	4.56	Strongly Agree
2. The system should show clear data on energy usage, storage, and savings.	4.71	Strongly Agree
3. SolMate should keep using both solar and backup (hybrid) power to ensure reliable electricity.	4.66	Strongly Agree
4. SolMate should be adapted for use in different places like farms, schools, or remote areas.	4.70	Strongly Agree
5. SolMate should include alerts or notifications when energy generation drops or system issues are detected.	4.71	Strongly Agree
6. SolMate should be affordable and available to low-income households who suffer frequent power outages.	4.74	Strongly Agree
7. I believe SolMate has the potential to improve the way we use solar energy in our community.	4.77	Strongly Agree
GRAND MEAN	4.69	Strongly Agree

Survey results revealed strong support for the proposed SolMate system, with a grand mean of 4.69 Strongly Agree, indicating respondents' agreement that the system should be affordable, user-friendly, and community-focused. Specifically, the highest-rated items emphasized affordability for low-income households mean of 4.74 and its potential to improve solar adoption in communities 4.77. These findings align with Junnel (2024), who noted that high upfront costs hinder solar adoption among Filipino households, making affordability crucial. Respondents also highlighted the importance of clear data visualization and alert notifications 4.71, echoing Gupta et al. (2022) and Luis et al. (2023), who found that real-time monitoring and mobile-based notifications improve user decision-making and system reliability. Furthermore, the preference for hybrid storage and sustainable design aligns with Adeyinka et al. (2024) and Samedova (2025), who emphasized that hybrid renewable systems enhance reliability during low sunlight conditions. Overall, the recommendations support integrating affordability, hybrid backup, and mobile IoT features into SolMate to address cost barriers, efficiency gaps, and monitoring challenges identified in both the survey and prior studies.

CONCLUSION

The SOLMATE: Smart IoT Sun-Tracking Solar Panel System effectively addresses the pressing challenges identified in solar energy adoption among households. Chapter IV presents clear evidence of both the opportunities and the obstacles in this area. While many respondents recognize the benefits of solar power, barriers such as high installation costs, inconsistent maintenance practices, and reduced efficiency during unfavorable weather remain persistent. These issues confirm the gaps in current solar utilization and validate the first objective of identifying existing challenges. Despite these limitations, respondents expressed strong support for system features that enhance usability and reliability, demonstrating a strong demand for solutions like SolMate.

Sun-tracking technology, hybrid backup power, and real-time monitoring emerged as the most valued improvements, directly addressing the second objective of determining critical system enhancements. Moreover, affordability and accessibility for low- to middle-income households were consistently highlighted as priorities, underscoring the importance of developing solutions that are both cost-effective and inclusive.

Overall, the findings confirm that the proposed SolMate system effectively aligns with user expectations and community needs. Through the integration of smart monitoring, hybrid storage, and efficient sun-tracking mechanisms, the system addresses the most pressing barriers identified in the study.

In conclusion, SolMate demonstrates the capacity to overcome existing barriers and promote wider adoption of renewable energy. This chapter concludes that there is strong acceptance and demand for SolMate as a practical, sustainable, and reliable energy solution tailored to Filipino households, particularly those in the low to mid-scale income bracket. Through continued innovation and scalability, SolMate can significantly contribute to sustainable energy practices in local communities.

RECOMMENDATIONS

Based on the results and conclusions, the following recommendations are presented:

1. **Expand testing locations beyond Lapu-Lapu City:** to compare results across different climates.
2. **Design a waterproof and dust-resistant enclosure for electronics:** to extend system durability.
3. **Integrate Predictive Maintenance Feature:** to enable the system to analyze performance data and notify users of potential hardware issues before they occur, ensuring consistent efficiency and reduced downtime.
4. **Voice Assistant Integration**: to incorporate compatibility with voice-controlled platforms (e.g., Google Assistant, Alexa) for hands-free monitoring and control.
5. **Field Testing in Diverse Environments**: to conduct large-scale testing in coastal, mountainous, and rural off-grid areas to assess adaptability and reliability under varying conditions.
6. **Advanced Energy Storage Options**: to expand energy storage by testing next-generation batteries (e.g., lithium-ion phosphate or solid-state) for improved efficiency, lifespan, and safety.
7. **Strengthen internet-independent features (offline data storage or SMS-based reporting):** to ensure reliability in areas with weak connectivity.
8. **Conduct awareness campaigns and training in partnership with LGUs and schools**: to promote renewable energy adoption and familiarize users with smart solar technologies.
9. **Real-time Weather Forecasting**: to allow SolMate to anticipate changes in sunlight intensity, cloud cover, or rainfall, automatically adjusting panel orientation and energy usage to maintain optimal performance.
10. **Encourage continuous research and development by future researchers and institutions:** to improve efficiency, scalability, and sustainability of IoT-enabled solar systems.

TRANSLATIONAL RESEARCH

The results presented in Chapter IV of the study on SolMate: Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization highlight both the current challenges in solar energy usage and the opportunities for innovation. The survey findings revealed that many households continue to face barriers such as high installation costs, inconsistent power output, and maintenance difficulties. These issues limit the efficiency and long-term adoption of traditional solar panel systems, emphasizing the need for more advanced and accessible solutions.

The data further indicated strong user support for integrating sun-tracking mechanisms, hybrid power management, and mobile-based monitoring into solar systems. Respondents strongly agreed that features such as dual-axis sun-tracking, backup storage, and real-time energy monitoring through mobile application would significantly improve system reliability and usability. The findings also confirmed that affordability and sustainability are critical priorities, with many participants highlighting the importance of making such technology available to low-income households that suffer frequent power outages.

In terms of development techniques, the results validated the necessity of intelligent system design. Respondents emphasized the benefits of IoT-enabled monitoring, hybrid storage, and user-friendly interfaces, which align with existing studies showing that these features enhance efficiency, resilience, and long-term system performance. Key system features such as recycling-oriented parts, accurate and real-time logs, and backup capacity were rated highly, reflecting the importance of sustainability and practicality.

The recommendations gathered from the survey further support the scalability and community impact of SolMate. Participants strongly agreed that the system should be affordable, accessible across various settings such as farms, schools, and remote areas, and equipped with alerts for performance issues. These insights confirm the system's potential to empower households and communities while promoting renewable energy adoption.

Through these results, the translational value of SolMate becomes clear: it not only addresses the persistent gaps in solar energy practices but also incorporates user-driven features to ensure wider acceptance and sustainability.

REFERENCES

Aboitiz Power. (2024). *A balanced energy transition approach for Cebu*. https://aboitizpower.com/news/energy-transition/a-balanced-energy-transition-approach-for-cebu

Adekanmi Miracle Adeyinka, Oladapo Christopher Esan, Ahmed Olanrewaju Ijaola, & Peter Kayode Farayibi. (2024). Advancements in hybrid energy storage systems for enhancing renewable energy-to-grid integration. *Sustainable Energy Research, 11*(1). https://doi.org/10.1186/s40807-024-00120-4

Ali, A. J., & Salih Al-Juboury, M. S. (2023). A Practical Study of Using Fixed and Tracker Solar Systems in Mosul City. *2023 International Conference on Engineering, Science and Advanced Technology (ICESAT)*, 133–138. https://doi.org/10.1109/icesat58213.2023.10347305

Al-Saadi, Y. R., Tapou, M. S., Badi, A. A., Abdulla, S., & Diykh, M. (2022). Developing Smart Self Orienting Solar Tracker for Mobile PV Power Generation Systems. IEEE Access, 10, 79090–79099. https://doi.org/10.1109/ACCESS.2022.3194026

Amoussou, I., Paddy, E. Y., Agajie, T. F., Ibrahim, F. S., Agajie, E. F., Nsanyuy, W. B., Bajaj, M., doe& Mohammadi, S. A. D. (2024). Enhancing residential energy access with optimized stand-alone hybrid solar-diesel-battery systems in Buea, Cameroon. Scientific Reports, 14(1). https://doi.org/10.1038/s41598-024-66582-0

Amoussou, I., Paddy, E.Y., Agajie, T.F. et al. (2024). Enhancing residential energy access with optimized stand-alone hybrid solar-diesel-battery systems in Buea, Cameroon. *Sci Rep 14*, 15543. https://doi.org/10.1038/s41598-024-66582-0

Anjum, S., & Mukherjee, V. (2022). Static and Dynamic Reconfiguration Strategies for Reducing Partial Shading Effects in Photovoltaic Array: A Comprehensive Review. *Energy Technology*, 2200098. https://doi.org/10.1002/ente.202200098

Boubakr, G., Gu, F., Farhan, L., & Ball, A. (2022). Enhancing Virtual Real-Time Monitoring of Photovoltaic Power Systems Based on the Internet of Things. Electronics, 11(15), 2469. https://doi.org/10.3390/electronics11152469

Chathuranga, B. G. A., Premachandra, K. W. R. S., Sujeewan, G., Rathwaththa, J. D. R. R., Abejeewa, P. A. I. S., Priyadarshana, H. V. V., & Koswattage, K. R. (2024). *A comparative experimental performance analysis for fixed solar PV systems and solar tracker PV systems in a tropical region*. International Journal of Research and Innovation in Applied Science, 9(9), 476–480. https://doi.org/10.51584/ijrias.2024.909041

Constantin, A.-I., Iosif, G., Chihaia, R.-A., Marin, D., Abu Shehadeh, G. U., Karahan, M., Gerikoglu, B., & Stavrev, S. (2023). Importance of preventive maintenance in solar energy systems and fault detection for solar panels based on thermal images. *Electrotehnica, Electronica, Automatica (EEA), 71*(1), 1–12. https://doi.org/10.46904/eea.23.71.1.1108001

Demir, B. E., (2023). A New Low-Cost Internet of Things-Based Monitoring System Design for Stand-Alone Solar Photovoltaic Plant and Power Estimation. Applied Sciences, 13(24), 13072–13072. https://doi.org/10.3390/app132413072

Department of Energy. (2023). OPENING STATEMENT OF ENERGY SECRETARY RAPHAEL P.M. LOTILLA DURING THE PRESS CONFERENCE ON THE PROLONGED POWER INTERRUPTION THAT AFFECTED PANAY ISLAND https://doe.gov.ph/press-releases/node/9884?ckattempt=1&page=118

El Hammoumi, A., Chtita, S., Motahhir, S., & El Ghzizal, A. (2022). Solar PV energy: From material to use, and the most commonly used techniques to maximize the power output of PV systems: A focus on solar trackers and floating solar panels. *Energy Reports, 8*, 11992–12010. https://doi.org/10.1016/j.egyr.2022.09.054

Emrani, A., Berrada, A., & Bakhouya, M. (2022). Optimal sizing and deployment of gravity energy storage system in hybrid PV-Wind power plant. Renewable Energy, 183, 12–27. https://doi.org/10.1016/j.renene.2021.10.072

Fernandez-Lores, S., Crespo-Tejero, N., & Fernández-Hernández, R. (2022). Driving traffic to the museum: The role of the digital communication tools. *Technological Forecasting and Social Change, 174*, 121273. https://doi.org/10.1016/j.techfore.2021.121273

Folgado, F. J., González, I., Calderón, M., Calderón, D., & Calderón, A. J. (2023). IoT Monitoring Solution for a Middle-Scale Grid Powered by PV Solar Tracker. *ECP 2023*, 40. https://doi.org/10.3390/ecp2023-14635

Gaspar-Figueiredo, D., Abrahao, S., Insfran, E., & Vanderdonckt, J. (2023). Measuring User Experience of Adaptive User Interfaces using EEG: A Replication Study. *ArXiv (Cornell University)*, 52–61. https://doi.org/10.1145/3593434.3593452

Giedraityte, A., Rimkevicius, S., Marciukaitis, M., Radziukynas, V., & Bakas, R. (2025). Hybrid Renewable Energy Systems—A Review of Optimization Approaches and Future Challenges. Applied Sciences, 15(4), 1744. https://doi.org/10.3390/app15041744

Gupta, S., Dhingra, S., Tanwar, S., & Aggarwal, R. (2022). What Explains the Adoption of Mobile Wallets? A Study from Merchants' Perspectives. *International Journal of Human–Computer Interaction*, 1–13. https://doi.org/10.1080/10447318.2022.2104408

Hassan, A. Y., Alaa A. K. Ismaeel, Said, M., Ghoniem, R. M., Deb, S., & Elsayed, A. G. (2022). Evaluation of Weighted Mean of Vectors Algorithm for Identification of Solar Cell Parameters. Processes, 10(6), 1072–1072. https://doi.org/10.3390/pr10061072 https://doi.org/10.13140/RG.2.2.19205.36325

IoT Applications Computing. (2022). *Google Books*. https://books.google.com/books?hl=en&lr=&id=87ZaEAAAQBAJ&oi=fnd&pg=PA107&dq=+IoT+in+renewable+energy&ots=rr9I1TgHyK&sig=3L12mAnEXXHPOsDED-G6dntg64M

Junnel G. (2024). Cost and Lack of Awareness Hinder Solar Power Adoption in the Philippines - Negosyante News. Negosyante News. https://negosyante.org/cost-and-lack-of-awareness-hinder-solar-power-adoption-in-the-philippines/

Leading Solar Energy & Solar Software Company | Enact. (2024, November 4). *ENACT*. https://enact.solar/

Li, P.-P., & Zhong, F. (2022). A Study on the Correlation Between Media Usage Frequency and Audiences' Risk Perception, Emotion and Behavior. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.822300 Limitations. https://doi.org/10.30564/jmser.v5i1.4538

Lopez, R., & Wang, P. (2023). Performance analysis of sun-tracking solar panels in varying environmental conditions. *Journal of Sustainable Energy, 19*(2), 95-112. https://doi.org/10.1016/jse.2023.95112

Lorenciana, C. (2024, June 15). Cebu must ensure long-term power supply as economy grows. CDN Digital. https://cebudailynews.inquirer.net/578701/cebu-must-ensure-long-term-power-supply-as-economy-grows

Luis, Monetta, A., Alonso-Suárez, R., Monteiro, M., & Marti, A. C. (2023). Utilizing smartphone sensors for accurate solar irradiance measurement and educational purposes. ArXiv.org. https://doi.org/10.48550/arXiv.2308.16158

Made Dika Nugraha, Kadek Agus Mahabojana, & Nyoman Angga Prabawa. (2023). Design and build an internet of thing (IOT) solar panel monitoring and solar tracking system. *International Research Journal of Engineering, IT and Scientific Research, 9*(4). https://doi.org/10.21744/irjeis.v9n4.2334

Matellio. (2023). IoT Based Solar Power Monitoring System with Benefits. *Matellio Inc.* https://www.matellio.com/blog/iot-based-solar-power-monitoring-system-development-with-benefits/

McCombes, S. (2023). *Descriptive research | Definition, types, methods & examples*. Scribbr. Retrieved from https://www.scribbr.com/methodology/descriptive-research/

Motahhir, S., El Hammoumi, A., & El Ghzizal, A. (2022). Internet of Things (IoT)-based solar tracker. *Arduino Project Hub.* Retrieved from https://projecthub.arduino.cc/motahhir/internet-of-things-iot-based-solar-tracker-eb940f

Ms. Gauri S. Patil, Ms. Priyanka A. Salgar, Ms. Panchashila P. Sasane, & Prof. V. A. Sawant. (2023). IoT Based Solar System Parameter Measurements. *International Journal of Advanced Research in Science, Communication and Technology*, 40–45. https://doi.org/10.48175/ijarsct-12008

Namila Chathuranga, Stanly Prashanthan Tissaveerasinghe, & Chandana Siriwardana. (2025). Compressed stabilised earth blocks as a sustainable building material: investigation of customer purchase intentions. *Built Environment Project and Asset Management.* https://doi.org/10.1108/bepam-06-2024-0144

Ndalloka, Z. N., Nair, H. V., Alpert, S., & Schmid, C. (2024). Solar photovoltaic recycling strategies. *Solar Energy, 270*, 112379. https://doi.org/10.1016/j.solener.2024.112379

P. Muthukumar, S. Manikandan, R. Muniraj, Jarin, T., & Sebi, A. (2023). Energy efficient dual axis solar tracking system using IOT. Measurement: Sensors, 28, 100825–100825. https://doi.org/10.1016/j.measen.2023.100825

Parthiban, R., & Ponnambalam, P. (2022). An Enhancement of the Solar Panel Efficiency: A Comprehensive Review. Frontiers in Energy Research, 10. https://doi.org/10.3389/fenrg.2022.937155

Ponce-Jara, M. A., Velásquez-Figueroa, C., Reyes-Mero, M., & Rus-Casas, C. (2022). Performance Comparison between Fixed and Dual-Axis Sun-Tracking Photovoltaic Panels with an IoT Monitoring System in the Coastal Region of Ecuador. *Sustainability, 14*(3), 1696. https://doi.org/10.3390/su14031696

Presidential Communications Office. (2024). *PBBM leads ceremonial energization of Cebu-Negros-Panay sub-grid to address power woes in the Visayas region*. https://pco.gov.ph/news_releases/pbbm-leads-ceremonial-energization-of-cebu-negros-panay-sub-grid-to-address-power-woes-in-the-visayas-region/

Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and

Rahman, M. M., & Theel, H. (2022). Integrating Open Innovation with Business Process Management: A Strategic Framework. International Journal of Innovation Science, 14(2), 273–289. https://doi.org/10.1108/IJIS-09-2021-0130

S.S. Dev (2025). *Acciona Energía celebrates groundbreaking ceremony for Daanbantayan solar plant in Cebu, marking a major renewable energy milestone*. https://solarquarter.com/2025/04/02/acciona-energia-celebrates-groundbreaking-ceremony-for-daanbantayan-solar-plant-in-cebu-marking-a-major-renewable-energy-milestone/

Samedova, K. (2025). Solar in Cloudy Climates: How Hybrid Systems Fill the Gap. *Medium*. https://medium.com/%40freen.com/solar-in-cloudy-climates-how-hybrid-systems-fill-the-gap-2c262a994b17

Sankpal, A., Priyanka, G., Asha, B., & Rutuja, S. (2024). IoT Based Solar Tracking and Monitoring System with ESP32. *International Journal of Enhanced Research in Management & Computer Applications, 13*(4), 639–645. https://www.erpublications.com/uploaded_files/download/prof-a-sankpal-miss-g-priyanka-miss-b-asha-miss-s-rutuja_fcWvv.pdf

Sarker, A. K., Azad, A. K., Rasul, M. G., & Doppalapudi, A. T. (2023). Prospect of Green Hydrogen Generation from Hybrid Renewable Energy Sources: A Review. Energies, 16(3), 1556. https://doi.org/10.3390/en16031556

Shakeel, S. R., Yousaf, H., Irfan, M., & Rajala, A. (2023). Solar PV adoption at household level: Insights based on a systematic literature review. *Energy Strategy Reviews, 50*, 101178. https://doi.org/10.1016/j.esr.2023.101178

Shinija, A. (2024). DESCRIPTIVE RESEARCH DESIGN. https://doi.org/10.13140/RG.2.2.19205.36325

Sodhi, M., Banaszek, L., Magee, C., & Rivero-Hudec, M. (2022). Economic Lifetimes of Solar Panels. Procedia CIRP, 105(105), 782–787. https://doi.org/10.1016/j.procir.2022.02.130

Stevanović, S., Stevanović, S., & Živković, R. (2022). ADVANTAGES AND DISADVANTAGES OF SOLAR ENERGY PRODUCTION AND USE. *Journal of Agricultural, Food and Environmental Sciences, JAFES, 76*(4), 65–70. https://journals.ukim.mk/index.php/jafes/article/view/1884

Taherdoost, H. (2022). What are Different Research Approaches? Comprehensive Review of Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations. https://doi.org/10.30564/jmser.v5i1.4538

Uzair, M., Al-Kafrawi, S., Al-Janadi, K., & Al-Bulushi, I. (2022). A Low-Cost, Real-Time Rooftop IoT-Based Photovoltaic (PV) System for Energy Management and Home

Automation. Energy Engineering, 119(1), 83–101. https://doi.org/10.32604/ee.2022.016411

Zsiborács, H., Pintér, G., Vincze, A., & Hegedűsné Baranyai, N. (2022). A control process for active solar-tracking systems for photovoltaic technology and the circuit layout necessary for the implementation of the method. *Sensors, 22*(7), 2564. https://doi.org/10.3390/s22072564

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- Programming (SQL, JAVA, HTML,CSS with bootstrap)
- Design (Figma, Canva)

Achievements & Certificates

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- Programming(HTML ,Java, Arduino, Python C, C#, C++)
- Hardware and Software Troubleshooting
- AutoCAD
- Robotics

Achievements & Certificates

- Introduction to Packet Tracer
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Tertiary Education	Bachelor of Science in Information Technology University of Cebu Lapu – Lapu and Mandaue
Senior High School	Technical Vocational Livelihood University of Cebu Lapu – Lapu and Mandaue
Junior High School	University of Cebu Lapu – Lapu and Mandaue
Elementary School	Saint Louis College Cebu

Skills

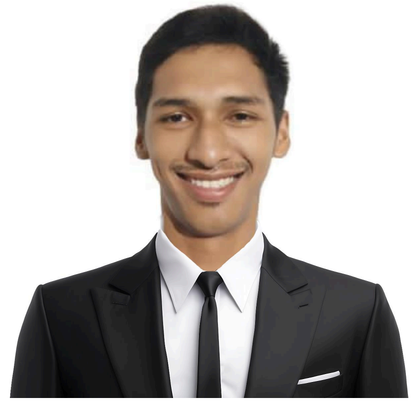
- Programming (HTML, CSS, C#, PHP, Laravel)
- Design (Canva, PicsArt)
- AutoCAD

Achievements & Certificates

- UCLM: Academic Scholar
- Consistent Dean's Lister
- SLCC: White Card, Blue Card Achiever
- Tech Talk : DB Programming
- Tech Talk: Networking Tutorial
- URO: Reframing, Adapting and Re-Introducing Qualitative Research in the Midst of a Pandemic Seminar

Kent Jerard B. Sepra

kentb.sepra@gmail.com



Age	24
Gender	Male
Date of Birth	August 21, 2000
Place of Birth	Cebu City
Civil Status	Single
Nationality	Filipino

Educational Background

Tertiary Education	Bachelor of Science in Information Technology University of Cebu Lapu – Lapu and Mandaue
Senior High School	University of Visayas Mandaue City, Cebu
Junior High School	University of Visayas Mandaue City, Cebu
Elementary School	Cabancalan 2 Elementary School

Skills

- Programming(HTML,C#,MySql,Java)
- Hardware and software Troubleshooting
- Hardware and software installation

Achievements & Certificates

- Tech talk 2025: Database programming
- ICT Congress 2023,2025

APPENDICES

Appendix A

TRANSMITTAL LETTER

April 14, 2025

Carl Steven A. Wiegel
Barangay Captain
Gun Ob Barangay Hall
Barangay Gun Ob, Lapu-Lapu City

Dear Mr. Carl:

We, the Team K3-P3—composed of Linzel Marie Paciencia, Rigil Kent Payo, Kent Jyls Noel, Kent Jerard Sepra, and Hubert Harold Plarisan—are BSIT students from the University of Cebu Lapulapu and Mandaue, currently working on our Capstone Project titled **"SolMate: Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization."**

In partial fulfillment of the requirements for our degree program, we respectfully seek your permission to conduct a survey that will help validate our study. Rest assured, all collected data will be treated with strict confidentiality and used solely for academic purposes.

We respectfully seek your favorable consideration of our request.

Sincerely Yours,

Linzel Marie P. Paciencia
Project Manager

Noted by:

Mr. Paul S. Ngujo
Capstone Adviser

Dr. Janette O. Tanquis
Dean, UCLM College of Computer Studies

Approved by:

Hon. Carl Steven A. Wiegel
Gun-ob Barangay Captain

Appendix B

Map of the Research Environment

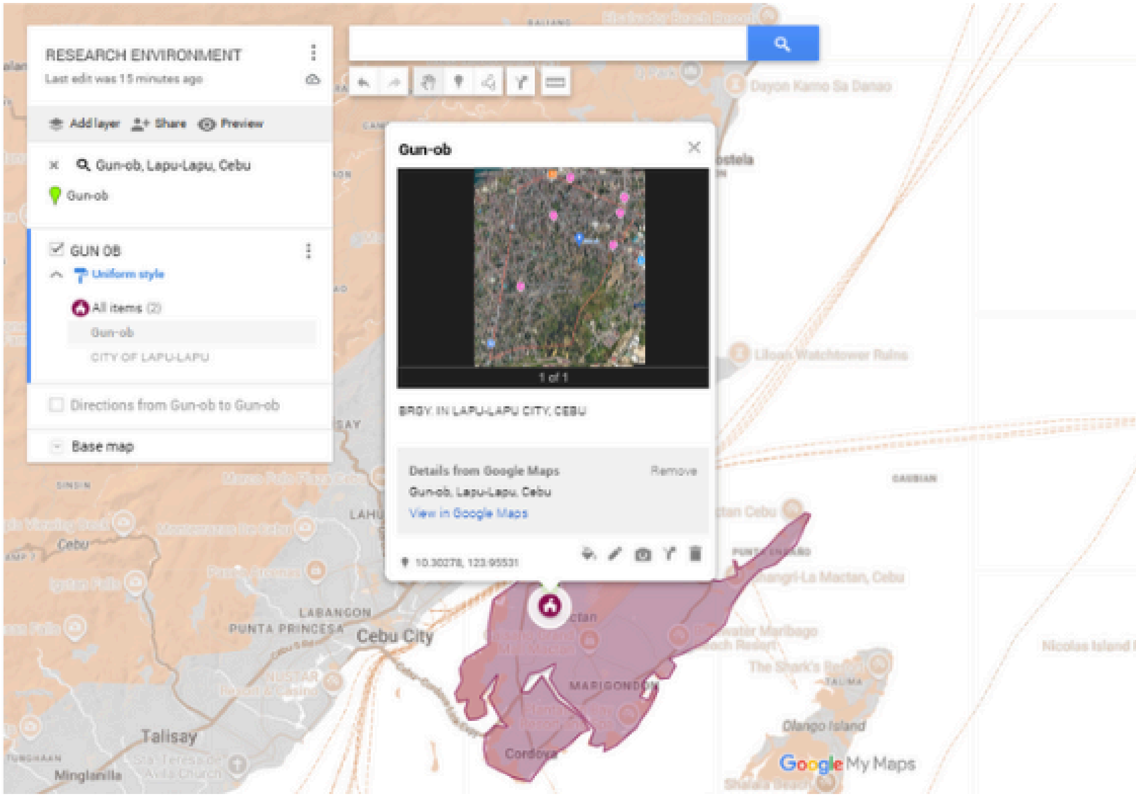


Figure 73: **Map of the Research Environment**

Appendix C

Survey Questionnaire

Dear Respondents,

We are conducting a survey as part of our requirements titled “SolMate: Smart IoT Sun-Tracking Solar Panel System with Mobile Monitoring and Energy Optimization.” Your participation is respectfully requested to help us gather valuable insights and experiences regarding solar panel usage in your area.

This survey is designed to evaluate the relevance, usability, and potential impact of SolMate’s features, particularly in improving energy efficiency and reliability through IoT technology and hybrid solar tracking systems.

Your Privacy is Paramount: Please be assured that your responses will be treated with the utmost confidentiality and anonymity. Access to the survey data will be strictly limited to the research team, and no personally identifiable information will be shared or published.

The survey will take approximately 5 to 10 minutes to complete. Your participation is crucial and deeply appreciated, as it will directly contribute to the development of a system that addresses real-world needs and promotes sustainable energy practices. Please be assured of the following:

- Your responses will be kept strictly confidential.
- Only the research team will access the data collected.
- No personally identifiable information will be shared or published.
- All results will be analyzed and reported in summary form only.

Your feedback will significantly contribute to the success of our project, helping us develop a system that is responsive to real-world needs and promotes sustainable energy practices.

Thank you very much for your time and cooperation.

Kinds Regards, The Research Team

Paciencia, Linzel Marie

Payo, Rigil Kent

Plarisan, Hubert Harold

Noel, Kent Jyls

Sepra, Kent Jerard

Section A: Demographic Information

Direction: Please indicate your answers by checking the boxes that apply to you.

Gender

☐ Female

☐ Male

☐ Prefer not to say

Age Group

☐ 18–25 years old

☐ 26–35 years old

☐ 36–45 years old

☐ 45–60 years old

☐ 60 years old and above

Employment Status

☐ Employed (Full-time)

☐ Employed (Part-time)

☐ Self-employed

☐ Unemployed

☐ Retired

Monthly Household Income

☐ Less than ₱10,000

☐ ₱10,000–₱19,999

☐ ₱20,000–₱29,999

☐ ₱30,000–₱39,999

☐ ₱40,000 and above

Do you currently use solar panels in your home/business?

☐ Yes

☐ No

If yes, how long have you been using solar panels?

☐ Less than 1 year

☐ 1–3 years

☐ More than 3 years

If you are using solar panels, what do you commonly use them for?

☐ Lighting

☐ Business equipment (freezer, tools, etc.)

☐ Charging devices (phones, power bank, etc.)

☐ Backup during power interruptions

☐ Household appliances (TV, electric fan, refrigerator, etc.)

If you currently use solar panels in your home or business, how often do you perform maintenance?

☐ Regular cleaning (at least once a month)

☐ I don’t do any maintenance

☐ Occasional cleaning (once every few months)

☐ Not applicable

☐ Maintenance only when performance drops

Section B: Solar Energy Usage Practices and Challenges

Please read each statement carefully and place a checkmark (✓) in the box that corresponds to your level of agreement, ranging from "Strongly Agree" in the leftmost column to "Strongly Disagree" in the rightmost column. This symbol represents your statement.

STRONGLY AGREE (5)	**AGREE (4)**	**NEUTRAL (3)**	**DISAGREE (2)**	**STRONGLY DISAGREE (1)**
SA	A	N	D	SD

Solar Energy Usage Practices and Challenges	SA	A	N	D	SD
1. Traditional solar panel systems are difficult to maintain without technical knowledge.					
2. The performance of conventional solar panels is greatly affected by weather conditions like rain, dust, or cloud cover.					
3. I am concerned about the long-term durability and lifespan of solar energy system					
4. Power output from traditional solar panels is often inconsistent throughout the day.					
5. Conventional solar systems may not be reliable for continuous power supply without backup sources.					
6. Hybrid systems that combine solar with other power sources offer more reliable energy than solar alone.					
7. Many traditional solar panel systems do not include features like sun-tracking.					
8. There is no need for backup power sources when using a traditional solar panel system.					
9. Sun-tracking technology is completely useless and makes no difference in solar energy production.					
10. To what extend do you agree or disagree with the statement: It is easy for most people to repair or adjust solar panel systems without any knowledge.					

11. The addition of IoT or mobile monitoring features only complicates the use of solar panels.					
12. Manual adjustments to solar panels are just as effective as automated sun-tracking systems.					
13. Mobile monitoring apps for solar energy systems are purely decorative and serve no functional purpose at all.					
14. Solar panel systems do not require any cleaning or maintenance after installation.					

Others (please specify):

Section C: Solar System Development Techniques

Please read each statement carefully and place a checkmark (✓) in the box that corresponds to your level of agreement, ranging from "Strongly Agree" in the leftmost column to "Strongly Disagree" in the rightmost column. This symbol represents your statement.

STRONGLY AGREE (5)	**AGREE (4)**	**NEUTRAL (3)**	**DISAGREE (2)**	**STRONGLY DISAGREE (1)**
SA	A	N	D	SD

Solar System Development Techniques	SA	A	N	D	SD
1. I believe that solar panels should adjust their position to follow the sun throughout the day to store more sun energy.					
2. Monitoring solar energy performance as it happens allows for smarter decision-making than waiting for monthly reports.					
3. A solar system should be able to automatically switch to backup power when sunlight is insufficient (hybrid power).					
4. I want to monitor my solar panel's performance (energy generation/consumption) through a mobile phone or app.					

5. The weight and size of the solar panels significantly influence the design requirements of the base structure.					
6. The environmental impact of the materials and construction methods used for the solar panel base should be taken into account.					
7. The system should be able to handle changes in power demand without interrupting the power supply.					
8. Delayed or occasional monitoring is more useful than real-time tracking because energy data doesn't need constant updates.					
9. A well-designed solar power can contribute to a more sustainable energy future.					
10. I believe that solar power has no potential for practical use.					
11. Having both solar and battery storage makes a system more reliable.					
12. Having both solar and battery storage makes a system less reliable.					
13. Real-time monitoring often leads to confusion and inaccurate results, making it unreliable for managing energy use.					
14. Real-time monitoring provides accurate energy data, helping users detect issues early and manage consumption better.					

Others (please specify):

Section D: Key Features of the Proposed System

Please read each statement carefully and place a checkmark (✓) in the box that corresponds to your level of agreement, ranging from "Strongly Agree" in the leftmost column to "Strongly Disagree" in the rightmost column. This symbol represents your statement

STRONGLY AGREE (5)	AGREE (4)	NEUTRAL (3)	DISAGREE (2)	STRONGLY DISAGREE (1)
SA	A	N	D	SD

Key Features of the Proposed System	SA	A	N	D	SD
1. A sun-tracking feature that follows the sun will help the solar panels produce more energy.					
2. It's important to include recycling and easy maintenance to make the system last longer and stay eco-friendly.					
3. Saving system data online is useful for checking past performance.					
4. Automatically adjusting the panels to follow the sun is better than doing it manually.					
5. A back-up battery that works even when there's no sunlight can make the system more reliable.					
6. The system's energy storage capacity should be sufficient to provide power during periods of low sunlight.					
7. A reliable and efficient solar power system is important for the widespread adoption of renewable energy.					
8. The features of a solar power system have no impact on its overall usefulness.					
9. This system uses solar energy, not gasoline, to create electricity.					
10. This system relies on gasoline, not solar energy, to generate electricity.					
11. A solar panel should be placed where there is a lot of sunlight, not in a dark room.					
12. A solar panel should be placed in a dark room, not where there is a lot of sunlight.					

Others (please specify):

Section E: Recommendation

Directions: Please read each statement carefully and place a checkmark (✓) in the box that corresponds to your level of agreement, ranging from "Strongly Agree" in the leftmost column to "Strongly Disagree" in the rightmost column. This symbol represents your statement.

STRONGLY AGREE (5)	AGREE (4)	NEUTRAL (3)	DISAGREE (2)	STRONGLY DISAGREE (1)
SA	A	N	D	SD

Recommendation	SA	A	N	D	SD
1. SolMate should be used in homes to help save more solar energy.					
2. The system should show clear data on energy usage, storage, and savings.					
3. SolMate should keep using both solar and backup (hybrid) power to ensure reliable electricity.					
4. SolMate should be adapted for use in different places like farms, schools, or remote areas.					
5. SolMate should include alerts or notifications when energy generation drops or system issues are detected.					
6. SolMate should be affordable and available to low-income households who suffer frequent power outages.					
7. I believe SolMate has the potential to improve the way we use solar energy in our community.					

Others (please specify):

Appendix D

UNIT TESTING

Proponent: Sepra, Kent Jerard — Module Name:Account Registration

Unit Name: Signup — Test Case:TC-001

Test Case Description: Valid entries

Expected Results: Registration Successful — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

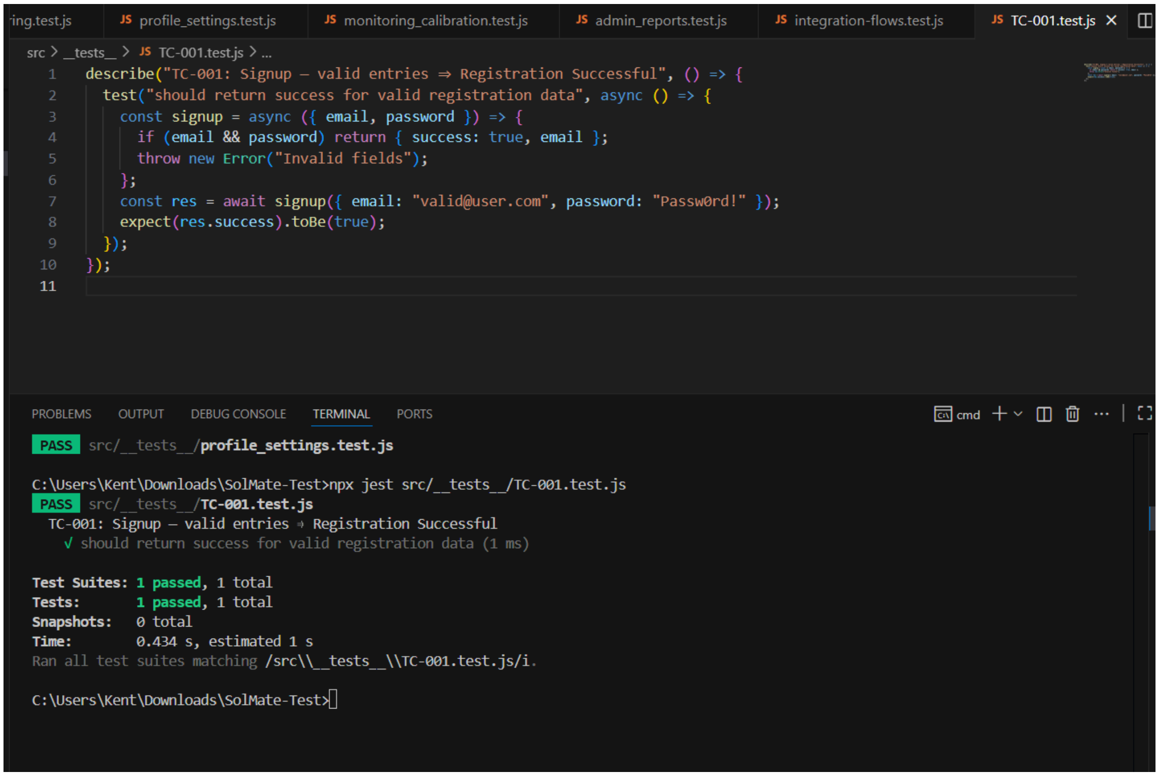


Figure 74: **Valid Entry Sign Up**

Proponent: Sepra, Kent Jerard — Module Name:Account Registration

Unit Name: Signup — Test Case:TC-002

Test Case Description: Invalid entries — Date Tested: 10/11/25

Expected Results: Account will not be registered

Action Result: Performed as expected — Result:Passed

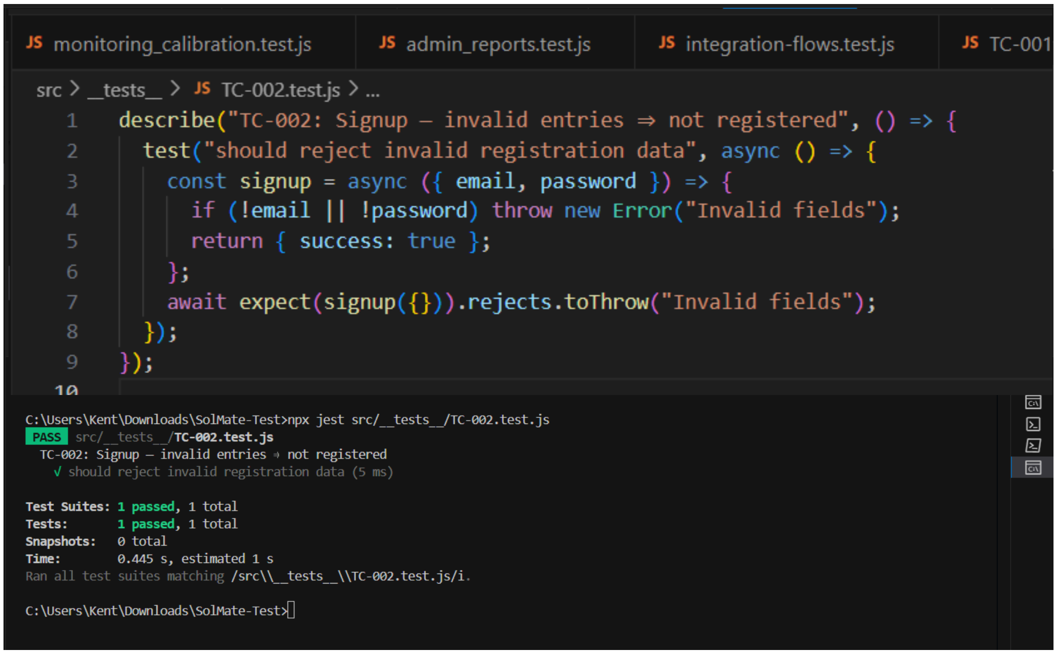


Figure 75: **Invalid Entry Sign Up**

Proponent: Sepra, Kent Jerard — Module Name: Account Validation

Unit Name: Login Account — Test Case: TC-003

Test Case Description: Valid entries — Date Tested: 10/11/25

Expected Results: The user logged in successfully

Action Result: Performed as expected — Result: Passed

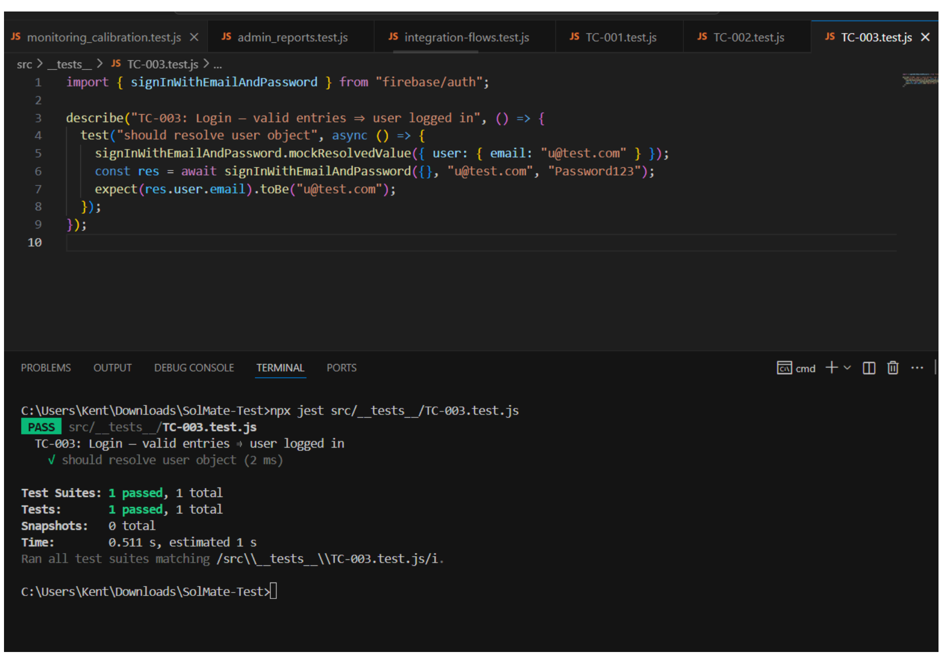


Figure 76: **Valid Entry Login**

Proponent: Sepra, Kent Jerard — Module Name:Account Validation

Unit Name: Login Account — Test Case:TC-004

Test Case Description: Invalid entries — Date Tested: 10/11/25

Expected Results: User login failed

Action Result: Performed as expected — Result:Passed

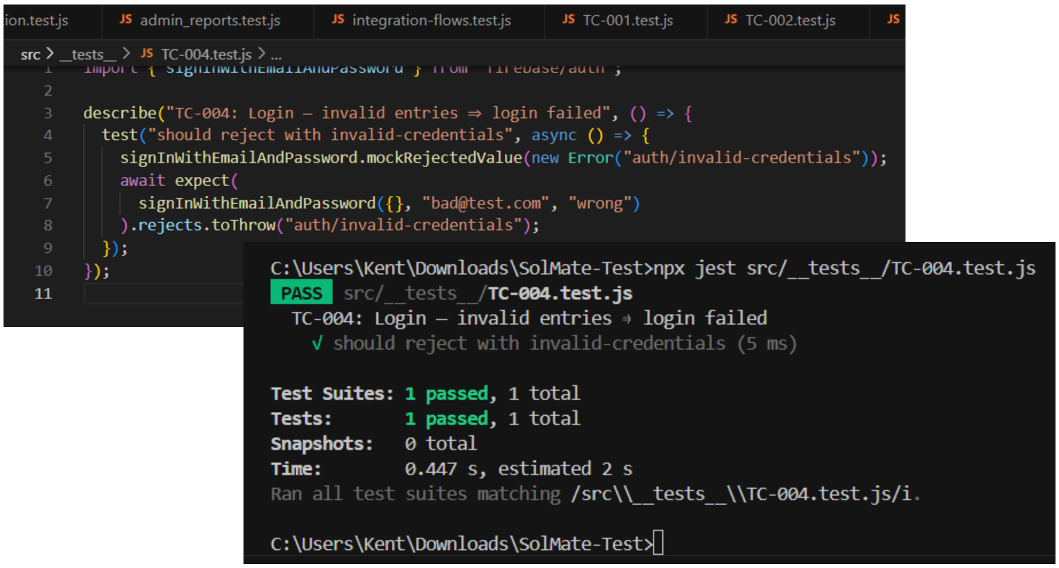


Figure 77: **Invalid Entry Login**

Proponent: Sepra, Kent Jerard — Module Name:Password Recovery

Unit Name: Forgot Password — Test Case:TC-005

Test Case Description: Submit valid email — Date Tested: 10/11/25

Expected Results: Reset link sent

Action Result: Performed as expected — Result:Passed

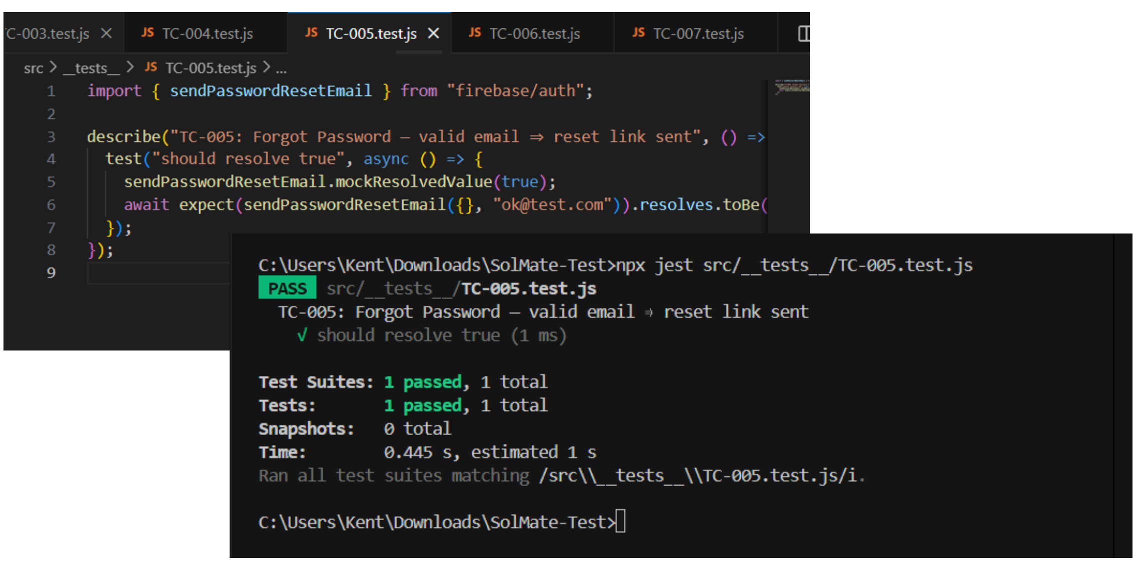


Figure 78: **Valid Email Password Recovery Entry**

Proponent: Sepra, Kent Jerard — Module Name:Password Recovery

Unit Name: Forgot Password — Test Case:TC-006

Test Case Description: Unregistered email — Date Tested: 10/11/25

Expected Results: Reset link sent failed

Action Result: Performed as expected — Result:Passed

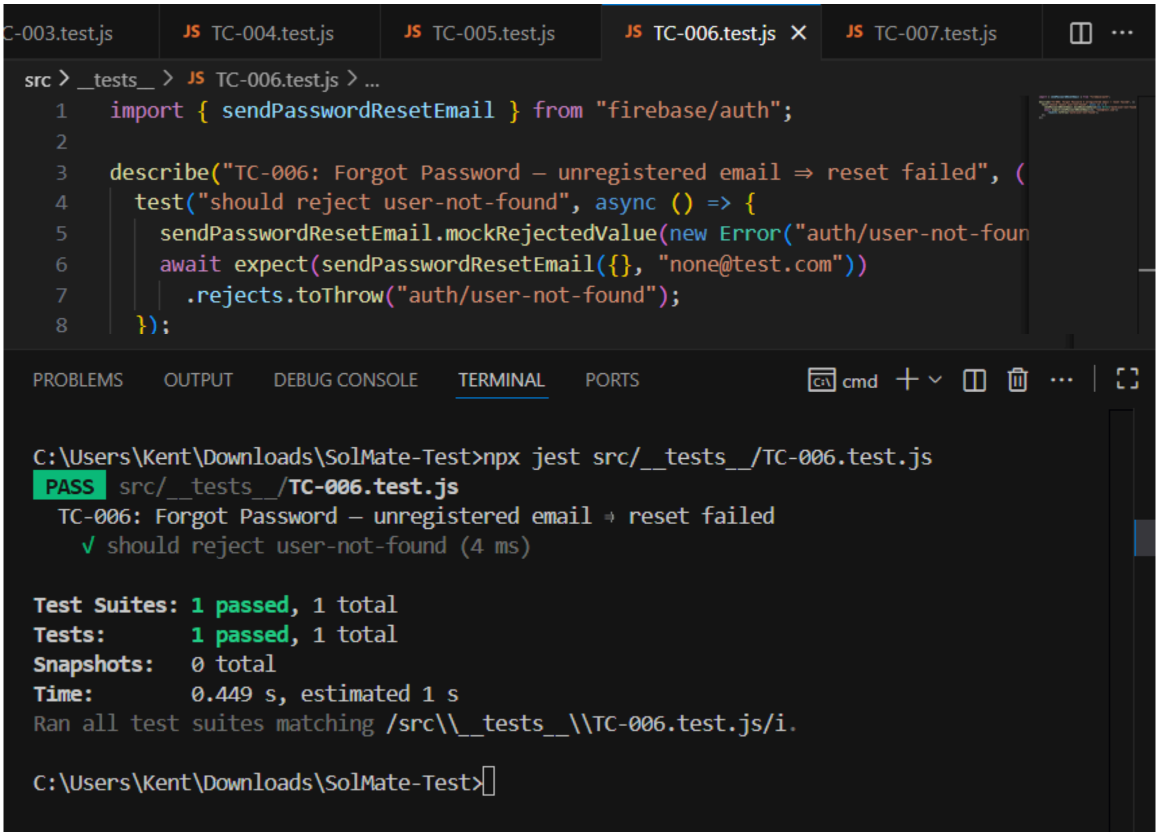


Figure 79: **Invalid Email Password Recovery Entry**

Proponent: Sepra, Kent Jerard — Module Name:Device Pairing

Unit Name:Pair Device — Test Case:TC-007

Test Case Description: Device Credentials — Date Tested: 10/11/25

Expected Results: Device paired to user

Action Result: Performed as expected — Result:Passed

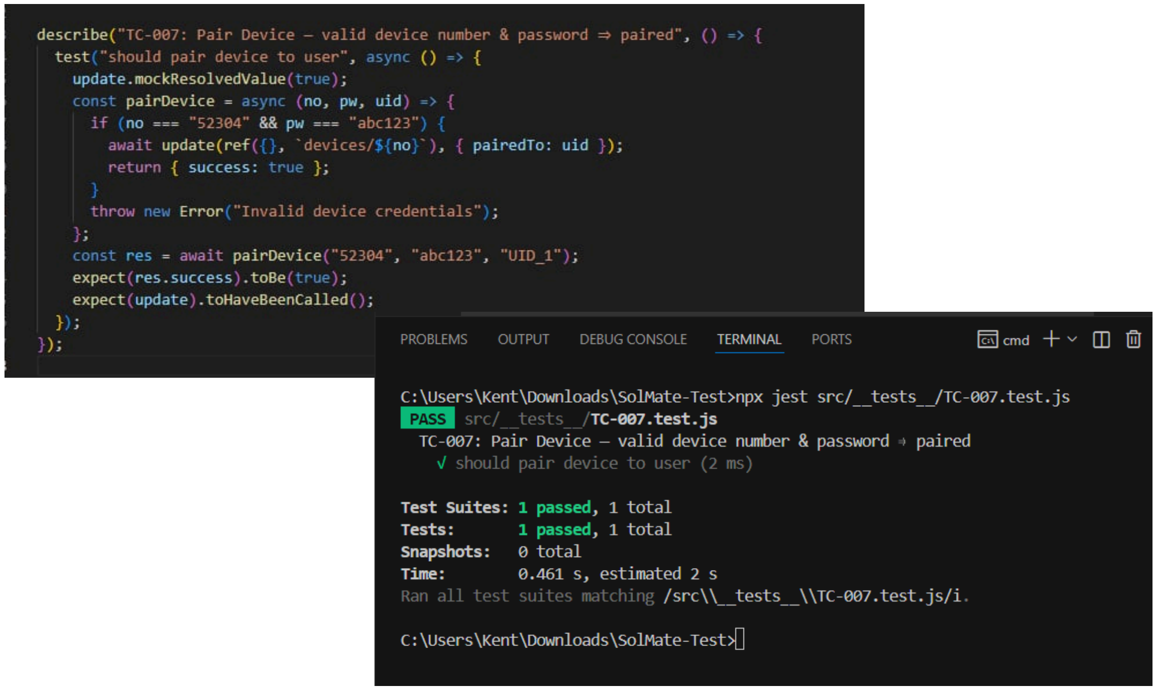


Figure 80: **Success Device Pairing**

Proponent: Sepra, Kent Jerard — Module Name:Device Pairing

Unit Name:Pair Device — Test Case:TC-008

Test Case Description: Invalid device credentials

Expected Results: Pairing blocked with error — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

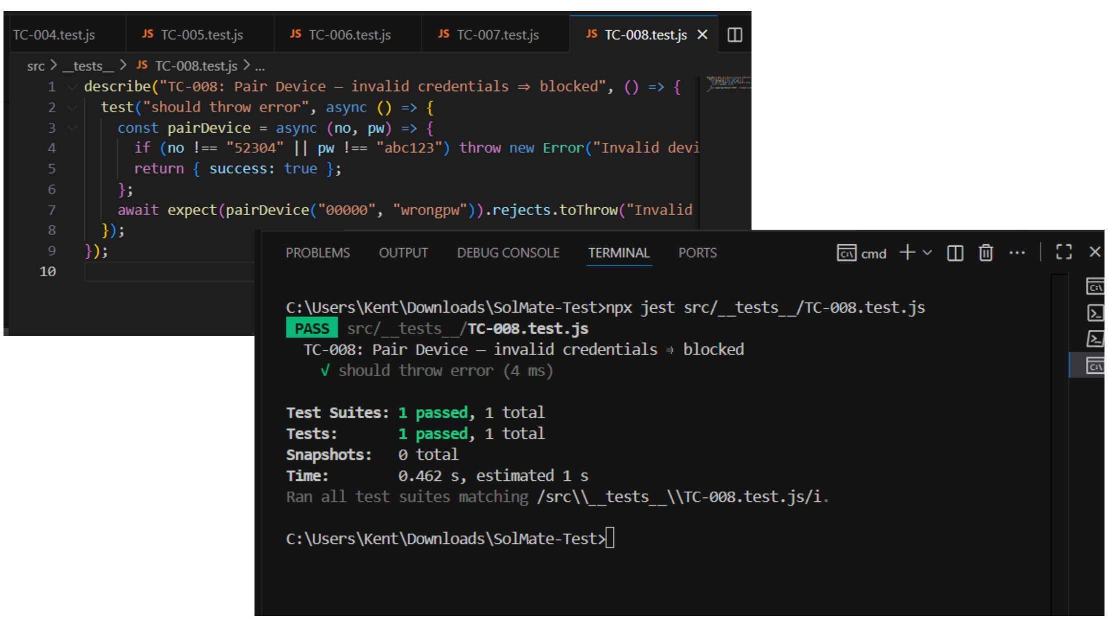


Figure 81: **Failed Device Pairing**

Proponent: Sepra, Kent Jerard — Module Name: Profile Management

Unit Name:Edit Profile — Test Case:TC-009

Test Case Description: Change current profile details

Expected Results: Update profile details — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

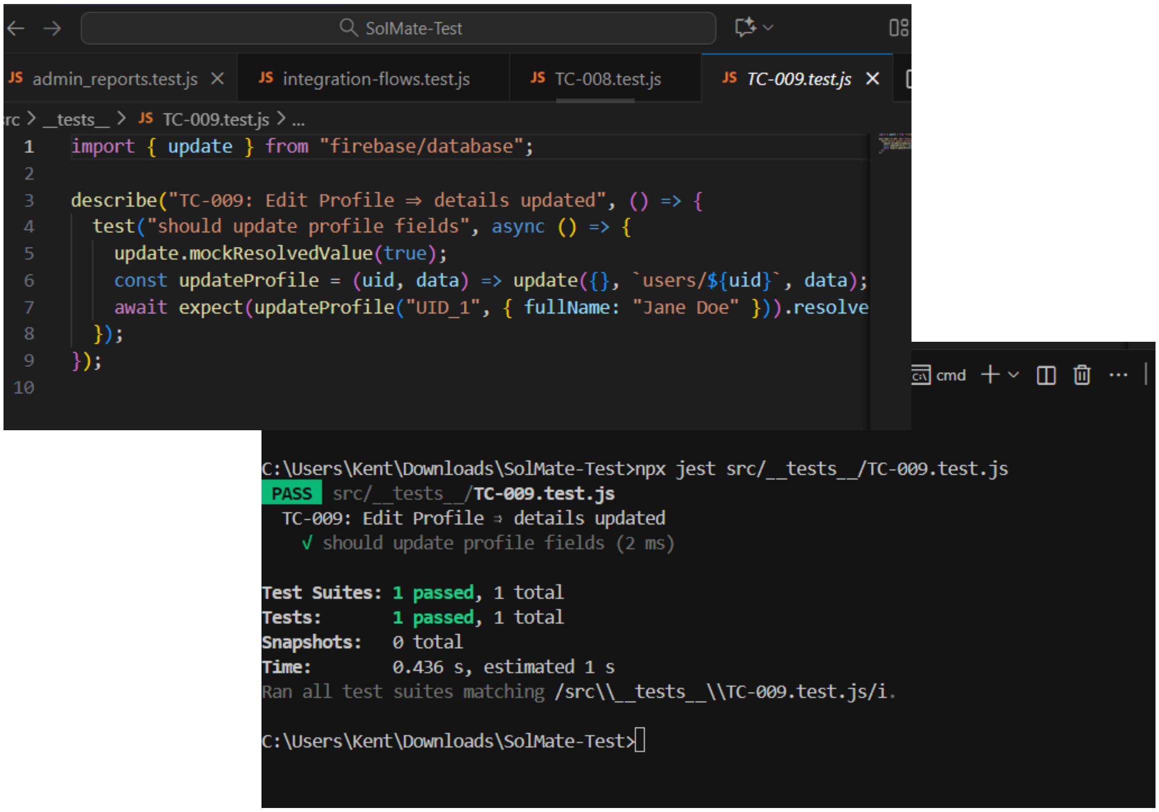


Figure 82: **Updated Profile Entry**

Proponent: Sepra, Kent Jerard — Module Name: Profile Management

Unit Name:Edit Profile — Test Case:TC-010

Test Case Description: Change current password

Expected Results: Password updated — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

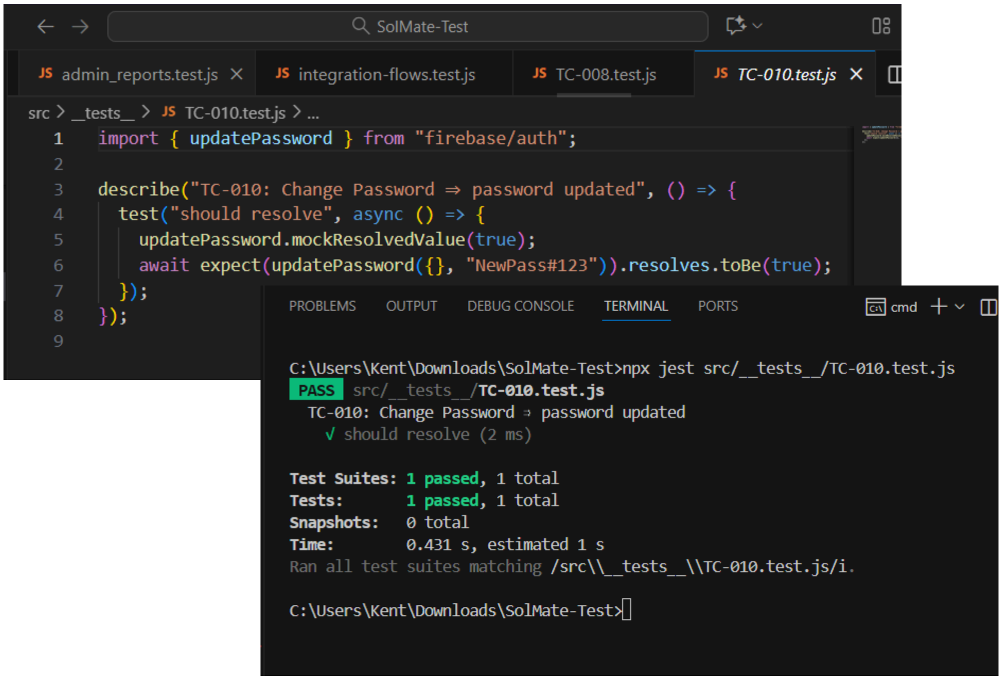


Figure 83: <u>**Updated Device Password Entry**</u>

Proponent: Sepra, Kent Jerard Module Name: Profile Management

Unit Name:Logout Test Case:TC-011

Test Case Description: User logs out Date Tested: 10/11/25

Expected Results: Session cleared, back to login

Action Result: Performed as expected Result:Passed

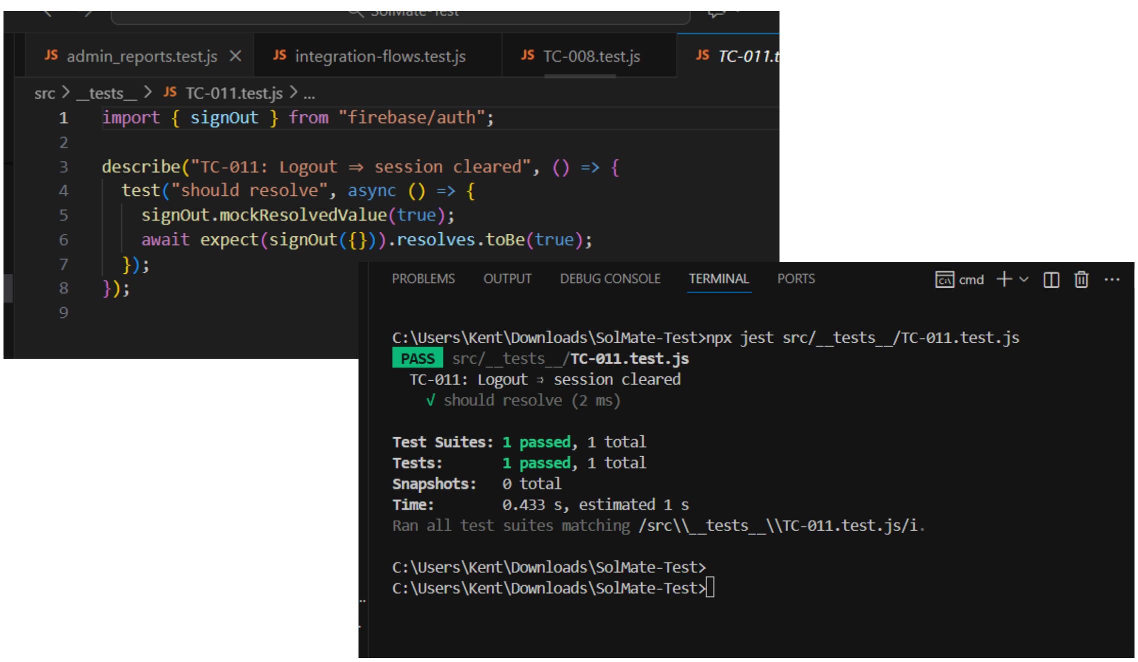


Figure 84: <u>**User Log Out**</u>

Proponent: Sepra, Kent Jerard — Module Name: Support Center

Unit Name:User Ticket — Test Case:TC-012

Test Case Description: Submit account ticket

Expected Results: Session cleared — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

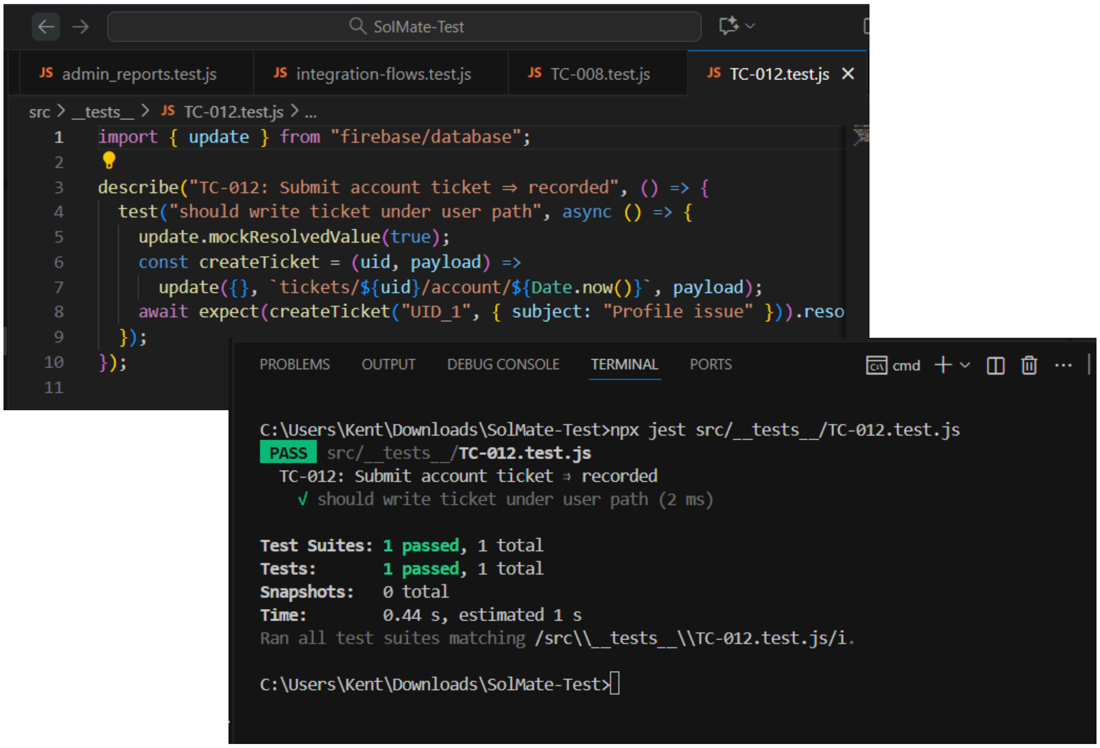


Figure 85: **Submit Support Ticket Entry**

Proponent: Sepra, Kent Jerard — Module Name: Device Monitoring

Unit Name:Energy Tracking — Test Case:TC-013

Test Case Description: Show live energy tracking

Expected Results: Live values displayed — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

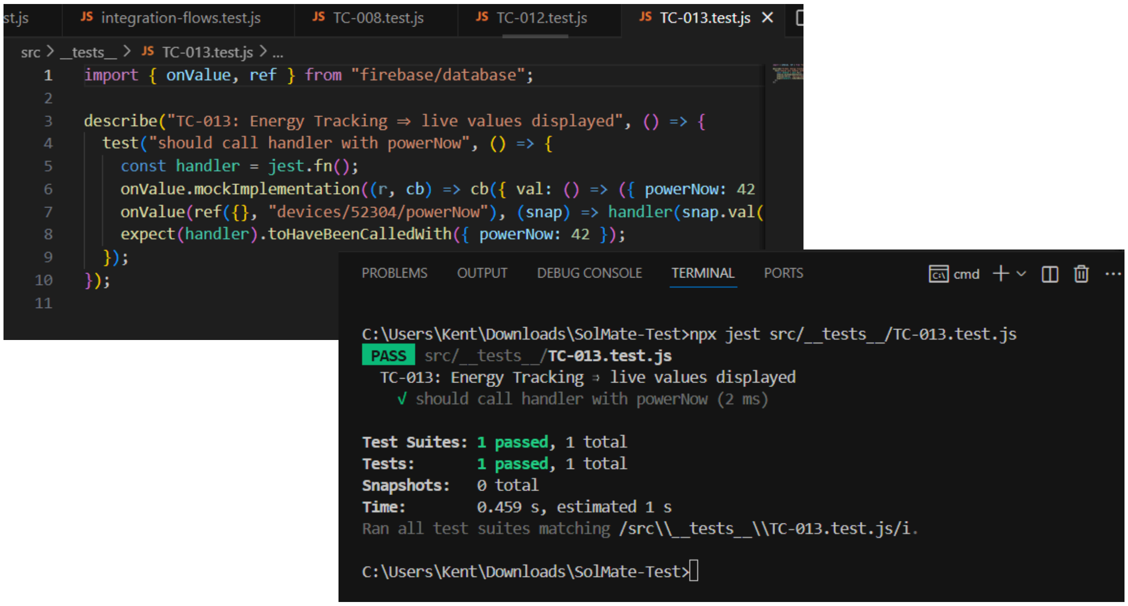


Figure 86: **View Device Output**

Proponent: Sepra, Kent Jerard — Module Name: Device Monitoring

Unit Name:Battery Level Monitoring — Test Case:TC-014

Test Case Description: Show battery

Expected Results: Live values displayed — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

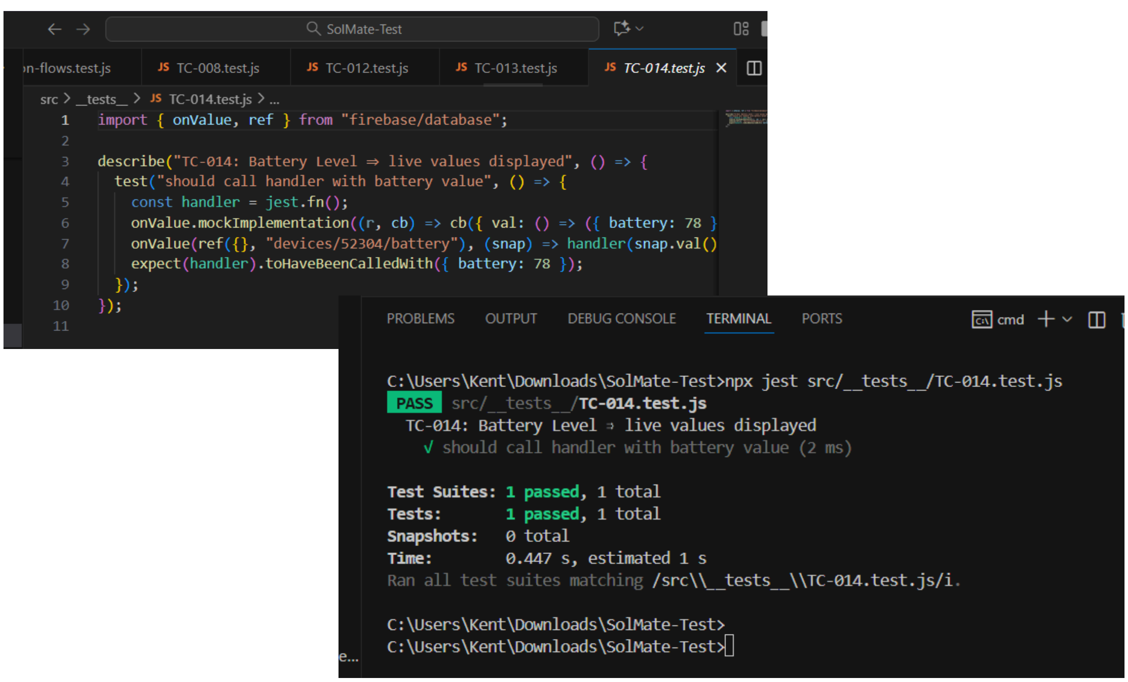


Figure 87: **Battery Display**

Proponent: Sepra, Kent Jerard — Module Name: Device Monitoring

Unit Name:Device Data Logging — Test Case:TC-015

Test Case Description: Show graphs

Expected Results: Graphs displaying — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

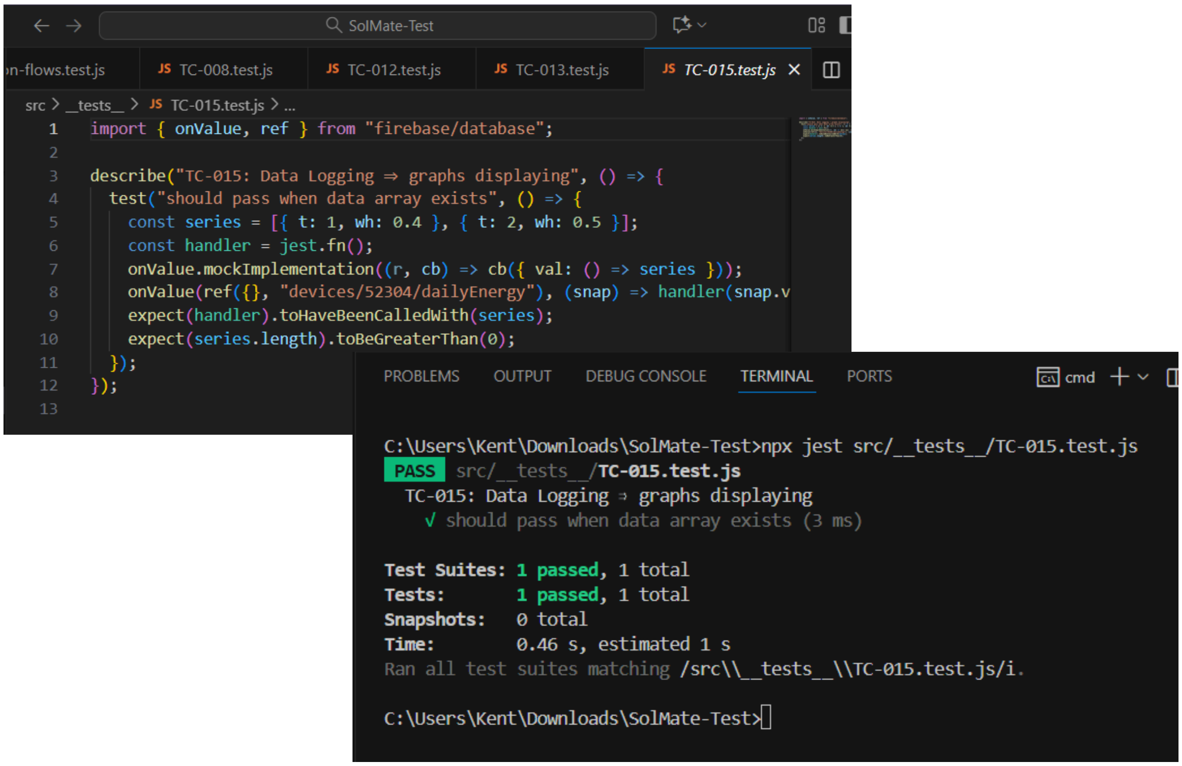


Figure 88: **View Energy Graph Display**

Proponent: Sepra, Kent Jerard — Module Name: Calibration

Unit Name:Adjust Duration — Test Case:TC-016

Test Case Description: Increase/decrease duration

Expected Results: New duration reflected — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

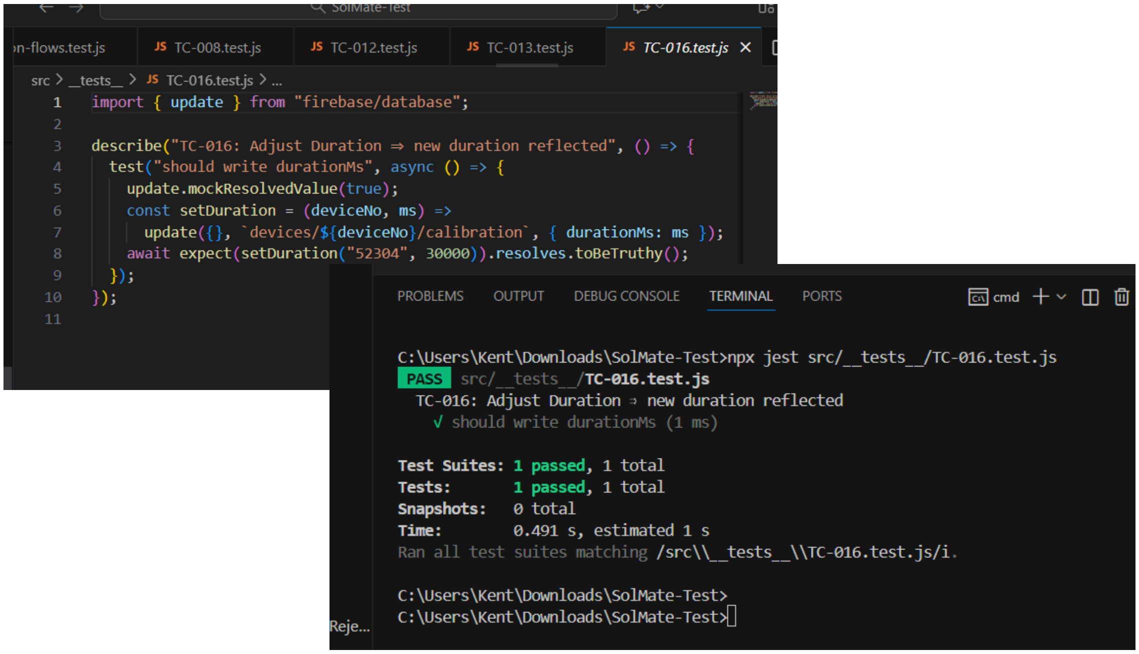


Figure 89: **Adjust Calibration Entry**

Proponent: Sepra, Kent Jerard — Module Name: Calibration

Unit Name:Set Interval — Test Case:TC-017

Test Case Description: Save interval schedule

Expected Results: Interval saved and applied — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

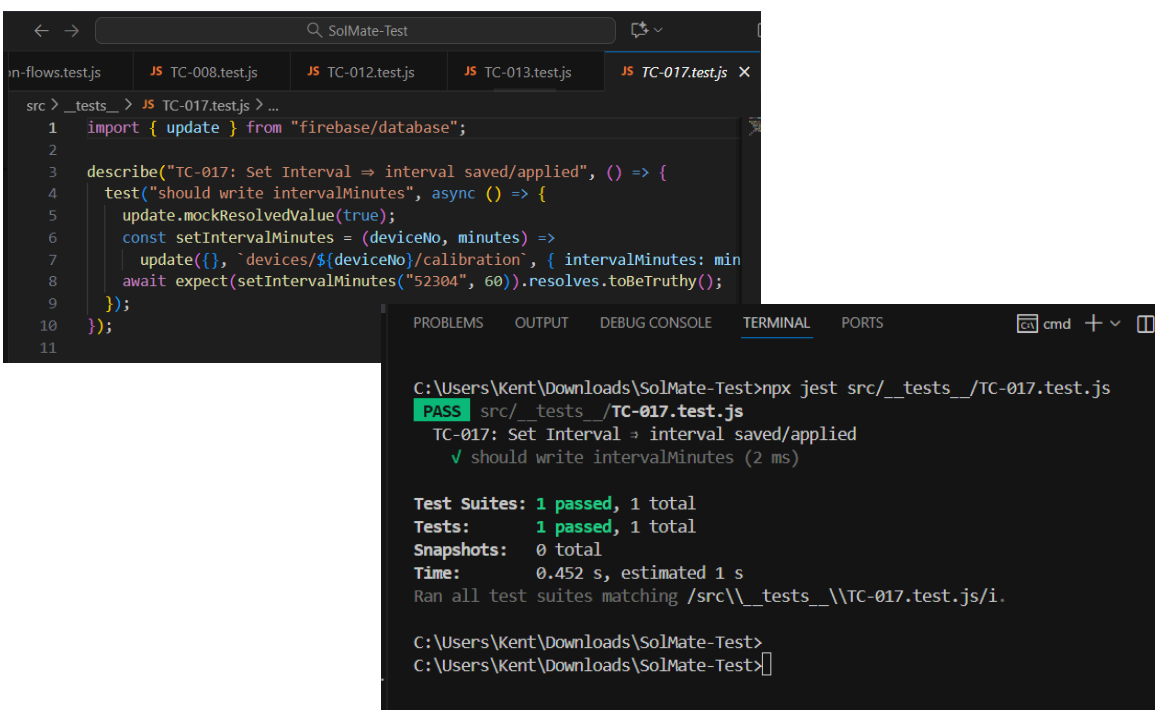


Figure 90: **Calibration Interval Configuration**

Proponent: Sepra, Kent Jerard | Module Name: Calibration

Unit Name:Calibration Management | Test Case:TC-018

Test Case Description: Trigger one-tap calibration

Expected Results: Motors run then auto-stop | Date Tested: 10/11/25

Action Result: Performed as expected | Result:Passed

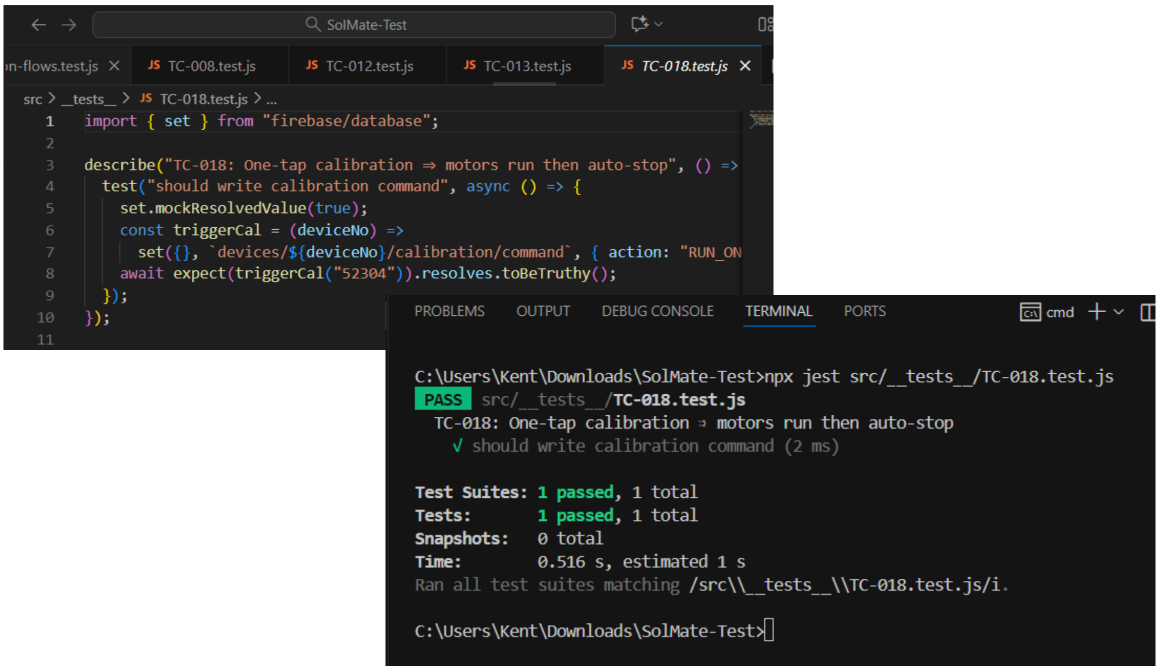


Figure 91: **Calibration Duration Configuration**

Proponent: Sepra, Kent Jerard | Module Name: Settings

Unit Name: Rename Device | Test Case:TC-019

Test Case Description: Change device name

Expected Results: Name updated across UI | Date Tested: 10/11/25

Action Result: Performed as expected | Result:Passed

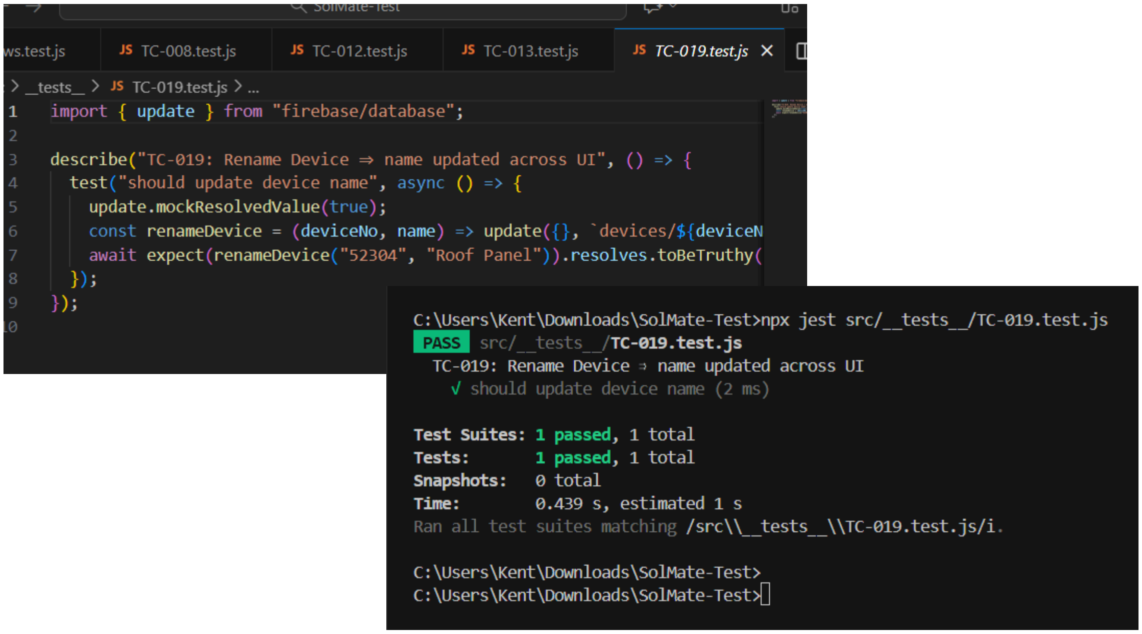


Figure 92: **Change Device Name Entry**

Proponent: Sepra, Kent Jerard | Module Name: Settings

Unit Name: Notifications | Test Case:TC-020

Test Case Description: Toggle notifications

Expected Results: Preference saved | Date Tested: 10/11/25

Action Result: Performed as expected | Result:Passed

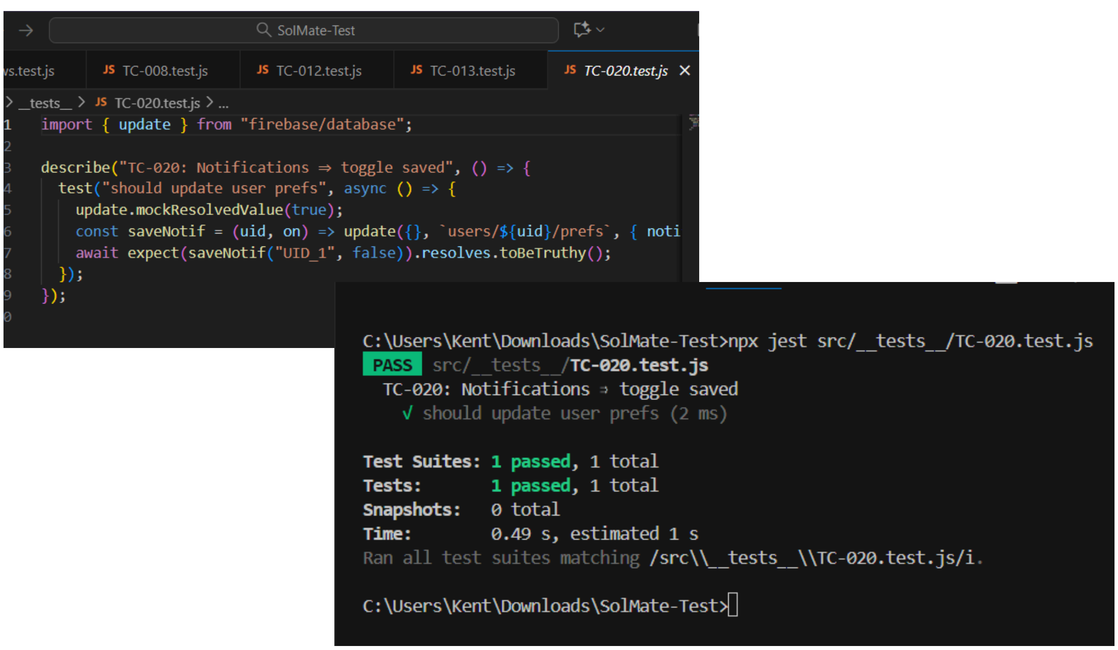


Figure 93: **Toggle Notification**

Proponent: Sepra, Kent Jerard — Module Name: Settings

Unit Name: Device Settings — Test Case:TC-021

Test Case Description: Submit device ticket — Date Tested: 10/11/25

Expected Results: Ticket recorded with device context

Action Result: Performed as expected — Result:Passed

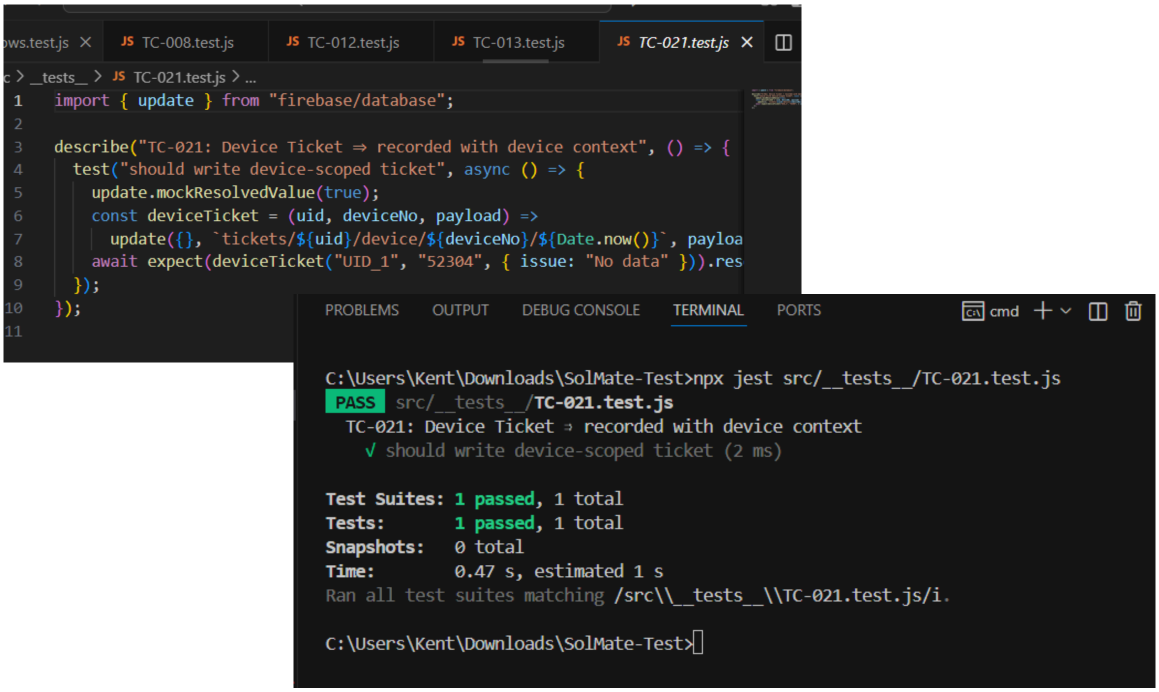


Figure 94: **Submit Device Ticket Entry**

Proponent: Sepra, Kent Jerard — Module Name: Settings

Unit Name: Disconnect Device — Test Case:TC-022

Test Case Description: Disconnect device — Date Tested: 10/11/25

Expected Results: Device removed from account

Action Result: Performed as expected — Result:Passed

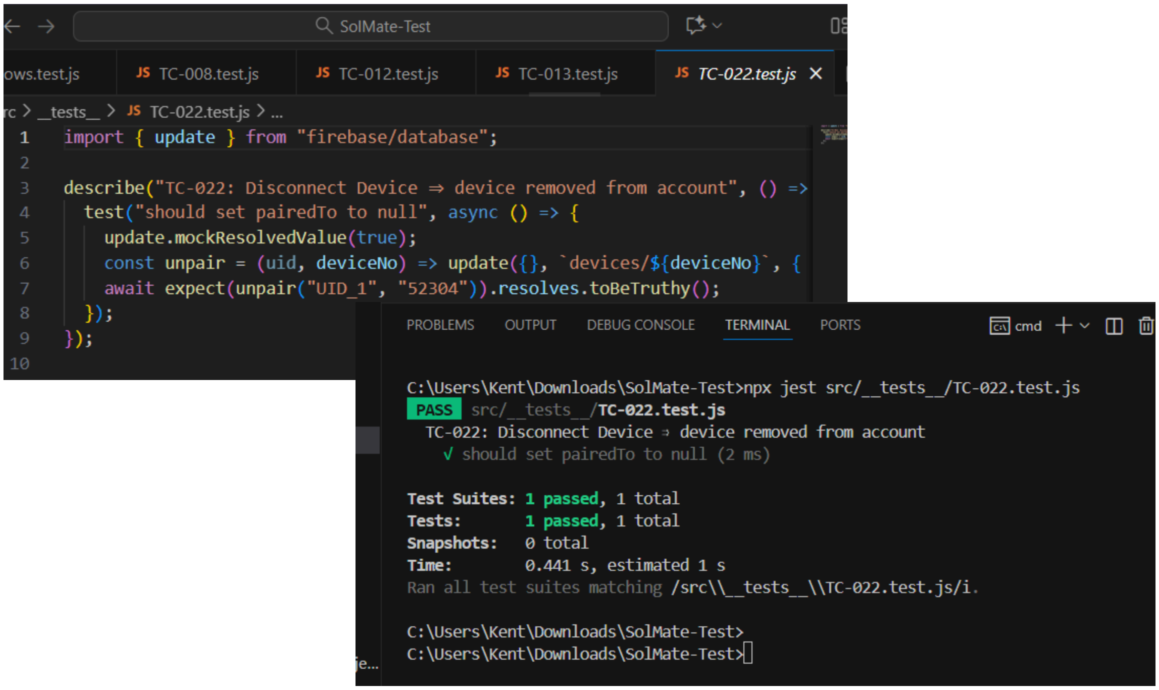


Figure 95: **Disconnect Device**

Proponent: Sepra, Kent Jerard — Module Name: User Management

Unit Name: Monitor User — Test Case:TC-023

Test Case Description: Monitor User Details — Date Tested: 10/11/25

Expected Results: Admin can monitor User Accounts

Action Result: Performed as expected — Result:Passed

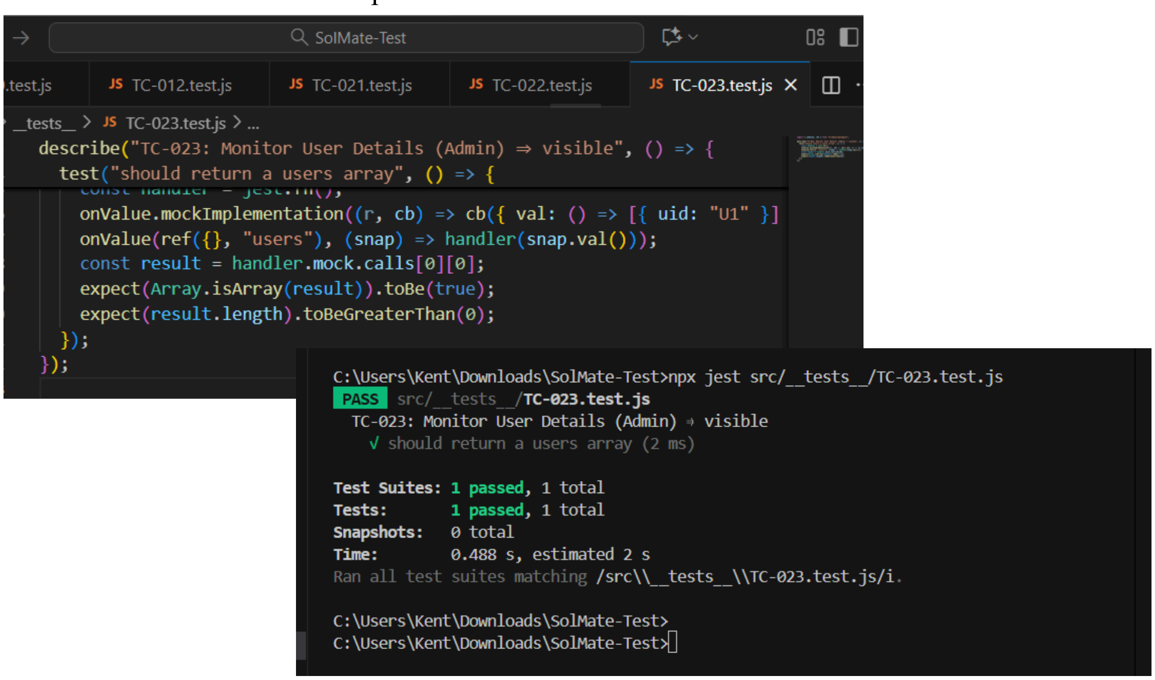


Figure 96: **Monitor User Details**

Proponent: Sepra, Kent Jerard | Module Name: Ticket Management

Unit Name: Receive Ticket | Test Case:TC-024

Test Case Description: Monitor Tickets | Date Tested: 10/11/25

Expected Results: Admin receive ticket

Action Result: Performed as expected | Result:Passed

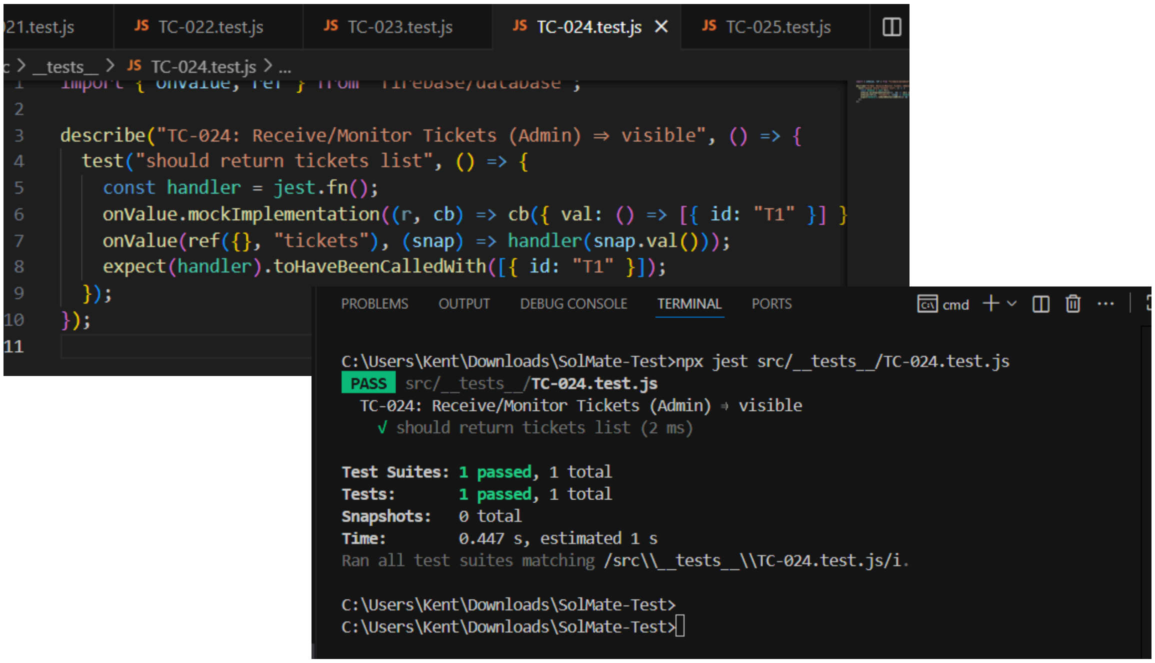


Figure 97: **Monitor User Ticket**

Proponent: Sepra, Kent Jerard | Module Name: Ticket Management

Unit Name: Ticket Status | Test Case:TC-025

Test Case Description: Status Ticket Management

Expected Results: Admin set ticket status | Date Tested: 10/11/25

Action Result: Performed as expected | Result:Passed

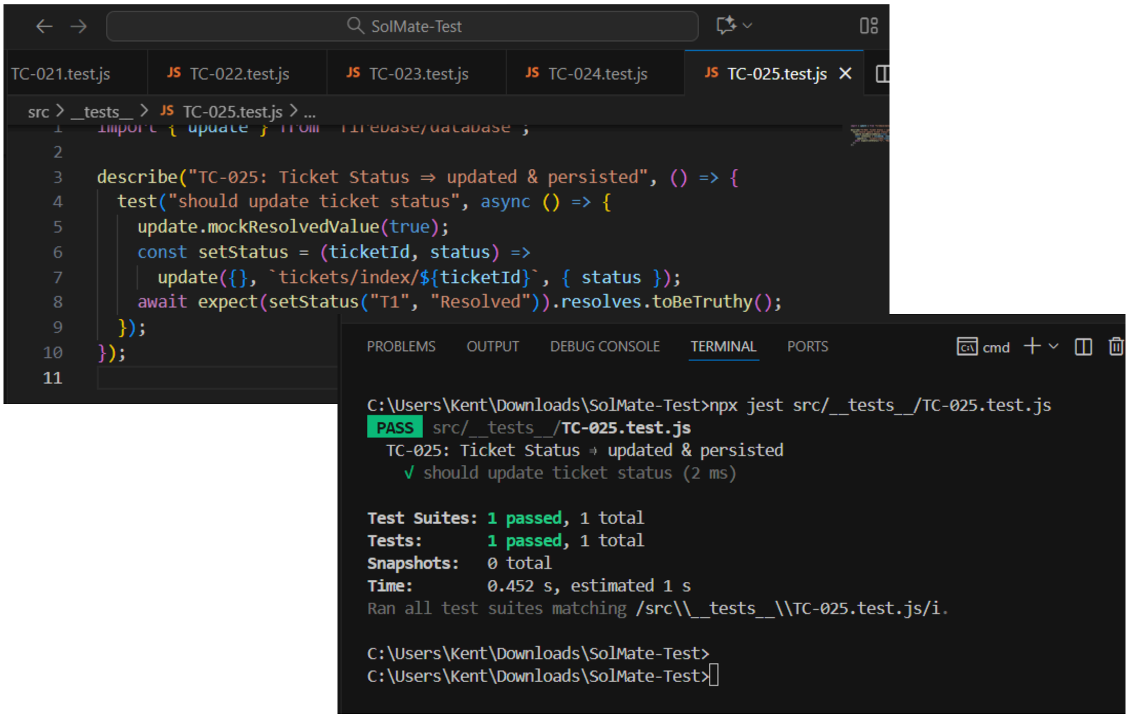


Figure 98: **Set Ticket Status**

Proponent: Sepra, Kent Jerard — Module Name: Ticket Management

Unit Name: Reply Ticket — Test Case:TC-026

Test Case Description: Reply Management

Expected Results: Admin replies a ticket — Date Tested: 10/11/25

Action Result: Performed as expected — Result:Passed

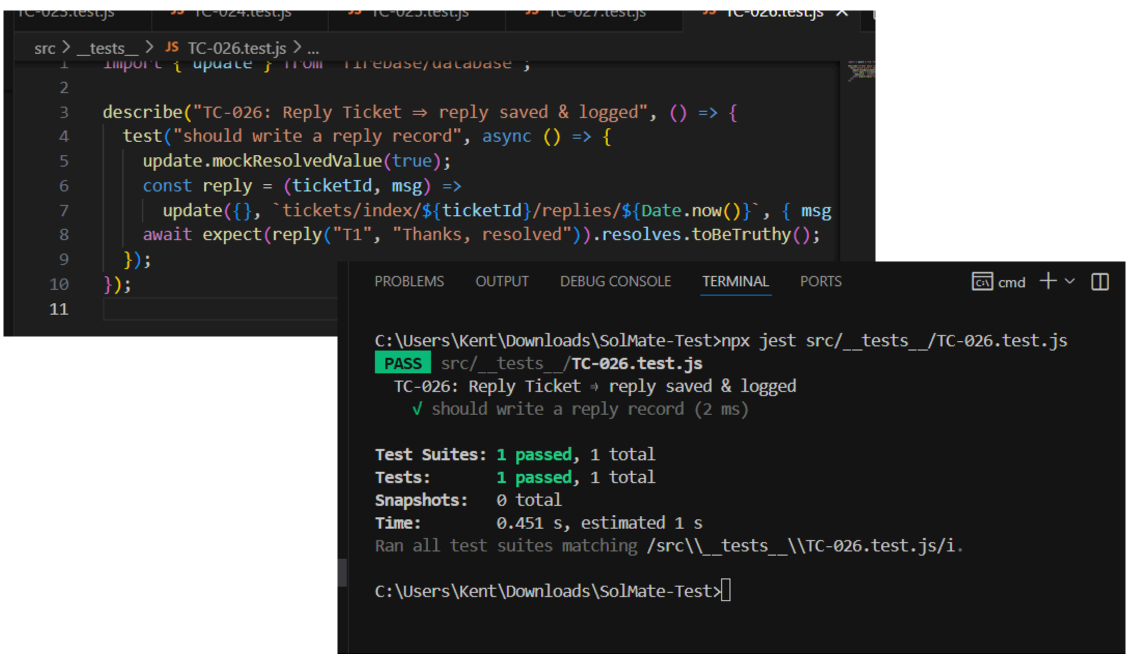


Figure 99: **Ticket Reply Management**

Proponent: Sepra, Kent Jerard | Module Name: Reports Generation

Unit Name: View User Reports | Test Case:TC-027

Test Case Description: View history/previous activity

Expected Results: View all history | Date Tested: 10/11/25

Action Result: Performed as expected | Result:Passed

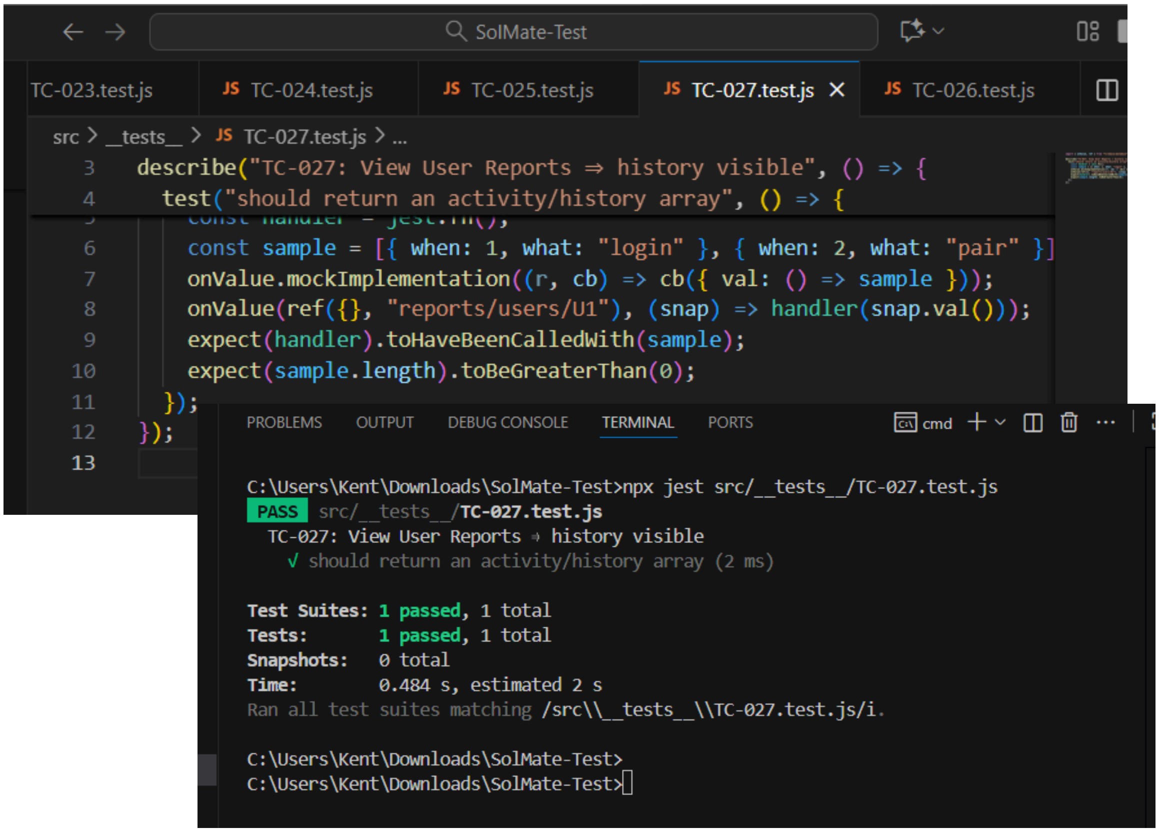


Figure 100: **Generate Report**

Proponent: Sepra, Kent Jerard | Module Name: Notification

Unit Name: Battery Alerts | Test Case:TC-028

Test Case Description: Display notification when battery ≤ 20%

Expected Results: Alert message appears | Date Tested: 11/2/25

Action Result: Performed as expected | Result:Passed

```
  test("Low-battery alert appears at 20% and 15%", () => {
    expect(batteryAlert(20)).toMatchObject({
      type: "battery",
      level: "low",
      message: expect.stringContaining("≤20%"),
    });
    expect(batteryAlert(15)).toMatchObject({ level: "low" });
  });
});
```

```
C:\Users\Kent\Desktop\SolMate-Test>npx jest src/__tests__/TC-028.test.js --verbose
 PASS  src/__tests__/TC-028.test.js
  TC-028: Battery Alerts — show message when battery ≤ 20%
    √ No alert above 20% (3 ms)
    √ Low-battery alert appears at 20% and 15% (4 ms)

Test Suites: 1 passed, 1 total
Tests:       2 passed, 2 total
Snapshots:   0 total
Time:        2.827 s
Ran all test suites matching /src\\__tests__\\TC-028.test.js/i.
```

Figure 101: **Battery Alert Notification**

Proponent: Sepra, Kent Jerard | Module Name: Notification

Unit Name: Critical Battery | Test Case:TC-029

Test Case Description: Display "Battery Critical" when ≤ 10%

Expected Results: Critical alert appears | Date Tested: 11/2/25

Action Result: Performed as expected | Result:Passed

```
describe("TC-029: Critical Battery — alert appears with timestamp", () => {
  const FIXED_NOW = 1_731_000_000_000; // deterministic time

  beforeAll(() => {
    jest.spyOn(Date, "now").mockReturnValue(FIXED_NOW);
  });

  afterAll(() => {
    Date.now.mockRestore();
  });

  test("No critical alert above 10%", () => {
    expect(criticalBatteryAlert(11)).toBeNull();
  });

  test("Critical alert at 10% and 5% with timestamp", () => {
    const a = criticalBatteryAlert
    const b = criticalBatteryAlert
```

```
C:\Users\Kent\Desktop\SolMate-Test>npx jest src/__tests__/TC-029.test.js
 PASS  src/__tests__/TC-029.test.js
  TC-029: Critical Battery — alert appears with timestamp
    √ No critical alert above 10% (3 ms)
    √ Critical alert at 10% and 5% with timestamp (2 ms)

Test Suites: 1 passed, 1 total
Tests:       2 passed, 2 total
Snapshots:   0 total
Time:        1.691 s, estimated 3 s
Ran all test suites matching /src\\__tests__\\TC-029.test.js/i.
```

Figure 102: **Critical Alert Notification**

Proponent: Sepra, Kent Jerard Module Name: Notification

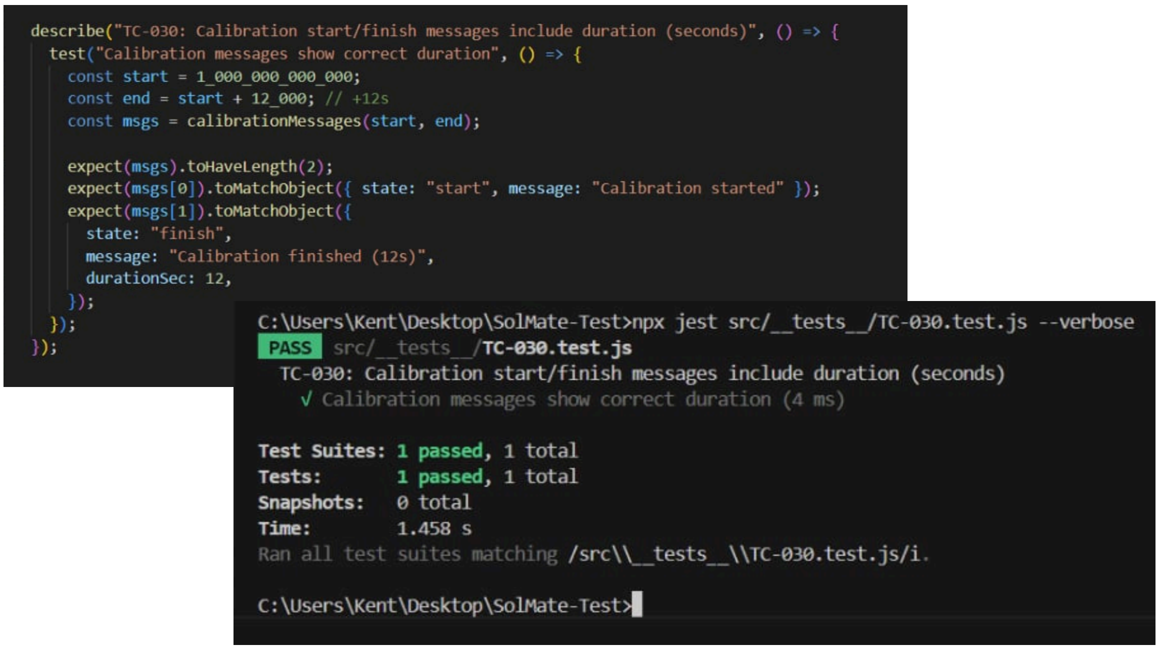
Unit Name: Calibration Updates Test Case:TC-030

Test Case Description: Display start and finish messages for calibration

Expected Results: Calibration started/finished” shown

Date Tested: 11/2/25

Action Result: Performed as expected Result:Passed



```
describe("TC-030: Calibration start/finish messages include duration (seconds)", () => {
  test("Calibration messages show correct duration", () => {
    const start = 1_000_000_000_000;
    const end = start + 12_000; // +12s
    const msgs = calibrationMessages(start, end);

    expect(msgs).toHaveLength(2);
    expect(msgs[0]).toMatchObject({ state: "start", message: "Calibration started" });
    expect(msgs[1]).toMatchObject({
      state: "finish",
      message: "Calibration finished (12s)",
      durationSec: 12,
    });
  });
});
```

```
C:\Users\Kent\Desktop\SolMate-Test>npx jest src/__tests__/TC-030.test.js --verbose
 PASS  src/__tests__/TC-030.test.js
  TC-030: Calibration start/finish messages include duration (seconds)
    √ Calibration messages show correct duration (4 ms)

Test Suites: 1 passed, 1 total
Tests:       1 passed, 1 total
Snapshots:   0 total
Time:        1.458 s
Ran all test suites matching /src\\__tests__\\TC-030.test.js/i.

C:\Users\Kent\Desktop\SolMate-Test>
```

Figure 103: **Calibration Notification**

Proponent: Sepra, Kent Jerard Module Name: Notification

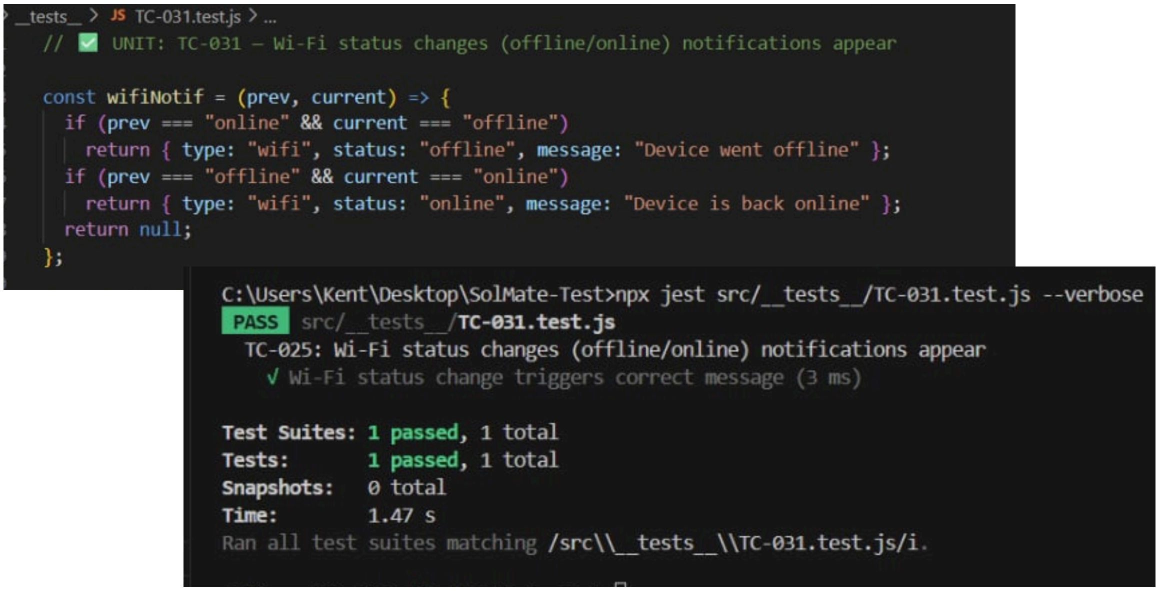
Unit Name: Wi-Fi Status Test Case:TC-031

Test Case Description: Show “Device went offline” and “Device back online”

Expected Results: Status updates display correctly

Date Tested: 11/2/25

Action Result: Performed as expected Result:Passed



```
> __tests__ > JS TC-031.test.js > ...
// ✅ UNIT: TC-031 – Wi-Fi status changes (offline/online) notifications appear

const wifiNotif = (prev, current) => {
  if (prev === "online" && current === "offline")
    return { type: "wifi", status: "offline", message: "Device went offline" };
  if (prev === "offline" && current === "online")
    return { type: "wifi", status: "online", message: "Device is back online" };
  return null;
};
```

```
C:\Users\Kent\Desktop\SolMate-Test>npx jest src/__tests__/TC-031.test.js --verbose
 PASS  src/__tests__/TC-031.test.js
  TC-025: Wi-Fi status changes (offline/online) notifications appear
    √ Wi-Fi status change triggers correct message (3 ms)

Test Suites: 1 passed, 1 total
Tests:       1 passed, 1 total
Snapshots:   0 total
Time:        1.47 s
Ran all test suites matching /src\\__tests__\\TC-031.test.js/i.
```

Figure 104: **<u>Connectivity Notification</u>**

Appendix E
INTEGRATION TESTING

Proponent: Noel, Kent Jyls

Module Name:Account Validation and Login

Date Tested: 10/11/25 Test Case ID: TC-001

Pre-Condition: Valid registration data

Expected Results: Newly created account can log in successfully.

Action Result: Performed as expected Result:Passed

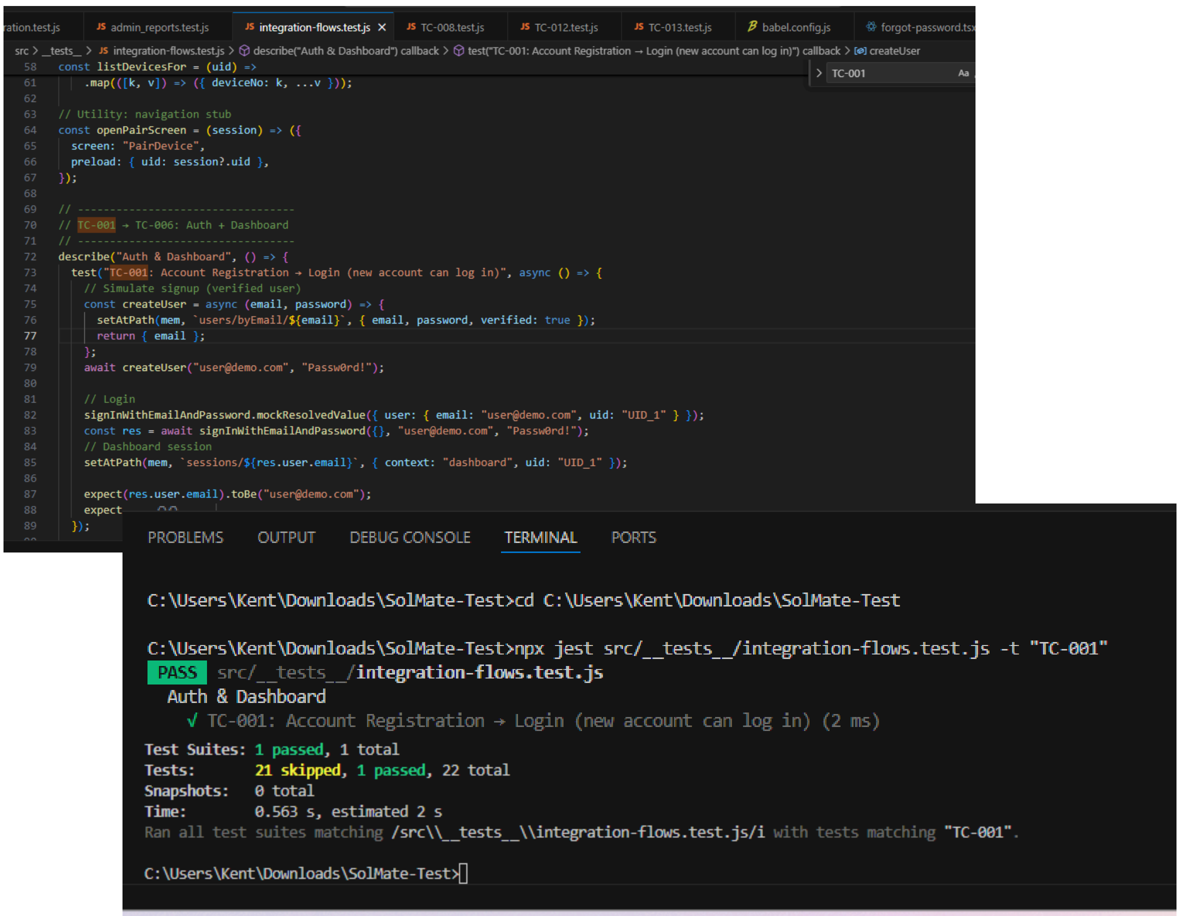


Figure 105: **<u>User Registration Test Result</u>**

Proponent: Noel, Kent Jyls

Module Name:Account Validation and Dashboard

Date Tested: 10/11/25 Test Case ID: TC-002

Pre-Condition: Account is verified and active

Expected Results: Dashboard renders with user context after login

Action Result: Performed as expected Result:Passed

```javascript
test("TC-002: Valid login → Dashboard renders with user context", async () => {
  signInWithEmailAndPassword.mockResolvedValue({ user: { email: "valid@test.com", uid: "UID_2" } });
  const res = await signInWithEmailAndPassword({}, "valid@test.com", "Password123");
  setAtPath(mem, `sessions/${res.user.email}`, { context: "dashboard", uid: "UID_2" });
  expect(mem.sessions["valid@test.com"].context).toBe("dashboard");
});
```

```
PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL   PORTS

C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-002"
 PASS  src/__tests__/integration-flows.test.js
  Auth & Dashboard
    √ TC-002: Valid login → Dashboard renders with user context (2 ms)

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.619 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-002".

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 106: **Dashboard Integration Flow**

Proponent: Noel, Kent Jyls

Module Name: Password Recovery and Account Validation

Date Tested: 10/11/25 Test Case ID: TC-003

Pre-Condition: Registered email exists; valid reset token not expired

Expected Results: Old password is rejected; new password accepted; login succeeds

Action Result: Performed as expected Result:Passed

```javascript
test("TC-003: Password recovery → old rejected, new accepted → login succeeds", async () => {
  setAtPath(mem, `users/byEmail/u@test.com`, { email: "u@test.com", password: "OLD", verified: true });

  // Apply reset (simulate)
  const applyReset = async (email, newPw) => {
    setAtPath(mem, `users/byEmail/${email}`, { email, password: newPw, verified: true });
  };
  await applyReset("u@test.com", "NEW123!");

  // Simulate login attempts
  signInWithEmailAndPassword
    .mockRejectedValueOnce(new Error("auth/wrong-password")) // old
    .mockResolvedValueOnce({ user: { email: "u@test.com", uid: "UID_3" } }); // new
  await expect(signInWithEmailAndPassword({}, "u@test.com", "OLD")).rejects.toThrow("auth/wrong-password");
  const res = await signInWithEmailAndPassword({}, "u@test.com", "NEW123!");
  expect(res.user.email).toBe("u@test.com");
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-003"
 PASS  src/__tests__/integration-flows.test.js
  Auth & Dashboard
    √ TC-003: Password recovery → old rejected, new accepted → login succeeds (13 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.548 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-00

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 107: **Password Validation Test**

Proponent: Noel, Kent Jyls

Module Name: Dashboard and Device Pairing

Date Tested: 10/11/25 Test Case ID: TC-004

Pre-Condition: User is logged in

Expected Results: Performed as expected

Action Result: Performed as expected Result:Passed

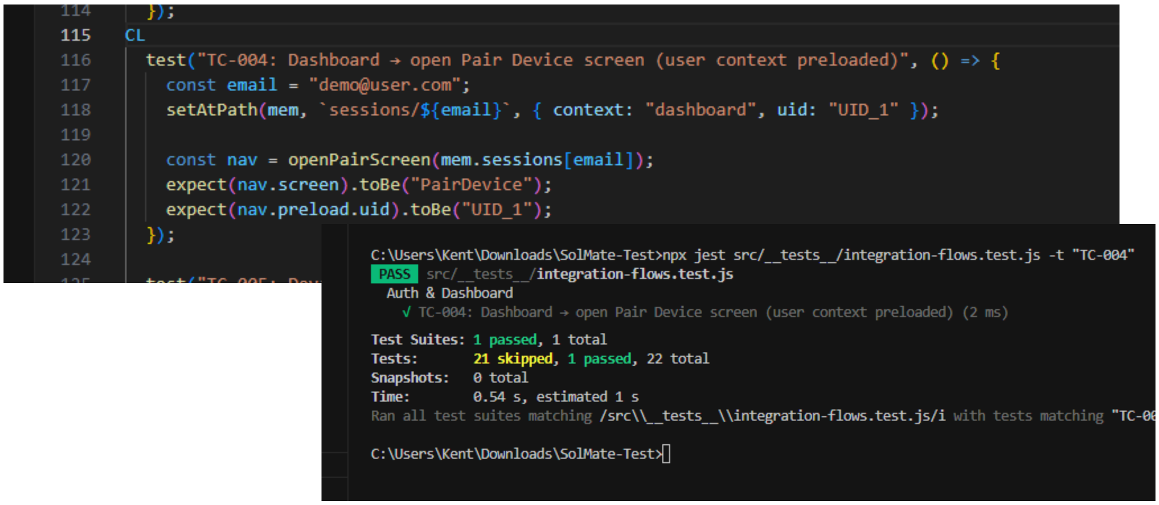


Figure 108: **Device Pairing Integration**

Proponent: Noel, Kent Jyls

Module Name: Device Pairing and Security & Access

Date Tested: 10/11/25 Test Case ID: TC-005

Pre-Condition: Device online; credentials valid

Expected Results: User–device binding is allowed and saved

Action Result: Performed as expected Result:Passed

Figure 109: <u>**Pairing Security Test**</u>

Proponent: Noel, Kent Jyls

Module Name: Device Pairing and Dashboard

Date Tested: 10/11/25 Test Case ID: TC-006

Pre-Condition: Successful pair or unpair operation has been performed

Expected Results: Paired device appears or disappears and status reflects correctly

Action Result: Performed as expected Result:Passed

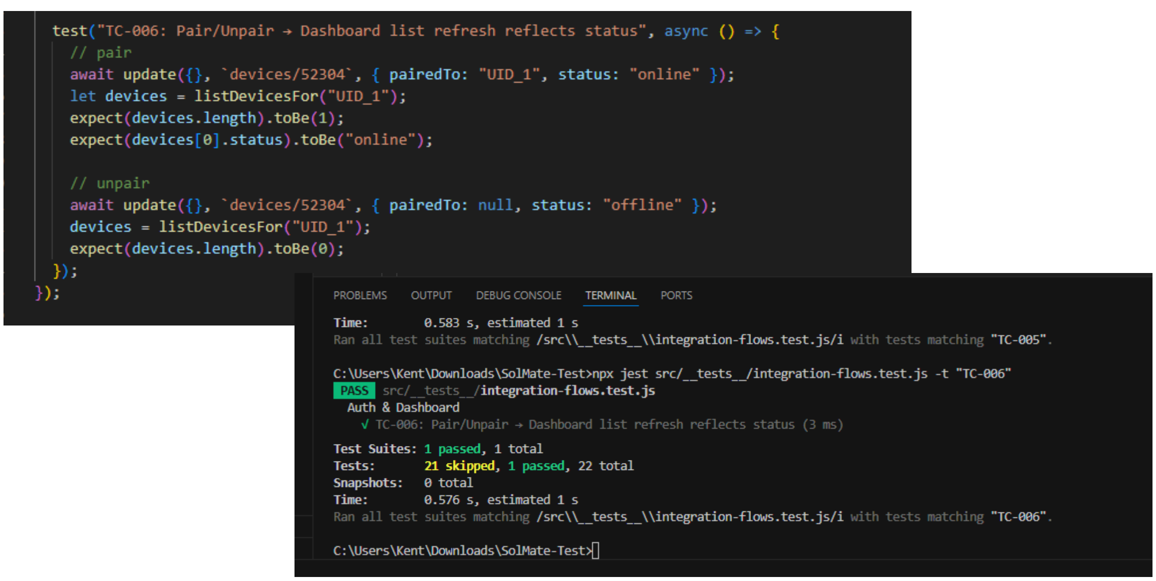


Figure 110: <u>**Device Status Update**</u>

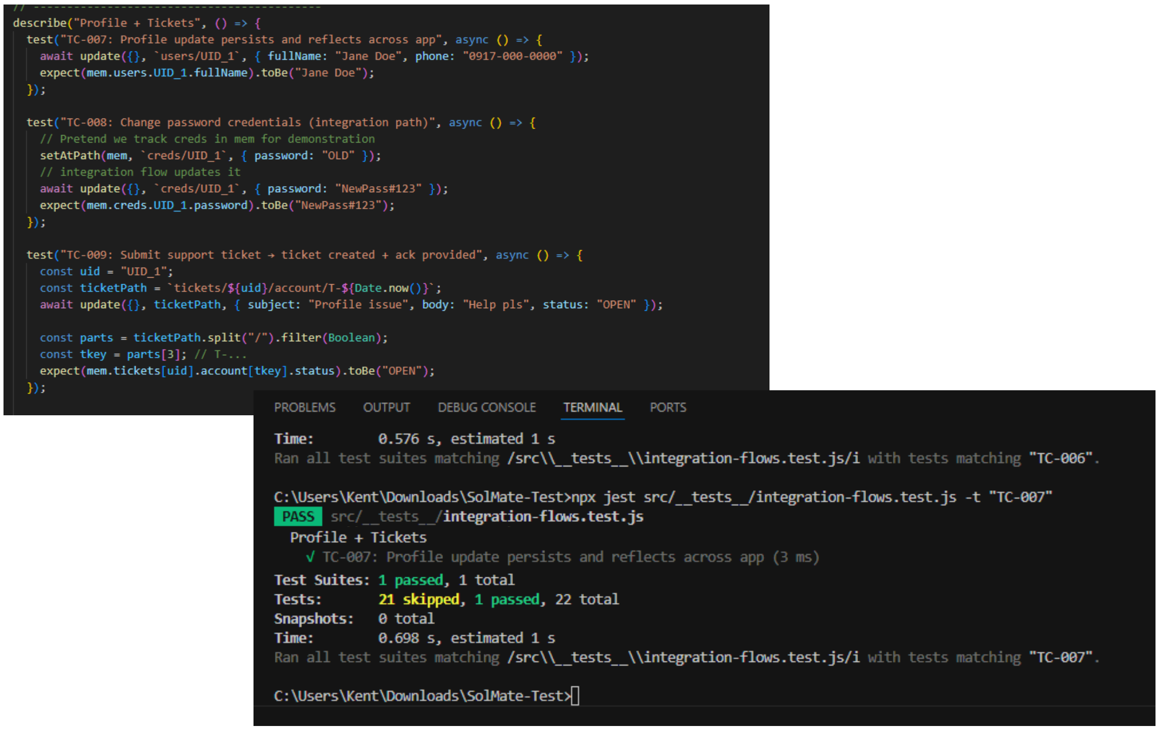
Proponent: Noel, Kent Jyls — Module Name: Profile Management

Date Tested: 10/11/25 — Test Case ID: TC-007

Pre-Condition: Authenticated user; valid fields

Expected Results: Profile changes are saved and reflected across the app

Action Result: Performed as expected — Result:Passed



```
describe("Profile + Tickets", () => {
  test("TC-007: Profile update persists and reflects across app", async () => {
    await update({}, `users/UID_1`, { fullName: "Jane Doe", phone: "0917-000-0000" });
    expect(mem.users.UID_1.fullName).toBe("Jane Doe");
  });

  test("TC-008: Change password credentials (integration path)", async () => {
    // Pretend we track creds in mem for demonstration
    setAtPath(mem, `creds/UID_1`, { password: "OLD" });
    // integration flow updates it
    await update({}, `creds/UID_1`, { password: "NewPass#123" });
    expect(mem.creds.UID_1.password).toBe("NewPass#123");
  });

  test("TC-009: Submit support ticket → ticket created + ack provided", async () => {
    const uid = "UID_1";
    const ticketPath = `tickets/${uid}/account/T-${Date.now()}`;
    await update({}, ticketPath, { subject: "Profile issue", body: "Help pls", status: "OPEN" });

    const parts = ticketPath.split("/").filter(Boolean);
    const tkey = parts[3]; // T-...
    expect(mem.tickets[uid].account[tkey].status).toBe("OPEN");
  });
```

```
PROBLEMS   OUTPUT   DEBUG CONSOLE   TERMINAL   PORTS

Time:        0.576 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-006".

C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-007"
PASS  src/__tests__/integration-flows.test.js
  Profile + Tickets
    √ TC-007: Profile update persists and reflects across app (3 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.698 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-007".

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 111: **User Profile Sync**

Proponent: Noel, Kent Jyls

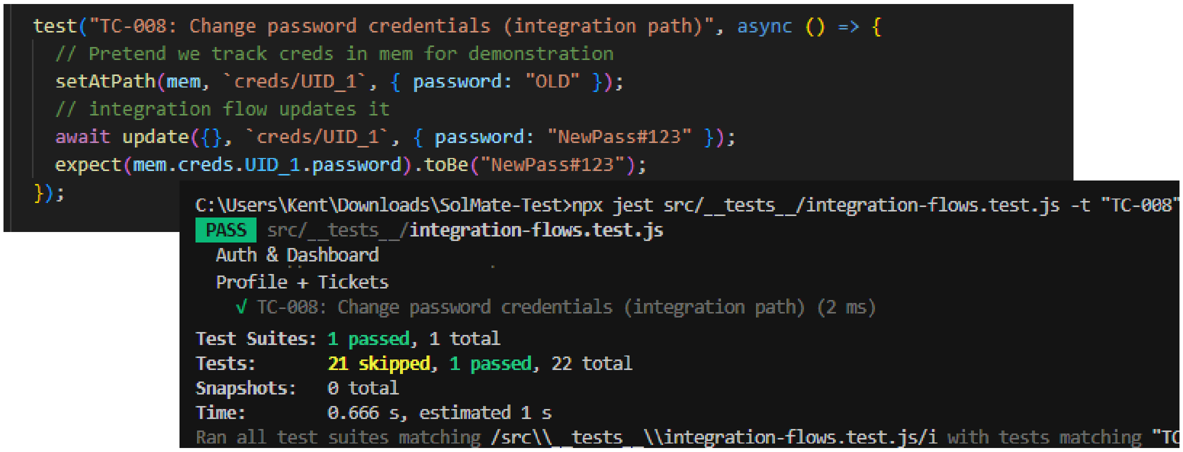
Module Name: Profile Management and User Management

Date Tested: 10/11/25 — Test Case ID: TC-008

Pre-Condition: Current password verified

Expected Results: Credentials updated

Action Result: Performed as expected — Result:Passed



```
test("TC-008: Change password credentials (integration path)", async () => {
  // Pretend we track creds in mem for demonstration
  setAtPath(mem, `creds/UID_1`, { password: "OLD" });
  // integration flow updates it
  await update({}, `creds/UID_1`, { password: "NewPass#123" });
  expect(mem.creds.UID_1.password).toBe("NewPass#123");
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-008"
 PASS  src/__tests__/integration-flows.test.js
  Auth & Dashboard
  Profile + Tickets
    √ TC-008: Change password credentials (integration path) (2 ms)

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.666 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC
```

Figure 112: **Credential Update Success**

Proponent: Noel, Kent Jyls

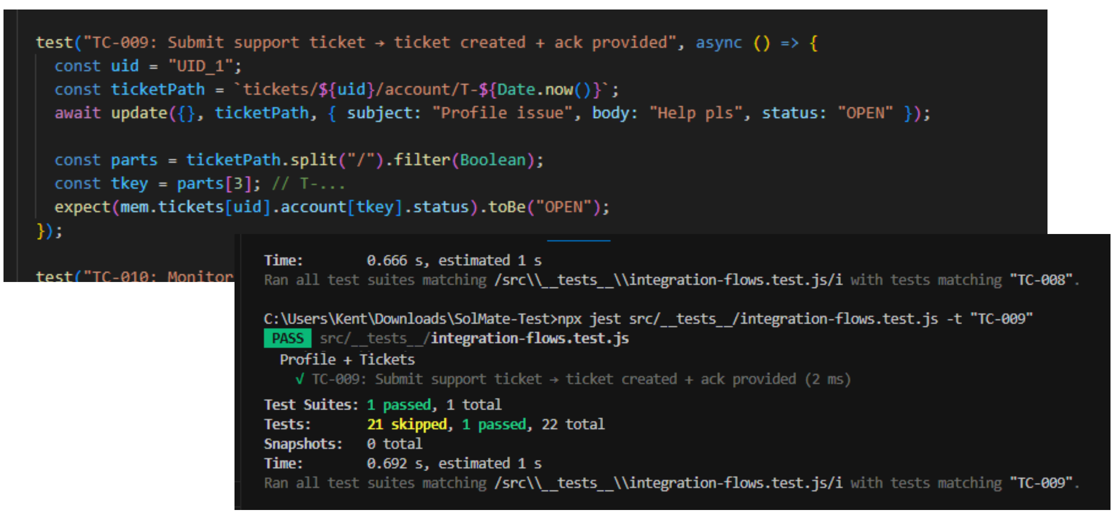
Module Name: Support Center and Tickets

Date Tested: 10/11/25 Test Case ID: TC-009

Pre-Condition: Form inputs valid

Expected Results: Ticket is created with reference number; confirmation issued

Action Result: Performed as expected Result:Passed



```
test("TC-009: Submit support ticket → ticket created + ack provided", async () => {
  const uid = "UID_1";
  const ticketPath = `tickets/${uid}/account/T-${Date.now()}`;
  await update({}, ticketPath, { subject: "Profile issue", body: "Help pls", status: "OPEN" });

  const parts = ticketPath.split("/").filter(Boolean);
  const tkey = parts[3]; // T-...
  expect(mem.tickets[uid].account[tkey].status).toBe("OPEN");
});

test("TC-010: Monitor
```

```
Time:        0.666 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-008".

C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-009"
 PASS  src/__tests__/integration-flows.test.js
  Profile + Tickets
    √ TC-009: Submit support ticket → ticket created + ack provided (2 ms)

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.692 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-009".
```

Figure 113: **Ticket Creation Success**

Proponent: Noel, Kent Jyls

Module Name: Device Monitoring and Energy Tracking

Date Tested: 10/11/25 Test Case ID: TC-010

Pre-Condition: Device is online and publishing Power Telemetry

Expected Results: Energy view shows current data consistent with telemetry

Action Result: Performed as expected Result:Passed

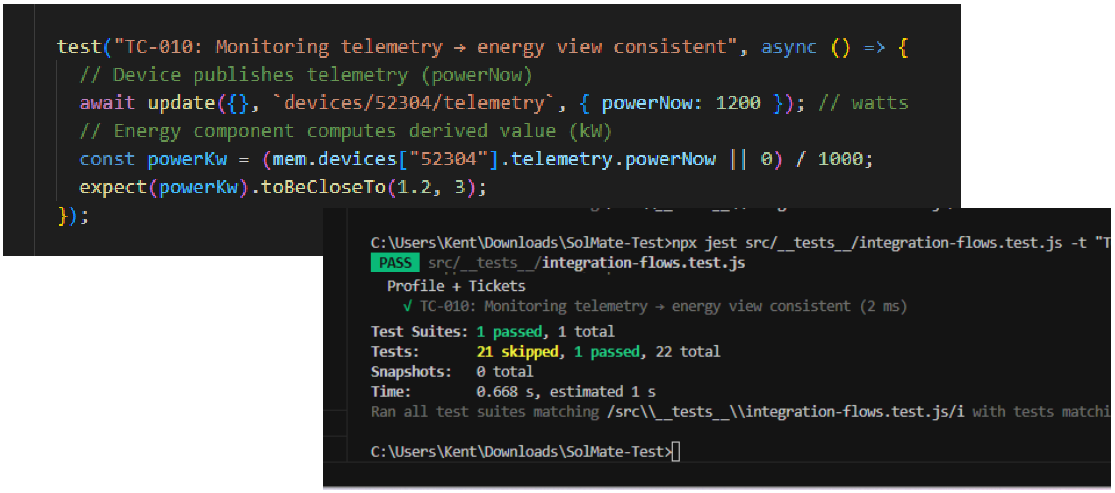


Figure 114: <u>**Energy Data Sync**</u>

Proponent: Noel, Kent Jyls

Module Name: Device Monitoring and Battery Level Monitoring

Date Tested: 10/11/25 Test Case ID: TC-011

Pre-Condition: Device is online and publishing Battery Output

Expected Results: Battery Level Shows

Action Result: Performed as expected Result:Passed

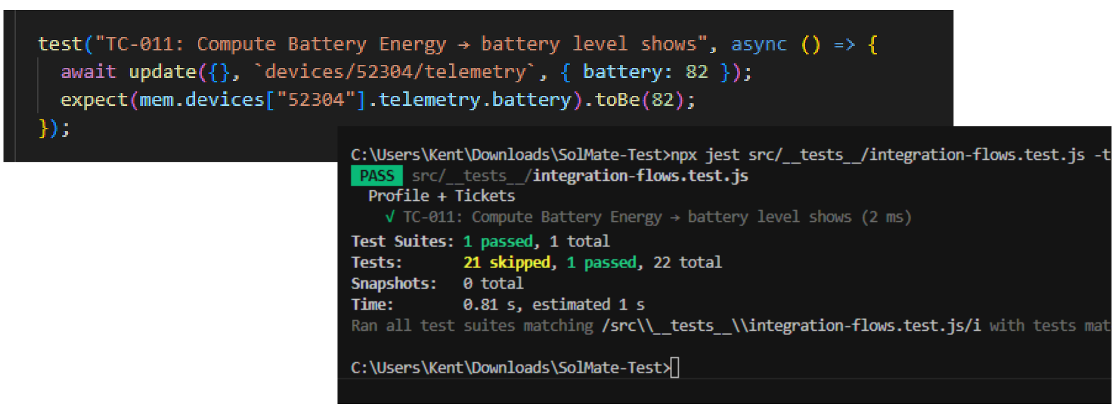


Figure 115: <u>**Battery Level Display**</u>

Proponent: Noel, Kent Jyls

Module Name: Device Monitoring and Device Data Logging

Date Tested: 10/11/25 Test Case ID: TC-012

Pre-Condition: Device is online and publishing power graphs

Expected Results: Energy view shows current data consistent with power graphs

Action Result: Performed as expected Result:Passed

```
    test("TC-012: Fetch power graphs → graph data visible", async () => {
      const series = [{ t: 1, wh: 0.4 }, { t: 2, wh: 0.5 }];
      await set({}, `devices/52304/dailyEnergy`, series);
      // onValue would return this; we read directly from mem to assert data presence
      expect((mem.devices["52304"].dailyEnergy || []).length).toBeGreaterThan(0);
    });
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t
 PASS  src/__tests__/integration-flows.test.js
  Profile + Tickets
    √ TC-012: Fetch power graphs → graph data visible (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.559 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests mat

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 116: **Power Data Logging**

Proponent: Noel, Kent Jyls

Module Name: Calibration and Duration Adjusted

Date Tested: 10/11/25 Test Case ID: TC-013

Pre-Condition: Authenticated owner

Expected Results: Duration is saved; Calibrate Now uses the updated value

Action Result: Performed as expected Result:Passed

```
describe("Calibration", () => {
  test("TC-013: Save new calibration duration → Calibrate Now uses updated value", async () => {
    await update({}, `devices/52304/calibration`, { durationMs: 30000 });
    // Now simulate pressing 'Calibrate Now' consuming the stored duration
    const durationUsed = mem.devices["52304"].calibration.durationMs;
    expect(durationUsed).toBe(30000);
  });

  test("TC-014: Save interval schedule → next calibration uses interval", async () => {
    await update({}, `devices/52304/calibration`, { intervalMinutes: 60 });
    const interval = mem.devices["52304"].calibration.intervalMinutes;
    expect(interval).toBe(60);
  });

  test("TC-015: Settings rename device persists across account", async () => {
    await update({}, `devices/52304`, { name: "Roof Panel A" });
    expect(mem.devices["52304"].name).toBe("Roof Panel A");
  });
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js
 PASS  src/__tests__/integration-flows.test.js
  Calibration
    √ TC-013: Save new calibration duration → Calibrate Now uses updated value (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.56 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests m

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 117: **Calibration Duration Saved**

Proponent: Noel, Kent Jyls

Module Name: Calibration and Interval Adjustment

Date Tested: 10/11/25 Test Case ID: TC-014

Pre-Condition: Interval configured

Expected Results: Next calibration occurs on the configured interval

Action Result: Performed as expected Result:Passed

```
test("TC-014: Save interval schedule → next calibration uses interval", async () => {
  await update({}, `devices/52304/calibration`, { intervalMinutes: 60 });
  const interval = mem.devices["52304"].calibration.intervalMinutes;
  expect(interval).toBe(60);
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-014"
 PASS  src/__tests__/integration-flows.test.js
  Calibration
    √ TC-014: Save interval schedule → next calibration uses interval (2 ms)

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.57 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC-014

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 118: **Calibration Interval Set**

Proponent: Noel, Kent Jyls

Module Name: Settings and Account Management

Date Tested: 10/11/25 Test Case ID: TC-015

Pre-Condition: Authenticated user; valid settings

Expected Results: Settings persist and reflect across the account

Action Result: Performed as expected Result:Passed

```
test("TC-015: Settings rename device persists across account", async () => {
  await update({}, `devices/52304`, { name: "Roof Panel A" });
  expect(mem.devices["52304"].name).toBe("Roof Panel A");
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js
 PASS  src/__tests__/integration-flows.test.js
  Calibration
    √ TC-015: Settings rename device persists across account (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.623 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests ma

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 119: **Account Settings Test**

Proponent: Noel, Kent Jyls

Module Name: Settings and Device Management

Date Tested: 10/11/25 Test Case ID: TC-016

Pre-Condition: Settings persist and reflect across the account

Expected Results: Disconnect removes device from account

Action Result: Performed as expected Result:Passed

```
test("TC-016: Settings disconnect device removes link", async () => {
  await update({}, `devices/52304`, { pairedTo: "UID_1" });
  await update({}, `devices/52304`, { pairedTo: null });
  expect(mem.devices["52304"].pairedTo).toBe(null);
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js
PASS src/__tests__/integration-flows.test.js
  Calibration
    √ TC-016: Settings disconnect device removes link (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.657 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests m

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 120: **Device Disconnect Success**

Proponent: Noel, Kent Jyls

Module Name: Device Ticket and Ticket Creation

Date Tested: 10/11/25 Test Case ID: TC-017

Pre-Condition: Logged-in user

Expected Results: Ticket created with device metadata; confirmation provided

Action Result: Performed as expected Result:Passed

```
test("TC-017: Device-scoped ticket includes device metadata", async () => {
  const uid = "UID_1";
  const deviceNo = "52304";
  const path = `tickets/${uid}/device/${deviceNo}/T-${Date.now()}`;
  await update({}, path, { issue: "No data", device: deviceNo });
  const tkey = path.split("/").filter(Boolean).pop();
  expect(mem.tickets[uid].device[deviceNo][tkey].device).toBe("52304");
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t
PASS src/__tests__/integration-flows.test.js
  Calibration
    √ TC-017: Device-scoped ticket includes device metadata (3 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.694 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matc

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 121: **Device Ticket Creation**

Proponent: Noel, Kent Jyls

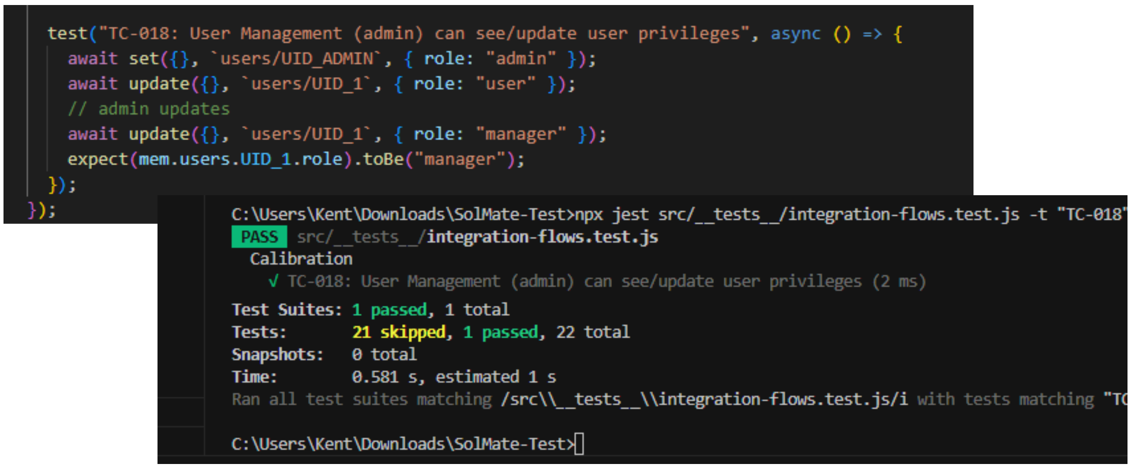
Module Name: User Management and Account Management

Date Tested: 10/11/25 Test Case ID: TC-018

Pre-Condition: Admin account is logged in

Expected Results: Admin oversees User account

Action Result: Performed as expected Result:Passed



```
test("TC-018: User Management (admin) can see/update user privileges", async () => {
  await set({}, `users/UID_ADMIN`, { role: "admin" });
  await update({}, `users/UID_1`, { role: "user" });
  // admin updates
  await update({}, `users/UID_1`, { role: "manager" });
  expect(mem.users.UID_1.role).toBe("manager");
});
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t "TC-018"
PASS src/__tests__/integration-flows.test.js
  Calibration
    √ TC-018: User Management (admin) can see/update user privileges (2 ms)

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.581 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests matching "TC

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 122: **User Account Control**

Proponent: Noel, Kent Jyls

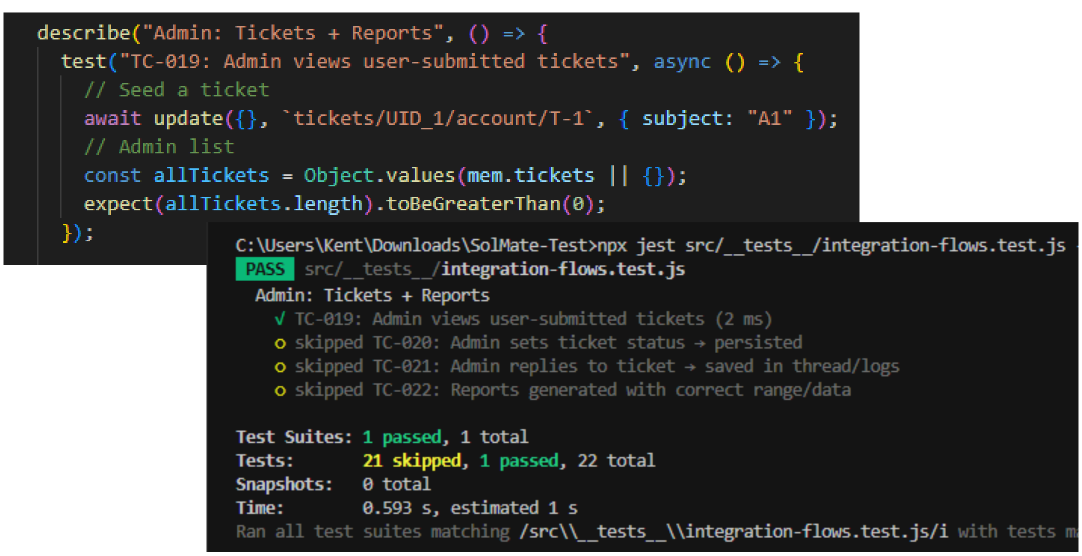
Module Name: Receive Tickets and Ticket Records

Date Tested: 10/11/25 Test Case ID: TC-019

Pre-Condition: User has submitted a ticket

Expected Results: Admin receives tickets

Action Result: Performed as expected Result:Passed



```
describe("Admin: Tickets + Reports", () => {
  test("TC-019: Admin views user-submitted tickets", async () => {
    // Seed a ticket
    await update({}, `tickets/UID_1/account/T-1`, { subject: "A1" });
    // Admin list
    const allTickets = Object.values(mem.tickets || {});
    expect(allTickets.length).toBeGreaterThan(0);
  });
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js
PASS src/__tests__/integration-flows.test.js
  Admin: Tickets + Reports
    √ TC-019: Admin views user-submitted tickets (2 ms)
    o skipped TC-020: Admin sets ticket status → persisted
    o skipped TC-021: Admin replies to ticket → saved in thread/logs
    o skipped TC-022: Reports generated with correct range/data

Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.593 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests m
```

Figure 123: **Admin Receives Tickets**

Proponent: Noel, Kent Jyls

Module Name: Ticket Status and Ticket Records

Date Tested: 10/11/25 Test Case ID: TC-020

Pre-Condition: A ticket exists

Expected Results: Admin receives tickets

Action Result: Performed as expected Result:Passed

```
test("TC-020: Admin sets ticket status → persisted", async () => {
  await update({}, `tickets/index/TX-1`, { status: "OPEN" });
  await update({}, `tickets/index/TX-1`, { status: "Resolved" });
  expect(mem.tickets.index["TX-1"].status).toBe("Resolved");
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js -t
 PASS  src/__tests__/integration-flows.test.js
  Admin: Tickets + Reports
    √ TC-020: Admin sets ticket status → persisted (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.654 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests mat

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 124: **<u>Ticket Status Records</u>**

Proponent: Noel, Kent Jyls

Module Name: Reply Tickets and Admin Dashboard

Date Tested: 10/11/25 Test Case ID: TC-021

Pre-Condition: Ticket thread exists

Expected Results: Admin replies tickets

Action Result: Performed as expected Result:Passed

```
test("TC-021: Admin replies to ticket → saved in thread/logs", async () => {
  const key = `tickets/index/TX-2/replies/R-${Date.now()}`;
  await update({}, key, { msg: "We are checking" });
  const parts = key.split("/").filter(Boolean);
  const tid = parts[2]; // TX-2
  expect(mem.tickets.index[tid].replies).toBeTruthy();
});
```

```
C:\Users\Kent\Downloads\SolMate-Test>npx jest src/__tests__/integration-flows.test.js
 PASS  src/__tests__/integration-flows.test.js
  Admin: Tickets + Reports
    √ TC-021: Admin replies to ticket → saved in thread/logs (2 ms)
Test Suites: 1 passed, 1 total
Tests:       21 skipped, 1 passed, 22 total
Snapshots:   0 total
Time:        0.579 s, estimated 1 s
Ran all test suites matching /src\\__tests__\\integration-flows.test.js/i with tests

C:\Users\Kent\Downloads\SolMate-Test>
```

Figure 125: **<u>Admin Replies Tickets</u>**

Proponent: Noel, Kent Jyls

Module Name: Reports Generation and Dashboard / Database

Date Tested: 10/11/25 Test Case ID: TC-022

Pre-Condition: System stores user activity

Expected Results: Admin generates user reports

Action Result: Performed as expected Result:Passed

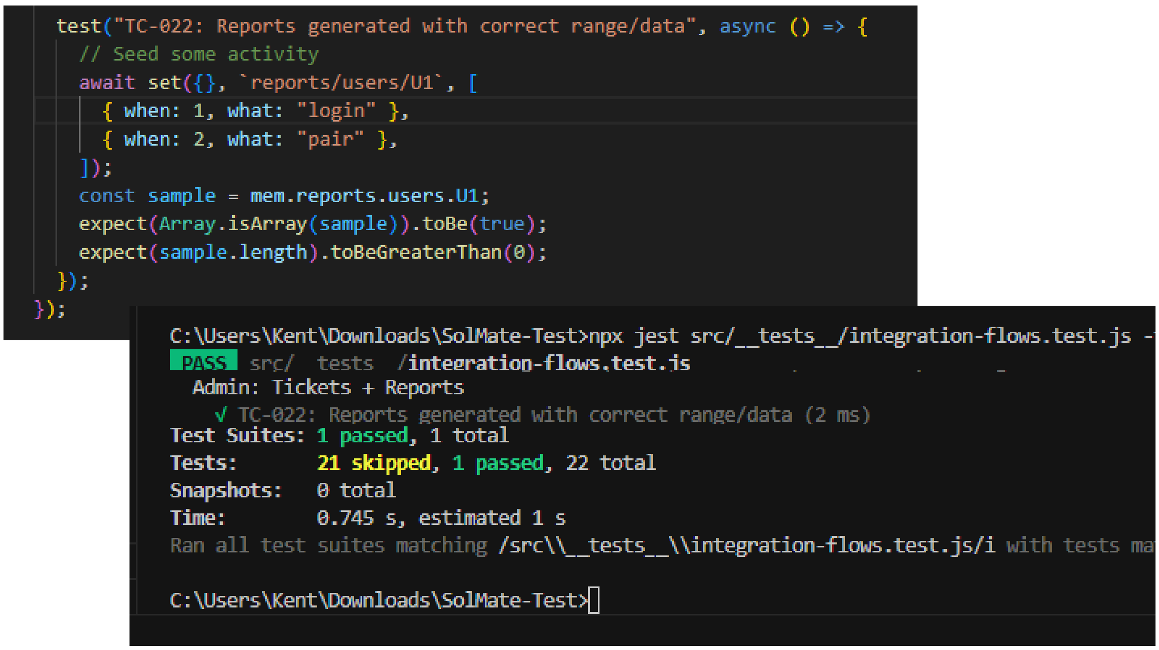


Figure 126: **Admin Generates Reports**

Proponent: Noel, Kent Jyls

Module Name: Notification and Device Monitoring

Date Tested: 11/2/25 Test Case ID: TC-023

Pre-Condition: Device is online and publishing data

Expected Results: Battery and calibration alerts appears

Action Result: Performed as expected Result:Passed

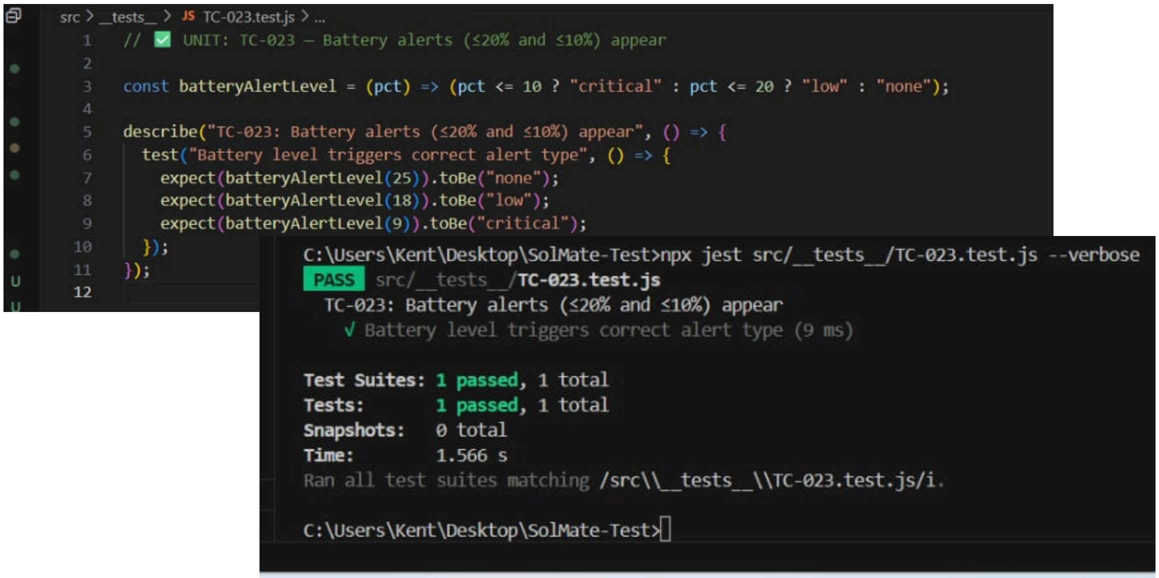


Figure 127: **<u>Device Monitoring Notification</u>**

Proponent: Noel, Kent Jyls

Module Name: Notification and Calibration

Date Tested: 11/2/25 Test Case ID: TC-024

Pre-Condition: Calibration is triggered manually or on interval

Expected Results: Start and finish messages appear with “number seconds” duration

Action Result: Performed as expected Result:Passed

Figure 128: **<u>Notification and Calibration Integration</u>**

Proponent: Noel, Kent Jyls

Module Name: Notification and System / IoT

Date Tested: 11/2/25 Test Case ID: TC-025

Pre-Condition: Wi-Fi connection changes state

Expected Results: “Device offline/online” notifications appear

Action Result: Performed as expected Result:Passed

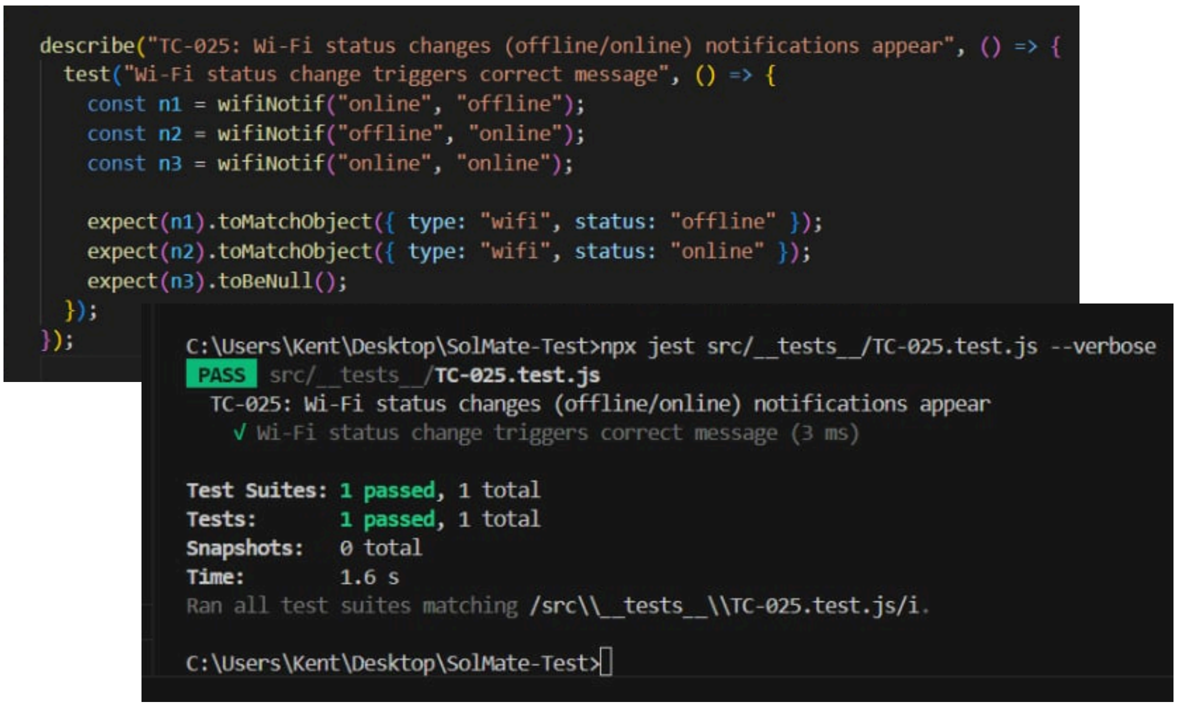


Figure 129: **IoT State Change Notification**

Proponent: Noel, Kent Jyls

Module Name: Notification and Dashboard

Date Tested: 11/2/25 Test Case ID: TC-026

Pre-Condition: User logged in and viewing Notification tab

Expected Results: Notifications grouped by date, deletions and clear-all actions update Firebase in real time

Action Result: Performed as expected Result:Passed

```
describe("TC-026: Notification Center actions (group, delete, clear-all)", () => {
  test("Group, delete, clear-all work correctly", () => {
    const map = {
      "N-1": { id: "N-1", day: "2025-11-02", message: "Low" },
      "N-2": { id: "N-2", day: "2025-11-02", message: "Offline" },
      "N-3": { id: "N-3", day: "2025-11-01", message: "Finished" },
    };

    const grouped = groupByDate(Object.values(map));
    expect(Object.keys(grouped)).toEqual(["2025-11-02", "2025-11-01"]);

    const afterDelete = deleteNotif(map, "N-2");
    expect(afterDelete["N-2"]).toBeUndefined();

    const emptied = clearAll();
    expect(Object.keys(emptied)).toHaveLength(0);
  });
});
```

```
C:\Users\Kent\Desktop\SolMate-Test>npx jest src/__tests__/TC-026.test.js --verbose
 PASS  src/__tests__/TC-026.test.js
  TC-026: Notification Center actions (group, delete, clear-all)
    √ Group, delete, clear-all work correctly (4 ms)

Test Suites: 1 passed, 1 total
Tests:       1 passed, 1 total
Snapshots:   0 total
Time:        1.43 s
Ran all test suites matching /src\\__tests__\\TC-026.test.js/i.

C:\Users\Kent\Desktop\SolMate-Test>
```

Figure 130: **Notification and Dashboard Real-Time Integration**

Appendix F

Ethics Committee Protocol Approval

University of Cebu
Research Ethics Committee

PROTOCOL APPROVAL

Form 2.7

August 13, 2025

Protocol Version Approved: One (1)
ICF Version Approved: One (1)

LINZEL MARIE P. PACIENCIA
University of Cebu
LM Campus

Re: **BSIT(3)-2025-08-001.** **SOLMATE: SMART IOT SUN-TRACKING SOLAR PANEL SYSTEM WITH MOBILE MONITORING AND ENERGY OPTIMIZATION**

We wish to inform you that your study protocol under (expedited/full board review), is hereby granted approval for implementation by the UCREC. This ethical clearance is valid for one year from August 13, 2025 until expiration date August 13, 2026.

Investigator Responsibilities after Approval:

- Submit document amendments for REC approval before implementing them
- Submit RNE's reports to the REC within 14 days
- Submit progress report every 12 months
- Submit final report after completion of protocol procedures at the study site
- Report protocol deviation/ violation
- Comply with all relevant international and national guidelines and regulations
- Abide by the principles of good clinical practice and ethical research
- Apply for continuing review if conduct of study will last more than 1 year.
- Be prepared for a site visit by members of the UCAREC.
- Submit Continuing Review before expiration of approval

Very truly yours,

DR. JUANITO N. ZUASULA, JR. MD
Chair, UCREC

Appendix G

Grammarly Result

Appendix H

2S - COMPLIANCE CHECKLIST FOR ORAL DEFENSE PHASE

Appendix I

4S - ORAL DEFENSE PAYMENT FORM

Appendix J

9S - ASSESSMENT RUBRICS FOR ORAL DEFENSE PHASE

Appendix K

11S - STATISTICIAN / CONTENT EXPERT'S ACCEPTANCE

Appendix L

26S - PANEL MEMBER'S ATTENDANCE SHEET FOR PROPOSAL HEARING / ORAL DEFENSE