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EcoVolt: An AI-Powered Agrowaste Electricity Support System using EFO Algorithm

A Capstone Project Submitted to the Faculty of Information Technology Department of John Paul College, MG Andaya Compound, Odiong, Roxas, Oriental Mindoro

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BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY

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CHAPTER 1

INTRODUCTION

Project Context

The Philippines, like many developing countries, faces significant challenges in rural electrification, waste management, and climate vulnerability. In agricultural areas, access to energy is often limited due to reliance on non-renewable fuels and a lack of dependable infrastructure. Meanwhile, agricultural waste, including rice husks, corn stalks, and organic residues, accumulates in large amounts. This waste is often unmanaged and can harm the environment. This situation provides a chance to see waste as a resource with help from Information Technology.

EcoVolt is an AI-driven system designed to convert agricultural waste into energy. It integrates energy management, real-time data analysis, and a cloud-based web application. The system turns agricultural waste into electricity using biomass processing units equipped with sensors. The pilot project is located at Faminialagao Farm in Maraska, Roxas, Oriental Mindoro, chosen for its consistent availability of biomass and importance to rural energy development. The system focuses on devices like microcontrollers, sensors, and energy converters, and includes expert advice from mechanical and electrical engineers to ensure reliability and safety.

At the heart of EcoVolt is the Energy Flow Optimization algorithm, which uses machine learning to improve performance. Regression models predict biomass input, neural networks establish input-output relationships, and reinforcement learning fine-tunes operational settings using real-time data. These models train on both synthetic and historical data, allowing the system to adjust quickly to changes in biomass quality, energy demand, and environmental factors. The web analytics integration enables ongoing monitoring of energy supply, device condition, and usage trends, providing useful insights for users and stakeholders.

The cloud-connected web platform is the digital interface for interacting with the system. Through a graphical user interface, users such as farmers, technicians, and local officials can access system data remotely, receive alerts, and view interactive dashboards. The platform allows secure data syncing, predictive maintenance, and automatic reporting. Reports are generated daily, weekly, and monthly, offering insights into energy conversion efficiency, biomass use, and environmental effects. This empowers users to make informed choices, improve energy efficiency, and engage in sustainable practices

EcoVolt is designed for modular scalability, making it adaptable to different farm sizes and energy needs. Each unit works independently but can connect with others for community-wide use. The system supports integration with existing grid infrastructure and can be customized based on local conditions and technologies. By combining AI, IoT,

and cloud computing, EcoVolt presents a new approach to rural electrification that is data-driven, adaptable, and environmentally sound.

The research method combines technical development with field validation. Hardware will be tested in different environmental conditions, while the software will be assessed through user studies and feedback. Interviews and surveys will evaluate the effectiveness of the graphical interface, the clarity of data, and the overall impact on energy usage. This mixed-method approach ensures EcoVolt is technically reliable and socially relevant.

Ultimately, EcoVolt supports broader sustainable development goals by promoting clean energy access, responsible consumption, and climate resilience. It aligns with SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). By applying IT innovations to turn waste into energy, EcoVolt changes the role of technology in caring for the environment and empowering rural communities. It is more than just a system; it is a platform for inclusive, intelligent, and sustainable energy change.

Objectives of the Study

This study aims to design and develop **EcoVolt**, an AI-powered Agrowaste-to-Energy Conversion System integrated with a cloud-connected monitoring platform tailored for rural and agricultural electrification.

1. Convert agricultural waste into electricity by using sensor-integrated biomass processing from Faminialagao Farm.

2. Use AI algorithms to optimize energy flow smartly.

3. Create a web application with real-time monitoring, alerts, and a user-friendly

4. Implement cloud-based data syncing and remote access.

5. Produce analysis reports on production using web analytics and data visualization tools.

Scope and Limitation of the Study

The scope of the design and development of EcoVolt, an AI-powered Agrowaste-to-electricity system, combined with a cloud-based monitoring platform, encompasses the creation of a functional system that transforms agricultural waste into usable energy using a smart Energy Flow Optimization (EFO) algorithm. The system integrates sensors, machine learning models, and a web application to provide a user interface for performance visualization and real-time monitoring.

The system will utilize Agrowaste sourced from the Faminialagao Farm to generate energy. The research will be conducted in selected agricultural

communities, evaluating EcoVolt's performance in terms of energy efficiency, adaptability, and usability.

The scope also includes testing operational parameters under different biomass inputs, assessing the performance of the system in varying environmental conditions, and monitoring the real-time flow of data for optimization. This will involve evaluating how well the system adapts to changes in biomass quality, energy production rates, and local grid demand.

However, there are potential challenges related to the accuracy and reliability of the sensors used to measure biomass input, energy output, and environmental factors. Sensor performance may differ based on brand specifications, installation processes, and environmental wear over time. Additionally, the system's reliance on machine learning and real-time data

Optimization could be influenced by intermittent internet connectivity or limitations in computational resources. The effectiveness of the EFO algorithm will also depend on the availability and quality of historical data, which may vary by region and agricultural cycle.

Furthermore, environmental conditions such as humidity, temperature fluctuations, and exposure to corrosive organic waste may affect the performance and longevity of microcontrollers and hardware components. Finally, the scalability of the EcoVolt system may be constrained by geographic or infrastructure differences in rural communities, particularly where access to technology and internet connectivity is limited.

Conceptual Framework

The figure below shows the input, process, and output of the development of our project.

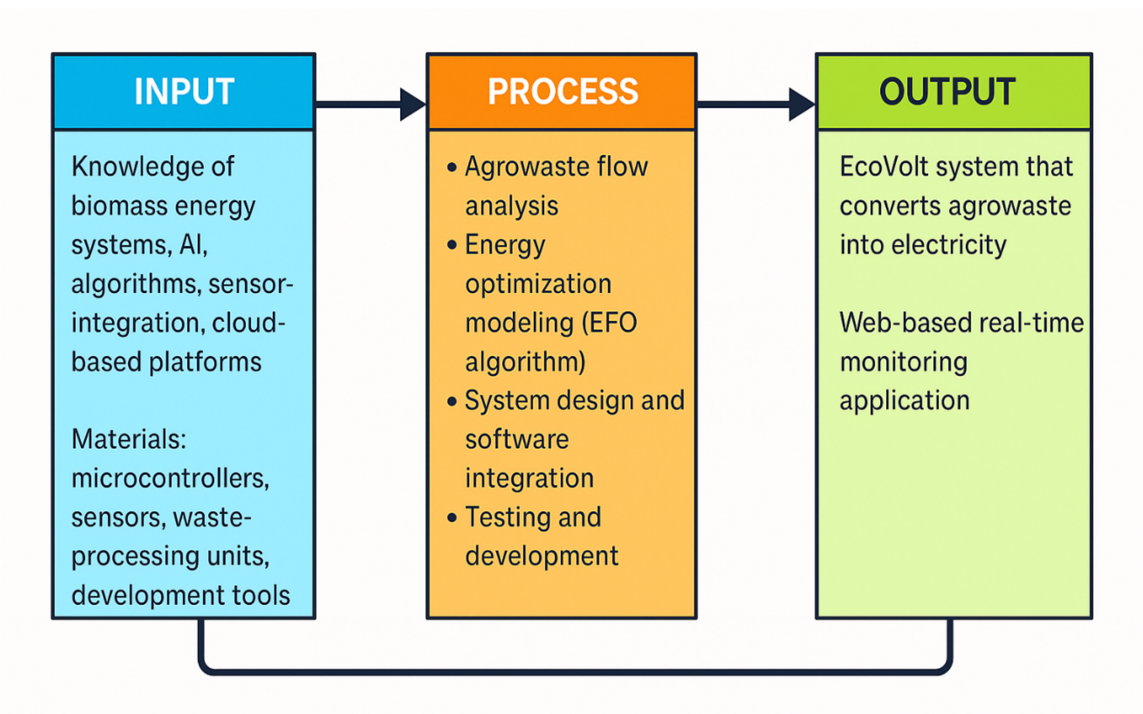


Figure 1. Conceptual Framework

Figure 1. This shows the conceptual framework of the study follows the Input–Process–Output (IPO) model to illustrate the system development and implementation of EcoVolt: an AI-powered Agrowaste-to-Energy Conversion System. The **input** involves gathering essential knowledge about biomass energy systems, artificial intelligence algorithms, sensor integration, and cloud-based

Platforms. It also includes the procurement of materials such as microcontrollers, sensors, waste-processing units, and development tools required to build the system. The **process** encompasses the stages of research and development, including the analysis of Agrowaste flow, energy optimization modeling through the EFO algorithm, system design, software integration, and testing. During this phase, the researchers study existing problems in waste-to-energy applications and apply machine learning techniques to generate adaptable solutions. The **output** is the fully developed EcoVolt system that converts agrowaste into electricity while continuously optimizing operations for maximum efficiency. It provides real-time monitoring via a web-based application and demonstrates sustainable energy generation suitable for deployment in rural and agricultural communities.

Definition of Terms

For clarification and to comprehend the study better, the following important terms are well defined.

Agrowaste, organic waste materials from agricultural activities, includes crop residues, husks, and spoiled harvests. These materials are used as input for biomass energy production.

EcoVolt is the proposed AI-powered system that converts agricultural waste into usable electricity. It uses a smart optimization algorithm and real-time monitoring tools.

The Energy Flow Optimization (EFO) Algorithm is a machine learning-based model. It analyzes past and present energy data to adjust system operations for better efficiency and sustainability.

The Biomass Processing Unit is a physical part of the system. It converts Agrowaste into biogas or syngas using technologies like anaerobic digestion or thermal gasification.

Artificial Intelligence (AI) is a field of computer science. It focuses on creating systems that can learn, reason, and adapt. In this case, it helps optimize energy production from biomass.

The Cloud-Based Platform is an online system that connects hardware components and monitoring tools. It allows users to see real-time data, receive notifications, and manage energy flows remotely.

Sensors are devices placed throughout the system. They track variables such as biomass quantity, gas output, temperature, and environmental conditions.

A Microcontroller is a small integrated circuit. It manages and controls the hardware operations of the EcoVolt system based on sensor input.

Optimization is the process of improving energy generation and system performance. It involves adjusting operational variables using mathematical models and algorithms.

Real-Time Monitoring involves continuously tracking and displaying system status and performance metrics. This enables immediate feedback and decision-making.

Sustainability is about minimizing waste and maximizing efficiency. It ensures long-term balance in environmental and operational aspects of energy systems.

CHAPTER 2

REVIEW OF RELATED LITERATURE/SYSTEM

This chapter presents the related literature and systems that the researchers considered to strengthen the importance of the present study. It also presents the synthesis of the art to fully understand the research for better comprehension of the study.

Related Literature

According to Arya, Sharma, and Tripathi (2023), Artificial Intelligence and Machine Learning have become important tools in waste-to-energy systems. They enable predictive analysis and smart optimization. By using regression models and time-series forecasting, AI can predict biomass input and energy demand with high accuracy. This allows systems like EcoVolt to adjust operational settings in real time. As a result, energy conversion efficiency improves and waste is reduced. Integrating AI not only boosts sustainability but also cuts down on manual work, lowers operational costs, and supports long-term environmental goals.

According to Melinda, Williams, and Anderson (2024), AI integration in waste-to-energy conversion improves process monitoring, automated sorting, and energy forecasting. Their study shows that AI-driven systems can reduce environmental impact

while increasing energy yield, which supports EcoVolt's goal of sustainable Agrowaste transformation.

According to Fang, Yu, and Osman (2023), artificial intelligence in smart cities has changed waste logistics by cutting transportation distances by up to 36.8% and raising sorting accuracy to nearly 99%. These findings back EcoVolt's use of AI for efficient biomass collection and classification.

According to Sinthiya, Chowdhury, and Haque (2022), AI-based smart waste management systems solve complex problems and boost operational efficiency. Their systematic review shows how machine learning models can optimize waste segregation and energy recovery, which is key to EcoVolt's flexible design.

According to Mukherjee and Cugurullo (2020), AI and robotics in urban waste treatment plants improve automation and lower human error. These technologies can expand and apply to rural systems like EcoVolt, especially in resource-limited areas.

According to Houssein et al. (2021), the Electric Fish Optimization (EFO) algorithm, a nature-inspired metaheuristic, demonstrates significant potential in solving complex

optimization problems. Their study highlights its robust performance in parameter optimization for photovoltaic models, showcasing its applicability in tuning energy conversion systems like EcoVolt for maximum efficiency by managing intricate operational variables.

According to Linga et al. (2022), a techno-economic analysis of a rice husk-based power plant in the Philippines utilized optimization models to determine financial viability and optimal plant capacity. Their work underscores the necessity of algorithmic modeling to balance feedstock supply logistics, energy output, and operational costs, a core function of the EcoVolt system's EFO algorithm.

According to Fathy et al. (2022), a modified EFO algorithm was proposed to enhance the performance of PEM fuel cells by optimally identifying their parameters. This research validates the adaptability of EFO for different energy systems and suggests that a customized version could be developed for EcoVolt to specifically address the unique parameters of agrowaste gasification or combustion.

According to Prem et al. (2023), a hybrid algorithm combining the Grey Wolf Optimizer and Particle Swarm Optimization was developed to manage energy flow in microgrids. This hybrid approach improved convergence speed and accuracy, offering a strategy for EcoVolt to potentially enhance its EFO algorithm by integrating elements from other optimizers for more dynamic load balancing.

According to Mabini et al. (2021), a study on optimizing the anaerobic digestion of pineapple cannery waste in the Philippines used response surface methodology (RSM). While not an AI algorithm, RSM provides a statistical framework for optimizing process parameters like temperature and pH, which can serve as a baseline or complementary tool for the EFO algorithm in the EcoVolt system.

According to Bui et al. (2022), the Harris Hawks Optimization (HHO) algorithm was applied to optimize the operation of a hybrid renewable energy system. The results showed HHO's superiority in minimizing cost and emissions, presenting it as a viable alternative or benchmark against which EcoVolt's EFO performance can be measured.

According to Orillaza and Biona (2022), a linear programming model was used to assess the optimal mix of biomass resources for polygene ration plants in the Philippines. This type of mathematical optimization is fundamental for strategic planning and can inform the high-level decision-making logic of the EcoVolt platform, especially in feedstock selection.

According to Al-qaness et al. (2022), a novel Marine Predators Algorithm (MPA) was enhanced with chaotic maps to improve global optimization capabilities for feature selection. This suggests a pathway for EcoVolt to improve. Its predictive models use advanced optimization algorithms to select the most relevant sensor data for analysis.

According to Bolivar and Lee (2023), a Convolutional Neural Network (CNN) model was developed for real-time image-based classification of municipal solid waste. The system achieved high accuracy in distinguishing material types, a technology directly transferable to EcoVolt for automating the sorting of different types of agrowaste (e.g., rice husk, coconut coir, sugarcane bagasse).

According to Del Rosario et al. (2022), a local study explored the development of an IoT-based waste segregation bin using image recognition for Philippine households. While on a smaller scale, the underlying machine learning principles for classifying waste types are foundational to what EcoVolt aims to achieve with diverse agricultural biomass.

According to Chen et al. (2024), sensor fusion techniques combining hyperspectral imaging and 3D laser scanning were used to improve the characterization of mixed waste streams. The fusion algorithm allowed for the identification of not just material type but also physical properties like moisture content, which is critical for optimizing the energy conversion process in EcoVolt.

According to Aglipay and Peralta (2023), a study from a Philippine university focused on using machine learning to estimate the energy potential of different agricultural residues based on their physical characteristics. This research provides a localized dataset and model framework that EcoVolt can leverage for its feedstock analysis and energy output prediction.

According to Jiang et al. (2022), a robotic sorting system guided by a reinforcement learning algorithm was developed to handle complex and cluttered

waste scenarios. The AI agent learned optimal picking strategies through trial and error, a sophisticated approach that could inspire the automation of agrowaste pre-processing in the EcoVolt system.

According to Dadios et al. (2021), research from De La Salle University in Manila explored the use of fuzzy logic controllers for various industrial automation processes. The principles of fuzzy logic for handling imprecise inputs (like variable moisture or contamination in agrowaste) could be integrated into EcoVolt's control system to make it more robust.

According to Han et al. (2023), an attention-based deep learning model was proposed for identifying contaminants in streams of recyclable materials. The attention mechanism helped the model focus on subtle visual cues, improving detection rates. EcoVolt could use a similar algorithm to detect rocks, soil, or plastics mixed with agrowaste.

According to Singh et al. (2022), a Long Short-Term Memory (LSTM) network was employed for predictive maintenance in a thermal power plant. The model successfully forecasted equipment failures by analyzing time-series data from sensors, a method

directly applicable to EcoVolt for predicting maintenance needs of its converters and generators.

According to Castillo and Reyes (2023), a study on the performance of a biomass gasifier in the Philippines highlighted common operational issues like clinker formation and tar condensation. This local operational data is invaluable for developing EcoVolt's predictive maintenance algorithms, allowing the AI to be trained on region-specific failure modes.

According to Zhao et al. (2024), a digital twin framework was integrated with machine learning for real-time monitoring and fault diagnosis of a waste-to-energy incinerator. The digital twin provided a virtual replica for simulating operational scenarios and testing maintenance strategies without disrupting plant operations, a sophisticated model that EcoVolt could aspire to.

According to Cruz and Fernandez (2022), a web-based monitoring system for off-grid solar power installations was developed and deployed in a remote community in the Philippines. The system utilized GSM technology for data transmission, providing a practical, low-cost architectural blueprint for EcoVolt's web monitoring platform, especially for deployment in rural areas with limited internet infrastructure.

According to Li et al. (2023), an unsupervised learning algorithm, specifically a variational autoencoder (VAE), was used to detect anomalies in sensor data from a biogas plant. This approach is powerful because it can identify novel or unforeseen system faults without prior training on specific failure types, enhancing the robustness of EcoVolt's monitoring.

According to Li et al. (2021), a federated learning framework was proposed for predictive maintenance across multiple decentralized power generation units. This allows models to be trained collectively without sharing sensitive raw data, a relevant architecture for a network of distributed EcoVolt units.

According to Beltran et al. (2021), a GIS-based assessment mapped the biomass waste potential from rice and coconut farming in a specific Philippine region. The spatial mapping algorithms used are crucial for optimizing the location of EcoVolt plants and planning feedstock collection logistics.

According to Wu et al. (2023), a Graph Neural Network (GNN) was used to model the complex interactions within a smart grid. This approach could be adapted by EcoVolt to model the entire agrowaste-to-electricity supply chain, from farm to grid, optimizing the entire system rather than just individual components.

According to Abundo et al. (2022), from the University of the Philippines, a life cycle assessment (LCA) model was developed for various waste-to-energy technologies in the Metro Manila context. The algorithms for calculating environmental and economic impacts can be integrated into the EcoVolt monitoring dashboard to provide sustainability metrics.

According to Al-Fuqaha et al. (2022), a comprehensive survey on AI and IoT for smart city management highlights algorithms for waste collection route optimization. The use of Ant Colony Optimization and Genetic Algorithms in this context can be directly applied by EcoVolt to manage the logistics of agrowaste collection from multiple farms.

According to Tiam-Lee and Tanchuling (2023), a system dynamics model was created to analyze the solid waste management system in Quezon City, Philippines. The modeling approach, focusing on feedback loops and system behavior over time, is valuable for EcoVolt to simulate the long-term sustainability and scalability of its agrowaste supply chain.

According to Zhang et al. (2022), a self-correcting machine learning model was developed for predicting energy generation from a biomass plant with variable feedstock quality. The model uses an online learning algorithm that continuously updates its parameters as new data arrives, ensuring sustained accuracy for a system like EcoVolt.

According to Demafelis et al. (2021), research from the University of the Philippines Los Baños analyzed the potential of sweet sorghum bagasse for bioethanol production. The study provides critical process parameters and conversion efficiency data specific to a local crop, which can serve as input data for EcoVolt's optimization and prediction algorithms.

According to Iqbal et al. (2022), a blockchain-based IoT system was designed for transparent and secure tracking of the waste management supply chain. This technology could be adapted by EcoVolt to create an immutable ledger for tracking agrowaste from source to energy production, ensuring fair payment to farmers and transparent reporting.

According to Guno et al. (2021), a study from Central Luzon State University (Philippines) used Geographic Information System (GIS) and multicriteria decision-making (MCDM) algorithms like the Analytical Hierarchy Process (AHP) to identify

suitable sites for a biomass power plant. This methodology is directly applicable for planning the expansion of the EcoVolt network.

According to Sarc et al. (2021), advanced data analytics and machine learning were used to predict the composition and calorific value of municipal solid waste based on historical data and socio-economic factors. This predictive modeling can be adapted by EcoVolt to forecast the energy potential of incoming agrowaste based on its source, season, and type.

According to Tuballa and Abundo (2022), a feasibility study on integrating anaerobic digesters for market waste in a Philippine city used simulation models to project methane yield and energy output. Such simulations provide a baseline for validating the predictive accuracy of EcoVolt's AI algorithms.

According to Abdel-Basset et al. (2021), a new metaheuristic algorithm called the "Slime Mould Algorithm" (SMA) was benchmarked for its performance in solving engineering design optimization problems. It offers another advanced bio-inspired algorithm for comparison with EFO to ensure EcoVolt uses the most effective optimization core.

According to Manigo and Corpuz (2023), a study from Mariano Marcos State University in Ilocos Norte, Philippines, developed a remote monitoring system for soil moisture using IoT sensors. The architecture and data handling protocols from such local agricultural IoT projects are highly relevant for designing EcoVolt's feedstock monitoring component.

According to Kumar et al. (2023), a deep reinforcement learning agent was trained to control the combustion process in a waste incinerator, optimizing for stable temperature and minimal emissions. This represents a state-of-the-art control algorithm that could be a long-term goal for EcoVolt's autonomous operation.

According to Leron and Soriano (2021), Philippine researchers investigated the co-firing of sugarcane bagasse and rice husk, using process simulation software (Aspen Plus) to model and optimize the gasification process. These simulations provide validated models that can be used to train and test EcoVolt's EFO algorithm.

According to Liu et al. (2022), a novel method combining near-infrared (NIR) spectroscopy with a Support Vector Machine (SVM) algorithm was developed for rapid,

non-destructive measurement of biomass moisture content. This system is ideal for EcoVolt's pre-processing stage to provide real-time data for the energy conversion model.

According to Binos, et al. (2022), a review by the Philippine Department of Energy outlined the policy landscape and technical potential for waste-to-energy projects. The document provides key data on available agrowaste volumes and government targets, which are essential parameters for configuring the constraints within the EcoVolt optimization algorithm.

According to Gu et al. (2024), a transferable deep learning model was built to diagnose faults in wind turbines, where a model trained on one turbine could be fine-tuned for another with minimal data. This transfer learning approach is highly relevant for deploying EcoVolt's predictive maintenance AI across multiple sites with slightly different hardware.

According to Alfaro et al. (2022), research from Mapúa University in Manila presented an AI-based system for classifying plastic waste using acoustic signatures. The innovative use of sound for material identification could supplement EcoVolt's vision systems, potentially detecting contaminants by the noise they make during handling.

According to WasteAnt Technologies (2024), their AI-powered waste analytics platform monitors waste flow in real time using sensors and predictive models. It prevents system blockages and improves operational uptime. EcoVolt can use similar real-time diagnostics to maintain uninterrupted energy conversion.

According to NC State and IBM (2023), their smart waste management system uses hyperspectral imaging and machine learning to identify organic materials. This improves sorting accuracy and supports renewable energy production, similar to EcoVolt's biomass classification process.

According to AMP Robotics (2022), the Cortex platform uses AI and robotics to sort recyclable materials at superhuman speed. EcoVolt can integrate similar object recognition for Agrowaste refinement and preprocessing.

According to ZenRobotics (2021), their robotic waste sorting system uses sensor fusion and AI to separate materials efficiently. EcoVolt can apply this technology to automate Agrowaste segregation before energy conversion.

Synthesis

The related literature, studies, systems, and algorithms highlight the increasing importance of incorporating artificial intelligence, machine learning, and automated technologies into waste-to-energy systems, especially in rural and agricultural areas. Researchers consistently recommend developing and implementing smart, cloud-connected platforms like EcoVolt to improve agrowaste conversion, system monitoring, and energy distribution. These digital innovations tackle the ongoing challenges faced by traditional biomass processing methods, which often depend on fixed setups, manual work, and slow diagnostics.

The common inefficiencies identified include unpredictable biomass yield, poor energy forecasting, limited operational flexibility, and high maintenance costs due to the lack of real-time data. Several studies have confirmed that using AI-powered analytics and algorithmic decision-making greatly improves precision, system responsiveness, and energy recovery while also encouraging environmental sustainability and lessening reliance on human monitoring.

Integrating smart technologies such as regression models, neural networks, and reinforcement learning allows systems like EcoVolt to learn and optimize energy output in real-time. This represents a significant advancement from traditional systems and provides a data-driven solution to improve rural electrification and develop a scalable model for sustainable Agrowaste use. By addressing major inefficiencies and automating the most essential processes, EcoVolt offers a transformative approach to modern energy infrastructure based on technical accuracy and environmental impact.

CHAPTER 3

METHODOLOGY

This chapter discusses the research strategy, procedures, and the system phases that the proponents used during development. This section also presents the strategies that the researchers utilized to gathering and assessing the information prerequisite to understand the objectives of the study, project processes, and its implementation

Development Method

The approach used by the researchers in developing the system is Rapid Application Development (RAD).

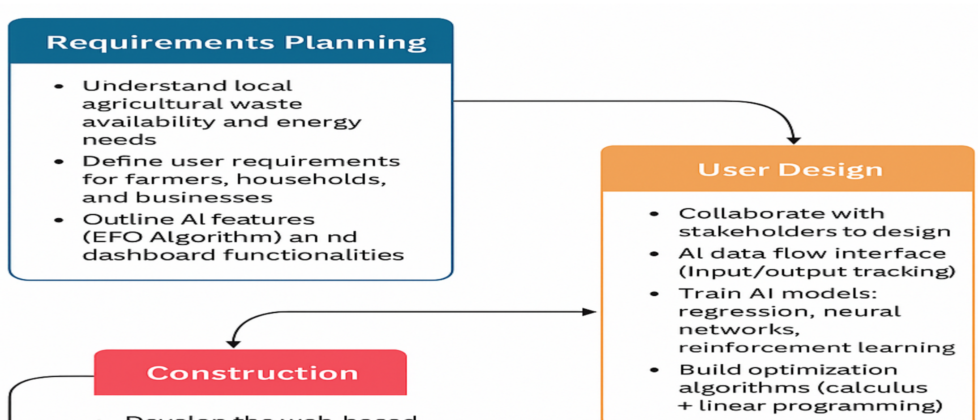


Figure 2. Rapid Application Development Model

The approach used by the researchers in developing the EcoVolt system is Rapid Application Development (RAD). This methodology was adopted due to its iterative and adaptive nature, which suits the dynamic needs of the AI-driven EcoVolt platform. The RAD model was considered ideal for this study, as it allows faster delivery of functional components, supports active collaboration with end users, and aligns with the project's limited time frame. It enabled the team to produce a working prototype of the energy monitoring web application and refine the EFO algorithm based on real-time feedback and system performance.

RAD emphasizes user involvement, which was critical in shaping system features around the actual needs of farmers, households, and rural energy stakeholders. The development cycle was divided into multiple phases that allowed continuous improvements while remaining responsive to field conditions, energy data variability, and evolving stakeholder requirements.

The system development process under the RAD model is structured into distinct stages and further elaborated in the next section to demonstrate how the goals of efficiency, accessibility, and sustainability were achieved in a compressed development schedule.

Requirement Planning

The researchers initiated the requirements planning phase by engaging with key stakeholders from farming communities, including agricultural cooperative members, local government representatives, and energy users. Through interviews, field observations, and distributed questionnaires, the team gathered information about the region's Agrowaste volume, electricity usage patterns, and challenges related to energy access. This collaborative approach enabled the researchers to define the scope and primary objectives of EcoVolt, which include real-time monitoring of energy production, tracking biomass input, and developing an intuitive dashboard for system performance and environmental metrics.

The feedback they collected influenced the system's key features, such as the integration of the EFO algorithm to improve energy flow and a web-based platform designed for users with different levels of technical knowledge. By focusing development on real-world needs, the planning phase ensured that EcoVolt would be relevant to the community, flexible, and supportive of both environmental objectives and community empowerment.

Analysis and Rapid Design

After requirement planning, the researchers examined the Agrowaste practices and energy access in the local farming communities. These insights reinforced the need for a smart and affordable energy solution, paving the way for the idea of EcoVolt. In the rapid design phase, the team outlined the initial features of the system, focusing on integrating the EFO algorithm and creating an easy-to-use web interface for real-time energy monitoring. This phase emphasized accessibility, especially for rural users, and resulted in the development of the first system prototype.

Prototyping Cycle Phase

In the prototyping phase, the researchers quickly developed early versions of the EcoVolt system to visualize, evaluate, and refine its functionality. The initial prototypes included interface wireframes for the web application, which showed how users, like farmers and cooperatives, could monitor energy production, biomass input, and environmental impact in real time. The development team also created a basic hardware simulation that integrated sensor inputs for biomass volume, temperature, and energy flow.

The first working prototype combined a microcontroller with cloud connectivity to simulate the Energy Flow Optimization (EFO) algorithm. The team held continuous feedback sessions with pilot users and academic advisors to address usability concerns, refine data visualization features, and improve system responsiveness. Later versions added better sensor calibration, optimized algorithm performance, and an improved user dashboard designed for low-bandwidth rural settings.

This iterative prototyping approach made sure that both the AI system and the web application reflected user insights and technical testing. It aligned EcoVolt with the real needs and abilities of its target communities.

Refine

After gathering feedback from the testing and demonstration phases, the researchers conducted a final round of analysis to improve the EcoVolt system. User comments and observations identified areas that needed work, such as the EFO algorithm's performance, the responsiveness of sensor integrations, and the user interface of the web-based dashboard. The team also addressed technical issues related to data accuracy, cloud synchronization, and system usability.

These changes made sure that EcoVolt was stable, efficient, and easy to use, preparing it for wider use in farming communities.

Evaluations

After final adjustments, the researchers assessed the EcoVolt system by gathering user feedback and examining operational data. Feedback from farmers, cooperatives, and technical advisors showed its effectiveness, usability, and potential for wider use.

The evaluation pointed out strengths, identified areas needing improvement, and provided suggestions for future improvements and deployment.

Customer Approval

After completing the refinement phase, the updated EcoVolt prototype was shown to farming stakeholders and community representatives for final review. The system went through another round of user testing to confirm that it met their functional needs and expectations. This phase made sure that all essential features, including the EFO algorithm and the web dashboard, matched user preferences and worked well in real-world rural settings. After receiving positive feedback and validation, the team got stakeholder approval to move ahead with broader implementation.

Deployment

After thorough testing and final approval, the EcoVolt system was ready for full deployment in a pilot farming community. This stage involved setting up hardware components, configuring sensors and cloud databases, and making sure that the EFO algorithm and web app worked smoothly in a real-world environment. Once all systems were installed and checked for compatibility, EcoVolt was officially launched, ready to provide real-time, sustainable energy monitoring to its target users.

Development Method	August	September	October	November	December	January	February	March	April	May
1. Product Backlog										
1.1 Identify and list system requirements										
1.2 Prioritize features for development										
2. Sprint Planning										

2.1 Select backlog items for Sprint 1										
2.2 Define sprint goals and deliverables										
3. Sprint Backlog										
3.1 Break down selected features into tasks										
3.2 Assign responsibilities to team members										

4. Development (Sprints)										
4.1 Implement drone hardware integration										
4.2 Develop image capture and processing module										
4.3 Create dashboard and GIS mapping features										
5. Daily Scrum										

6. Sprint Review										
6.1 Demonstrate completed features										
6.2 Gather stakeholder feedback										
7. Sprint Retrospective										
7.1 Identify process improvements										

7.2 Plan changes for next sprint										
8. Increment										
8.1 Integrate all completed modules										
8.2 Conduct final system validation										

8.3 Prepare system for deployment										

Gantt Chart Legend: Done:

Table 1. Gantt Chart

This Gantt Chart shows the project timeline and progress of key phases involved in developing the EcoVolt system. It gives a clear view of the project's schedule, including planning, analysis and design, prototyping, development, testing, evaluation, and deployment, along with their respective start and end dates. This chart is a crucial tool for tracking progress, managing deadlines, and ensuring that each phase is completed on time. It supports the efficient execution and timely delivery of the EcoVolt: AI-Powered Agrowaste Electricity System, reinforcing the system's connection to sustainable development goals.

Requirements Specifications

The following outlines the hardware and software requirements used in the development of the EcoVolt AI-powered agrowaste-to-energy system.

Functional Requirements

The following are the functional requirements of the EcoVolt system. These features describe how the system operates and the intelligent capabilities it offers.

Features	Description
Monitoring	This feature uses sensors to detect and measure the quantity, moisture, and composition of agrowaste entering the system for processing.
Energy Flow Optimization (EFO)	This feature applies machine learning algorithms to analyze historical and real-time data, adjusting operational parameters to maximize energy output.
Real-Time System Diagnostics	This feature monitors temperature, pressure, and gas output continuously, alerting users to anomalies or inefficiencies in the conversion process.

Cloud-Based Monitoring	This feature allows users to remotely access system performance data, receive alerts, and manage operations via a secure web platform.
Predictive Maintenance Alerts	This feature uses AI to forecast potential equipment failures based on usage patterns and sensor feedback, reducing downtime and repair costs.
Waste Classification System	This feature uses image recognition and object detection algorithms to sort agrowaste and filter out non-processable materials before conversion.
Energy Output Logging	This feature records and stores energy production data for analysis, reporting, and future optimization.
User Authentication	This feature secures system access through QR code scanning or login credentials for both administrators and operators.

Environmental Impact Tracking	This feature calculates and logs carbon savings and emission reductions achieved through agrowaste conversion.

System Scalability Module	This feature enables the system to be scaled or replicated in other agricultural communities with minimal reconfiguration.

Table 2. Functional Requirements

The table above shows the important features of the system. These features make the system practical and functional for the efficient monitoring and management of crop health in precision agriculture.

User Interface

The following figure shows the interface of the project.

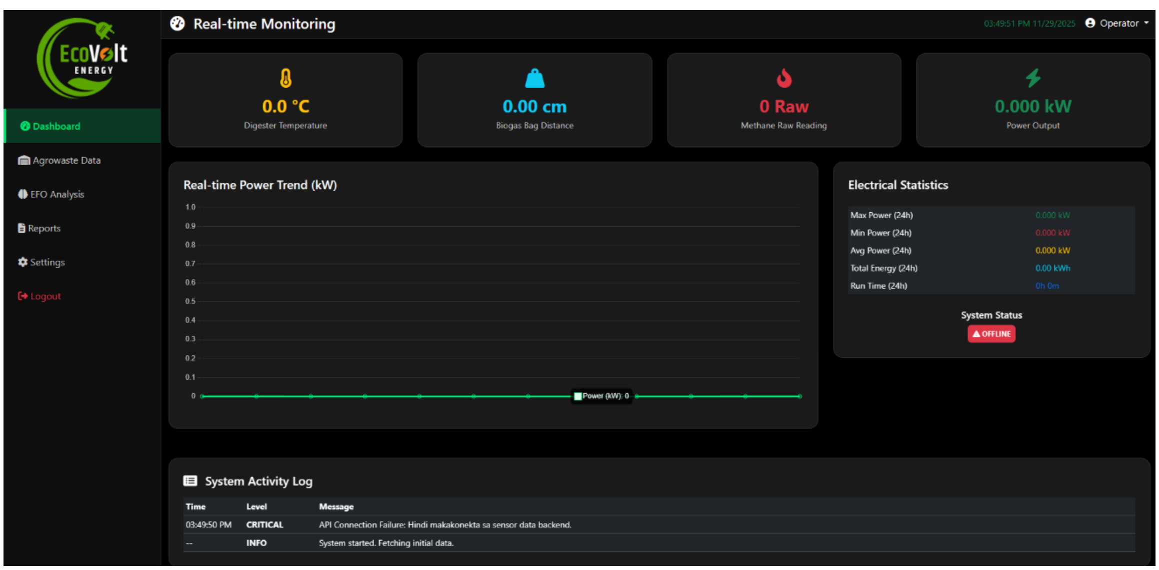


Figure 3. User Interface

The figure shows the interface of the EcoVolt system. It includes real-time data visualization, system diagnostics, energy output tracking, and user access controls—all designed to be intuitive and accessible for both technical and non-technical users.

Hardware Interface

The figure below shows the hardware interface and components used in developing the project.

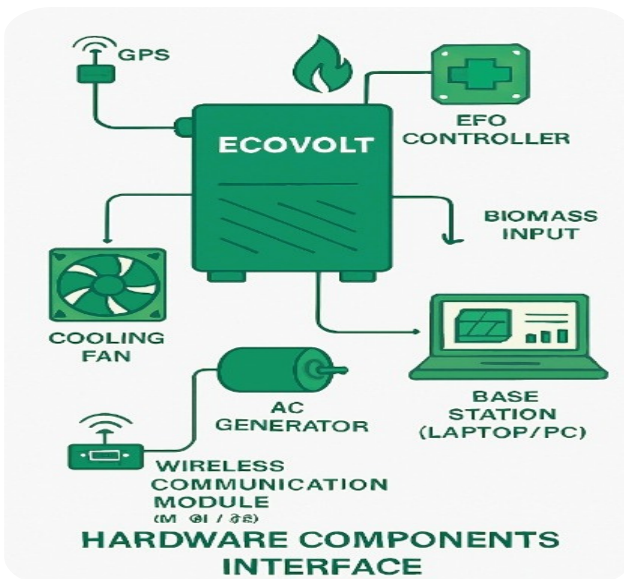


Figure 4. Hardware Interface

The hardware interface shows how key components work together in the development of the EcoVolt: AI-Powered Agrowaste Electricity System with EFO Algorithm and Web-App for Sustainable Energy Monitoring. This interface allows smooth communication between physical modules and the software system, enabling real-time energy generation, monitoring, and improvement.

The setup includes a biomass input module that acts as the source of organic waste material for conversion. The EcoVolt processing unit, which has the EFO controller, manages the energy flow optimization algorithm and system operations. A cooling fan and AC generator are connected to control temperature and change mechanical energy into electricity, respectively.

A GPS module provides location data for system tracking and deployment in rural areas. The wireless communication module (Wi-Fi/4G) guarantees constant data transmission between the hardware and the base station, which is a laptop or PC running the EcoVolt web application. This base station shows system diagnostics, energy output, and environmental impact metrics.

Together, these components create a complete hardware ecosystem that supports AI-driven agrowaste conversion, remote monitoring, and sustainable electrification for underserved communities.

Software Interface

For the EcoVolt system, the home interface acts as the main hub for monitoring agrowaste input, energy conversion performance, and environmental impact metrics. Authorized users, such as system operators, technicians, and administrators, log in

through a secure authentication process to access their personalized dashboard. Once logged in, users are directed to the home page where they can view real-time data visualizations like biomass input levels, energy output (in kWh), system temperature, pressure, and gas flow rates.

The interface includes an interactive Energy Flow Optimization (EFO) graph that shows how the system changes operational parameters to maximize energy yield. Users can also access a waste classification panel that uses image recognition to identify and filter out non-processable materials before conversion. A notifications panel provides alerts for system issues, maintenance schedules, and performance thresholds that need immediate attention.

From the dashboard, users can start or schedule biomass processing cycles, review historical energy production logs, and create reports on carbon savings and system efficiency. The interface features a Diagnostics Module where technicians can check sensor feedback, hardware status, and predictive maintenance alerts. Administrators can access system settings, user management tools, and options for tuning algorithms.

All collected data is stored securely in the system's cloud database and can be retrieved for historical analysis, performance review, and improvement planning. The design of the interface focuses on clarity, accessibility, and responsiveness, ensuring that users with different technical backgrounds can operate the system well. Through this central platform, EcoVolt helps communities manage agrowaste resources smartly and make informed decisions for sustainable energy generation.

Security Requirements

EcoVolt's security requirements detail the measures put in place to protect the system from unauthorized access, data breaches, and misuse. A secure authentication system is enforced for all users, with unique accounts and role-based access control to make sure each user can only access features relevant to their responsibilities. Administrators have full access to system configuration, diagnostics, algorithm settings, and user management. Technicians and operators only have access to monitoring, maintenance, and performance reporting functions.

All users must log in using unique usernames and strong passwords. The system uses encryption during transmission and storage to protect sensitive data. Secure wireless protocols, such as SSL/TLS, encrypt communication between hardware modules and the cloud-based dashboard. This setup prevents data interception and tampering during remote access.

Access to critical system functions, such as changing Energy Flow Optimization (EFO) parameters, overriding alerts, or starting biomass processing cycles, is limited to authorized personnel. The system keeps detailed activity logs for all user actions. This allows administrators to audit usage, detect issues, and respond to suspicious behavior.

Other security features include automatic session timeouts, two-factor authentication for administrative accounts, and regular backup routines. These measures help maintain data integrity and enable recovery in case of system failure. By bringing together authentication, encryption, access control, and monitoring, EcoVolt ensures that only verified users can interact with sensitive components. This approach provides strong protection against potential security threats and ensures the safe and reliable operation of the energy system.

Technical Background

The technical foundation of the capstone project, EcoVolt: AI-Powered Agrowaste Electricity System for Rural Electrification, comes from the combination of artificial intelligence, Internet of Things (IoT), and renewable energy engineering. This system aims to tackle energy poverty in agricultural communities by converting biodegradable farm waste into usable electricity through a smart, modular bioenergy conversion unit.

EcoVolt uses sensor-based monitoring, AI-driven optimization methods, and real-time data analysis to automate and improve the energy generation process. IoT sensors in the biomass chamber constantly track factors like temperature, moisture content, and gas output. These readings go into a machine learning model that adjusts combustion and conversion settings on the fly to maximize energy production and reduce emissions.

A wireless communication module allows smooth data transfer between the conversion unit and a cloud-based dashboard. Users can see system performance, receive maintenance alerts, and access predictive analytics for fuel input and energy output on this dashboard. It focuses on being easy to use, so local technicians and community members can operate and maintain the system with little technical training.

The project highlights scalability and sustainability, making sure the system can be set up in off-grid rural areas with limited infrastructure. By combining agrowaste use, smart control systems, and community-focused design, EcoVolt helps provide clean energy access, encourages resource recycling, and supports agricultural communities in achieving self-sufficiency and environmental strength.

Hardware Specifications

The EcoVolt system was designed and developed using the following specifications for its bioenergy conversion unit, sensor network, and base station interface.

Hardware Component	Minimum Specifications	Recommended Specifications
Biomass Chamber	Stainless steel, 20L capacity	Corrosion-resistant alloy, 30L insulated chamber
Temperature Sensor	Thermocouple, ±2°C accuracy	Digital thermistor, ±0.5°C accuracy with real-time calibration
Microcontroller	Arduino Uno or equivalent	ESP8266 with built-in Wi-Fi
Processor (Base Station)	Intel Core i5	Intel Core i5 / AMD Ryzen 5
RAM (Base Station)	8GB	16GB
Storage	256GB SSD	512GB SSD or higher

Wireless Communication Module	2.4 GHz Wi-Fi	Dual-band Wi-Fi (2.4/5 GHz) or 4G LTE module
Display Screen (Base Station)	1366 x 768 pixels	1920 x 1080 pixels or higher
Power Supply	12V DC, 5A adapter	Solar-integrated 12V DC system with battery backup

Table 3. Hardware Specifications

The table above provides the minimum and recommended hardware specifications for the EcoVolt system. It includes the biomass chamber, sensor modules, microcontroller, base station processor, memory, storage, communication interface, and display resolution. These specifications help guarantee reliable performance and allow for scalability and suitability in rural deployment conditions.

Hardware Component	Requirements
Biomass Chamber	Corrosion-resistant alloy chamber with 30L capacity
Temperature Sensor	Digital thermistor with ±0.5°C accuracy and real-time calibration
Gas Sensor	NDIR sensor capable of detecting CH_4 and CO_2 concentrations
Pressure Sensor	Industrial-grade pressure sensor with 0–30 bar range
Microcontroller	ESP8266 with built-in Wi-Fi and

Cooling Fan	High-efficiency DC fan for thermal regulation
AC Generator	Compact generator with 1–2 kW output capacity
Charging Equipment	Smart battery charger with voltage regulation and overload protection
	Bluetooth connectivity
EFO Controller	ESP8266 with built-in Wi-Fi and Bluetooth connectivity
Wireless Communication Module	Dual-band Wi-Fi (2.4/5 GHz) or 4G LTE module
Base Station	Laptop with Intel Core i5 processor, 16GB RAM, 512GB SSD
Display Interface	1920 x 1080 resolution screen with real-time dashboard visualization
Power Supply	Solar-integrated 12V DC system with battery backup and surge protection

Table 4. Hardware Requirements

The table above lists the hardware needs for developing the EcoVolt system. This includes the main biomass processing parts, sensor modules, microcontroller, communication interface, power supply, and base station specifications required for the system to operate and be monitored. These components work together to provide reliable energy conversion, real-time diagnostics, and sustainable use in rural areas.

Software Component	Requirements
Operating System	Windows 11 Pro (Base Station), Ubuntu 22.04 LTS (Microcontroller Deployment)
Integrated Development Environment (IDE)	Visual Studio Code, Arduino IDE, Thonny

Programming Languages	PHP (sensor data processing, AI model), C++ (microcontroller control), HTML (dashboard interface)
Frameworks/Libraries	TensorFlow Lite, Scikit-learn, Matplotlib
Database	SQLite (local logging), Firebase Realtime Database (remote sync)
Backend	ARDUINO (API services), PHP with HTML (dashboard integration)
IoT & Communication Protocols	MQTT, HTTP REST API

Table 5. Software Specifications

The table above lists the software requirements for creating the EcoVolt system. It includes the operating systems, development environments, programming languages, libraries, databases, backend services, and visualization tools needed for sensor integration, AI processing, and real-time monitoring. These software components support smart control, remote diagnostics, and easy-to-use interfaces for managing sustainable energy.

System Analysis and Design

The system analysis and design of the capstone project, EcoVolt: AI-Powered Agrowaste Electricity System with EFO Algorithm and Web-App for Sustainable Energy Monitoring, involves a thorough evaluation of the system's functionality and the framework that governs its operation. The analysis looks into the energy needs of rural agricultural communities by converting biodegradable farm waste into usable electricity through smart automation and real-time monitoring.

The design combines essential hardware components like the biomass chamber, temperature and gas sensors, microcontroller, and AC generator with software modules that include the Energy Flow Optimization (EFO) algorithm, a cloud-based dashboard, and a predictive analytics engine. The system architecture includes a sensor-driven conversion unit that gathers operational

data, an AI controller that processes and optimizes energy flow, and a web-based interface that shows performance metrics and environmental impact.

The dashboard acts as the main user access point. It displays real-time energy output, biomass input levels, system diagnostics, and carbon savings. It also provides alerts for maintenance, system issues, and improvement suggestions. This design guarantees that both hardware and software components work together, offering a complete solution for generating sustainable energy and electrifying rural areas.

System Overview

The EcoVolt system was created to automate and improve the conversion of agrowaste to energy by using sensor technology, machine learning algorithms, and cloud-based monitoring. The main part of the system is a biomass processing unit equipped with temperature, pressure, and gas sensors that continuously monitor the conversion process. A microcontroller collects and sends this data to the EFO algorithm, which adjusts system parameters in real time to increase energy yield and reduce waste.

A wireless communication module allows real-time data transfer to a base station. Here, the web-based dashboard visualizes system performance, environmental metrics, and historical trends. Users can check energy output, receive alerts, and access AI-generated recommendations for system adjustments. The interface also allows scheduling of biomass input cycles and remote diagnostics, enabling technicians and administrators to manage operations effectively.

This setup helps agricultural communities make informed decisions about energy production and resource use. By combining smart control, real-time analytics, and user-friendly design, EcoVolt offers a scalable and sustainable solution for clean energy generation in rural areas.

System Architecture

The figure shows the system architecture and the organized design of the energy solution for rural electrification.

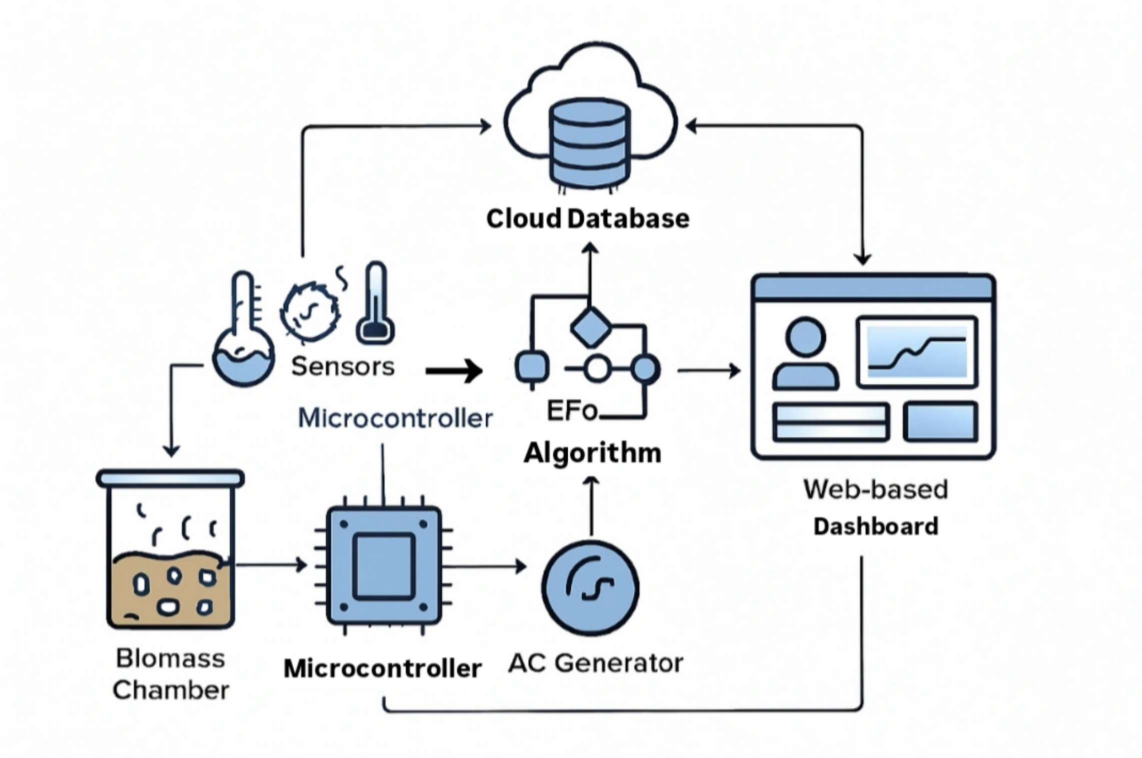


Figure 5. System Architecture

The diagram illustrates the operational flow and network structure of the EcoVolt system. It highlights the connection between the biomass processing unit, sensor array, AI controller, cloud-based dashboard, and end-user interface.

The system starts with the biomass chamber, where agricultural waste is placed for conversion. Embedded temperature, pressure, and gas sensors keep track of the internal conditions of the chamber. A microcontroller collects these sensor readings, acting as the local processing unit. It sends the data through a wireless communication module to the cloud-based server.

At the cloud level, the Energy Flow Optimization (EFO) algorithm examines the incoming data to establish the best operating parameters, including combustion timing, airflow regulation, and energy output modulation. The algorithm adjusts the system to improve energy efficiency and reduce emissions.

The processed data is stored in a centralized database and displayed on a web-based dashboard. This dashboard offers real-time insights into energy production, system health, biomass input levels, and carbon offset metrics. It also allows for user authentication, remote diagnostics, and scheduling of biomass input cycles.

This architecture allows for smooth integration between hardware and software components. It ensures secure data transmission, smart control, and easy monitoring. It follows IoT communication standards and cloud security protocols to keep the system reliable and protect data integrity.

Use Case Diagram

The use case diagram shows the interactions between users and the EcoVolt system. It illustrates how different features are accessed to meet specific operational and monitoring goals.

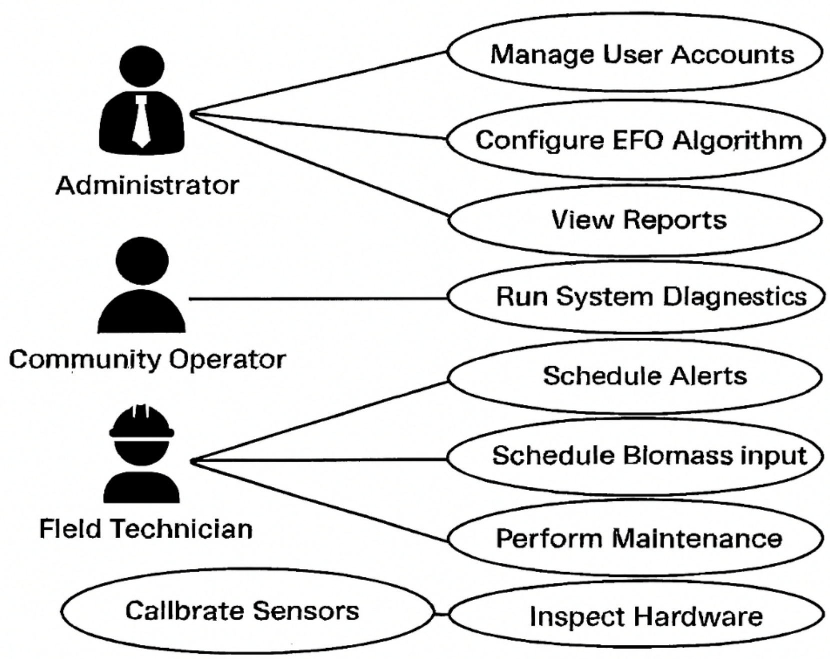


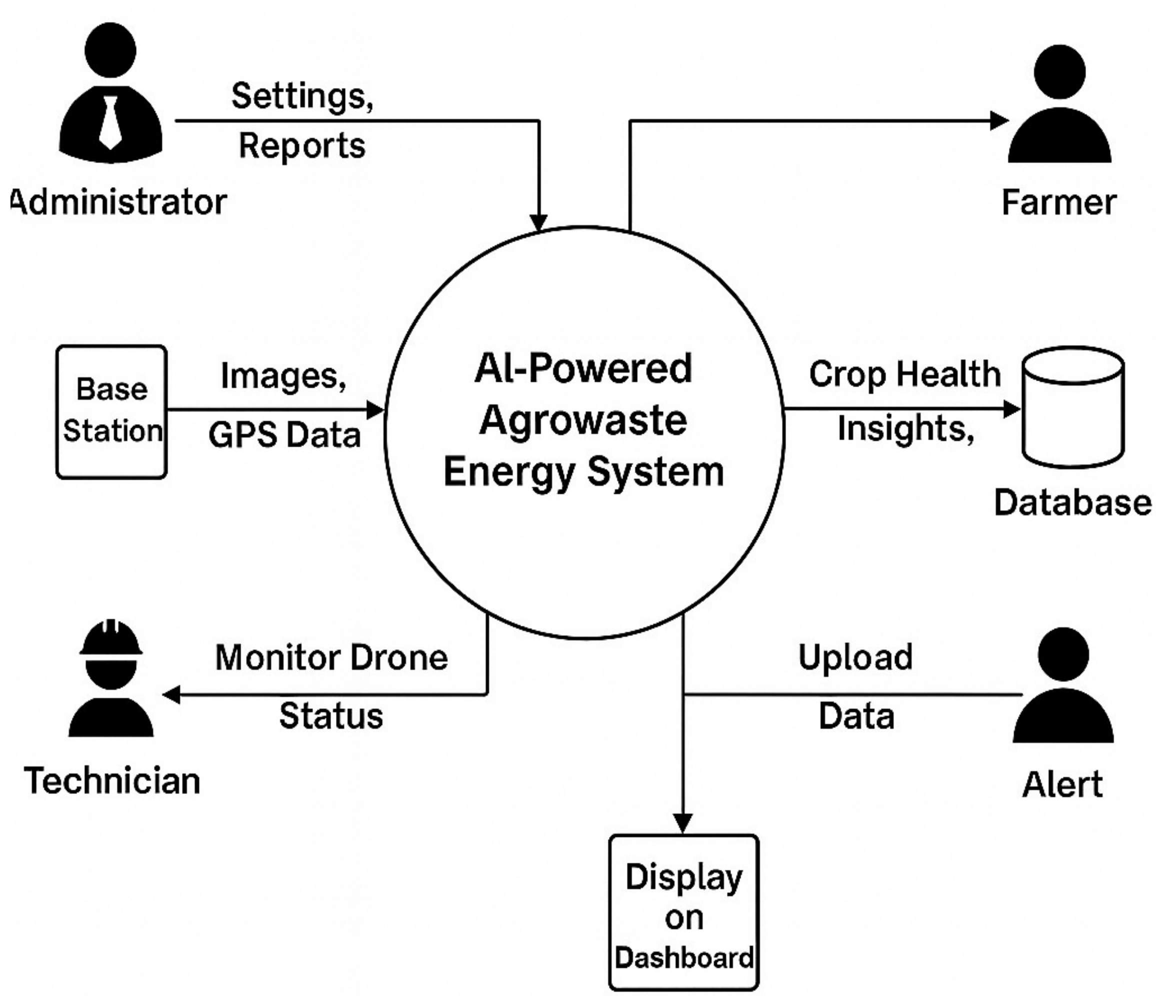
Figure 6. Use Case Diagram

The diagram shows how three main user roles—Administrator, Community Operator, and Field Technician—interact with the EcoVolt system.

Administrator: This role has full access to the system. They manage user accounts, configure the EFO algorithm, perform system diagnostics, analyze data, and generate reports. Administrators watch over system performance and ensure that operational standards are met.

Community Operator: Usually a local stakeholder or farmer representative, this role can monitor energy output, biomass input levels, and carbon offset metrics. Operators get alerts, view recommendations, and schedule biomass input cycles, but they cannot change system settings or access sensitive diagnostics.

Field Technician: This role is responsible for on-site maintenance, sensor calibration, and hardware inspections. Technicians can start manual diagnostics, upload sensor logs, and view system health reports. However, they have limited access to user management and algorithm settings.



Activity Diagram

An acti

vity diagram illustrates the program flow of control.

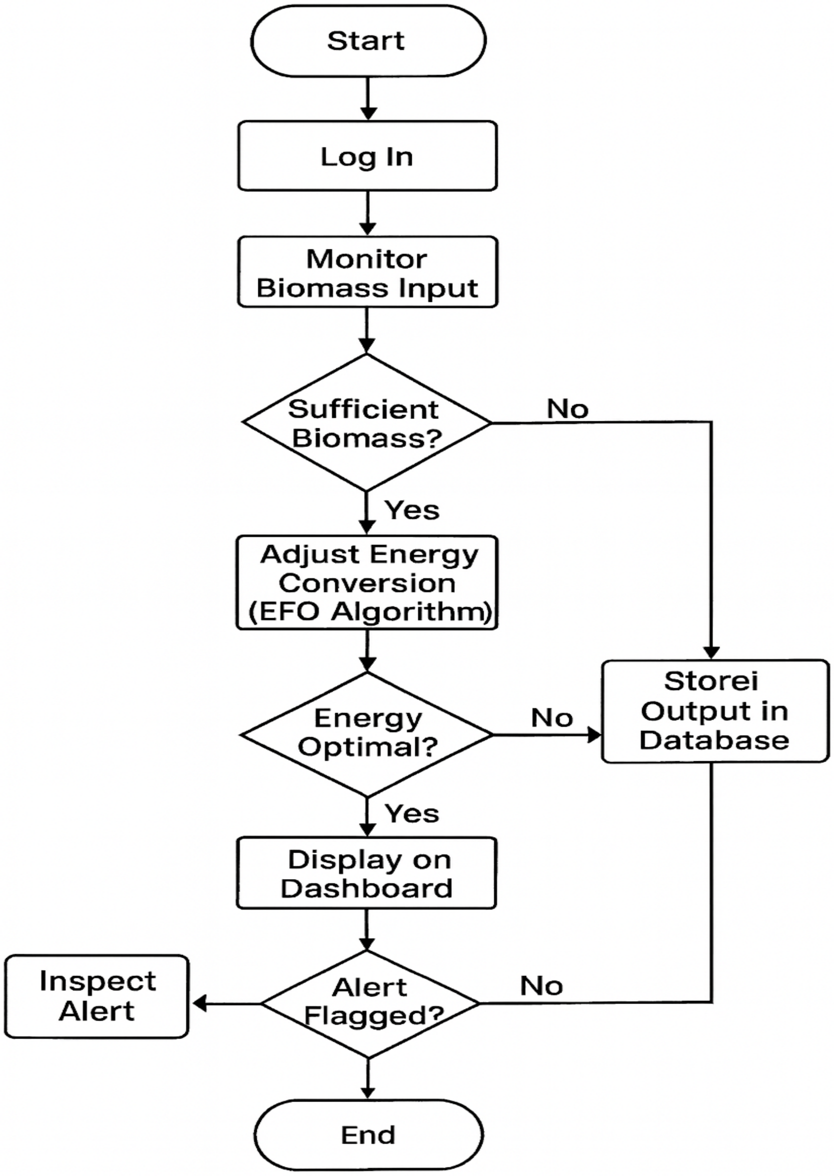
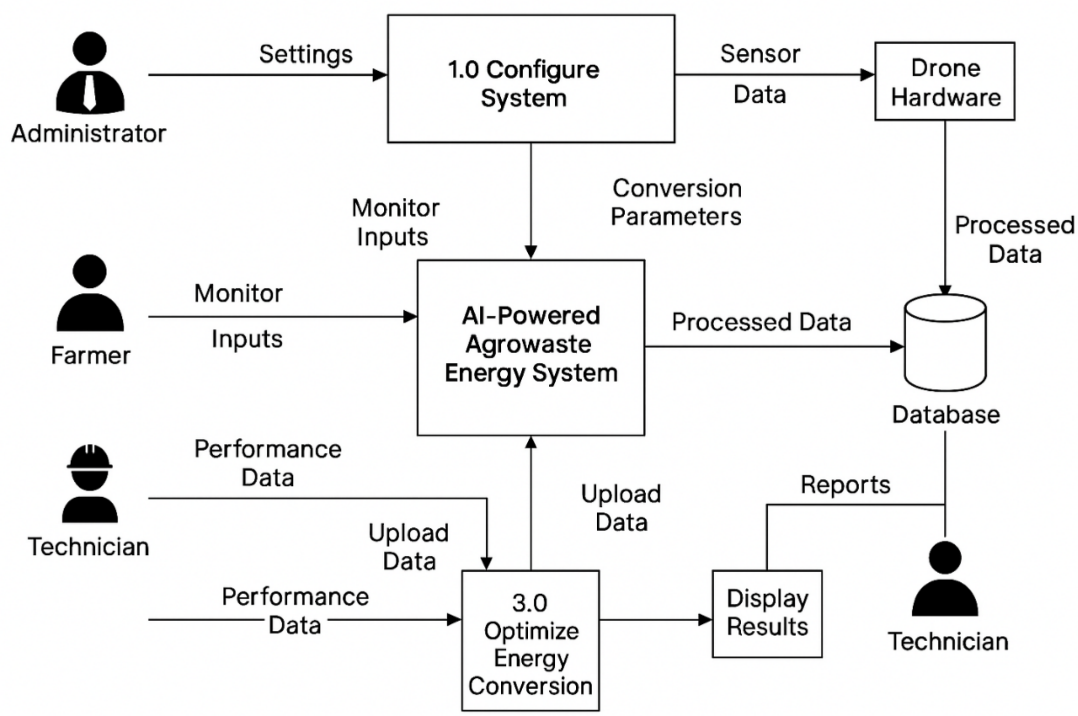


Figure 7. Activity Diagram

The activity diagram provides a **visual representation of the system's operational flow**, capturing how data and decisions move through the drone-based precision agriculture platform. It emphasizes **sequential actions, decision points, and system interactions** from start to finish.

Figure 8. Context Diagram



The context diagram for the AI-powered agrowaste-to-energy system illustrates its primary components, user roles, and data flow. It shows how the system receives input data from drones and technicians, processes it through the base station, and stores results in the central database. Administrators configure system settings and generate reports, farmers receive insights on crop health and energy recommendations, and technicians monitor drone performance and upload operational data. This diagram highlights the overall interaction between users and system modules, emphasizing the flow of information that supports sustainable rural electrification and precision agriculture.

Figure 9 Diagram 0

Presents a detailed view of the EcoVolt system's core processes and their interactions with external entities. It outlines key functions such as biomass input monitoring, sensor data collection, energy conversion via the EFO algorithm, system diagnostics, data storage, and dashboard visualization. The diagram shows how the Administrator, Community Operator, Field Technician, Biomass Hardware, and Base Station exchange data to maintain efficient system operation. Each role interacts with specific modules—such as configuration settings, performance analytics, and maintenance logs—ensuring a secure, intelligent, and user-friendly energy solution for rural communities.

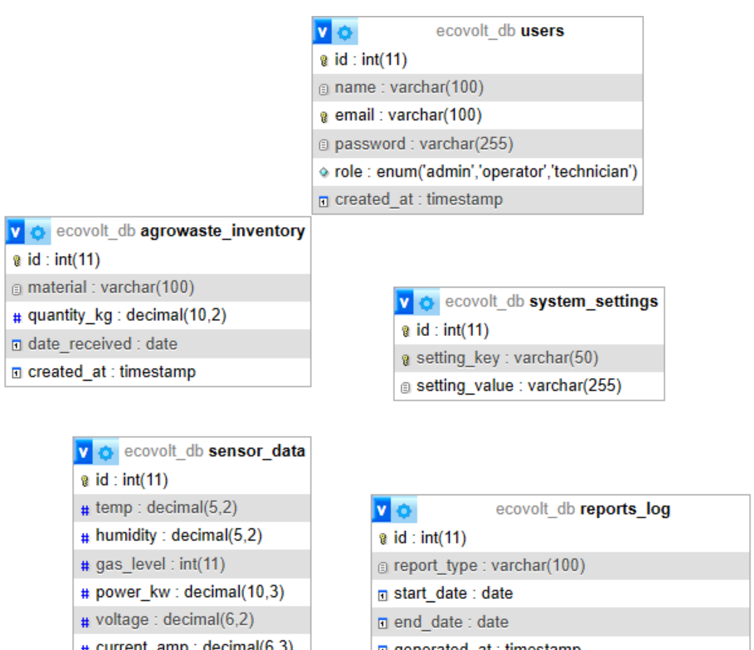


Figure 10. Database Schema

Presents the schema of the EcoVolt system's relational database. It illustrates how data are structured across interconnected tables to support core functionalities such as biomass tracking, energy conversion analytics, user roles, and system diagnostics. Key tables include Users, Biomass Inputs, Conversion Logs, Sensor Readings, and System Alerts, each linked through primary and foreign keys to ensure data integrity and efficient querying. This schema enables seamless data flow between modules, supporting real-time monitoring, historical analysis, and dashboard visualization for stakeholders like administrators, technicians, and community operators.

Testing and Evaluation

The evaluation of the EcoVolt: AI-Powered Agrowaste Electricity System aimed to assess its technical quality, usability, and user acceptance. Three established frameworks were used: the ISO 25010 Quality Model, the Technology Acceptance Model (TAM), and the System Usability Scale (SUS).

The ISO 25010 framework measured the system's functionality, performance efficiency, reliability, security, maintainability, and portability. Each criterion was rated on a 4-point Likert scale, letting respondents express their level of agreement with specific quality statements.

The Technology Acceptance Model (TAM) evaluated perceived usefulness and perceived ease of use after direct interaction with the system. Respondents assessed how well the system supported their tasks and how easy it was to operate.

The System Usability Scale (SUS) provided a standardized usability score from 0 to 100, giving an overall picture of user experience. The SUS questionnaire featured ten items that alternated between positive and negative statements to gather balanced feedback.

A total of 12 respondents took part in the evaluation, chosen through purposive sampling. The group included community operators, field technicians, and renewable energy experts. The evaluation involved a live demonstration of the system, hands-on testing of the EcoVolt dashboard and hardware interface, and the completion of structured questionnaires.

The gathered data were analyzed using descriptive statistics, including mean scores, standard deviations, and frequency distributions. This multi-framework approach ensured a thorough assessment of the system's technical performance and its acceptance among target users. The results offered useful insights for improvement and future deployment in rural communities.

Rating Scale

5 – Strongly Agree	4 – Agree	3 – Neutral	2 – Disagree	1 – Strongly Disagree

1. Functionality	**1**	**2**	**3**	**4**	**5**
1.1 The system performs all intended features (e.g., biomass monitoring, energy conversion, dashboard visualization) accurately.					
1.2 The energy output and system diagnostics are relevant and useful for decision-making.					
1.3 The system's features meet my expectations for sustainable energy management.					
2. Performance Efficiency					
2.1 The system processes data (e.g., sensor					

readings, conversion results) in a reasonable amount of time.					
2.2 The system operates smoothly without noticeable delays or lags.					
2.3 The system performs well even when handling multiple data inputs simultaneously.					

3. Reliability					
3.1 The system operates consistently without unexpected errors or crashes.					
3.2 The biomass unit and base station maintain stable operation during energy conversion.					
3.3 The system can recover easily from minor errors or interruptions.					
4. Security					
4.1 Access to the system is restricted to authorized users only.					

4.2 The system protects sensitive energy and user data from unauthorized access.					
4.3 Communication between the hardware modules and the dashboard is secure.					

5. Maintainability					
5.1 The system can be easily updated or improved when needed.					
5.2 The system's components are easy to troubleshoot and fix.					
5.3 The system allows modifications without affecting other features.					
6. **Portability**					
6.1 The system can operate on different compatible hardware setups.					
6.2 The system can be deployed in various rural locations without major adjustments.					

6.3 The system is adaptable to changes in hardware or software configurations.					

Technology Acceptance Model (TAM) Questionnaire

1. **Perceived Usefulness (PU)**	**5**	**4**	**3**	**2**	**1**
1.1 Using the system improves the efficiency of agrowaste energy conversion.					
1.2 The system helps me make better decisions regarding biomass input and energy management.					
1.3 The system increases my productivity in monitoring and managing energy output.					
1.4 The system provides valuable insights that are not possible with traditional energy systems.					

2. **Perceived Ease of Use (PEOU)**					
2.1 Learning to operate the system is easy for me.					
2.2 I find it easy to navigate and use the system's dashboard and features.					
2.3 It is easy for me to become skillful in using the system.					
2.4 The interaction with the system is clear and understandable.					

System Usability Scale (SUS) Questionnaire

1. **SUS Statements**					

1.1 I think that I would like to use this system frequently.					
1.2 I found the system unnecessarily complex. *(reverse-scored)*					

1.3 I thought the system was easy to use.					
1.4 I think that I would need the support of a technical person to be able to use this system. *(reverse-scored)*					
1.5 I found the various functions in this system were well integrated.					
1.6 I thought there was too much inconsistency in this system. *(reverse-scored)*					
1.7 I would imagine that most people would learn to use this system very quickly.					
1.8 I found the system very cumbersome to use. *(reverse-scored)*					

1.9 I felt very confident using the system.					
1.10 I needed to learn a lot of things before I could get going with this system. *(reverse-scored)*					

Scoring Guides

Mean Score Range	Interpretation
4.21 – 5.00	Very Satisfactory
3.41 – 4.20	Satisfactory
2.61 – 3.40	Neutral
1.81 – 2.60	Needs Improvement
1.00 – 1.80	Poor

Table 6. ISO 25010 Quality Model Scoring Guide

Mean Score Range	Interpretation

4.21 – 5.00	Very High Acceptance
3.41 – 4.20	High Acceptance
2.61 – 3.40	Moderate Acceptance
1.81 – 2.60	Low Acceptance
1.00 – 1.80	Very Low Acceptance

Table 7. Technology Acceptance Model (TAM) Scoring Guide

SUS Score Range	**Usability Rating**
85 – 100	Excellent
70-84	Good
50-69	OK / Fair
Below 50	Poor

Table 8. System Usability Scale (SUS) Scoring Guide

Chapter IV

RESULTS AND DISCUSSION

This chapter presents the system output, analysis, evaluation, and implementation results. It also discusses the findings obtained from the system evaluation, providing a detailed interpretation of the results and their implications for system performance and effectiveness.

Presentation of the System Output

The system is developed as an integrated platform designed to monitor EcoVolt system operations and provide users with real-time information. It enables continuous tracking of energy production, biomass input, and system status through connected sensors and a centralized dashboard. The system implements role-based access control, allowing different users to access specific features according to their assigned roles. This ensures secure, organized, and efficient system management while supporting informed decision-making for sustainable energy operations.

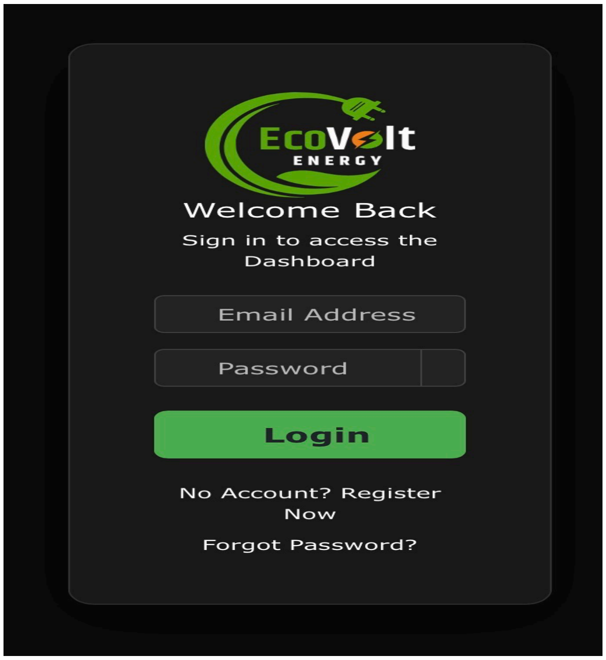


Figure 11. Log in Form

Figure 11 shows the login page of the EcoVolt system. The interface allows users to access the system by entering their registered email address and password using any compatible device. This login mechanism ensures that only authorized users can access the dashboard and system features, supporting secure and controlled system operation.

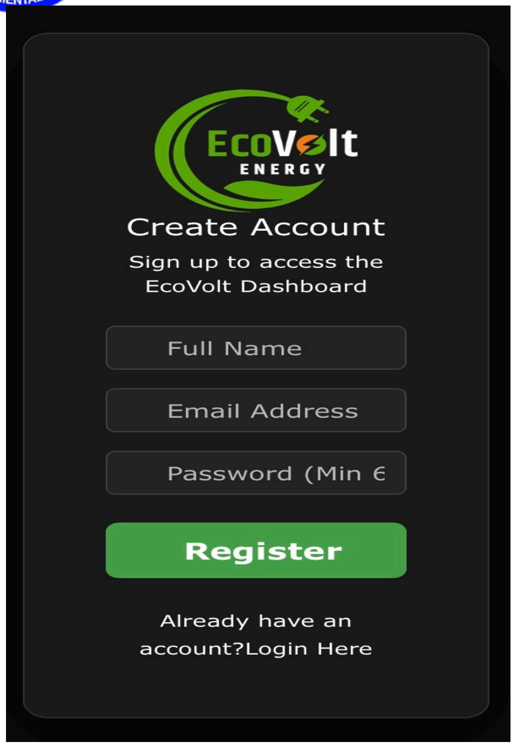


Figure 12. Sign up/Register

This figure shows the sign-up page of the EcoVolt system. The interface allows users to create an account by entering their full name, email address, and password. A “Register” button is provided to submit the information and create an account, while a login option is available for users who already have an existing account. The sign-up page is designed to be simple and intuitive, supporting ease of use and efficient user registration.

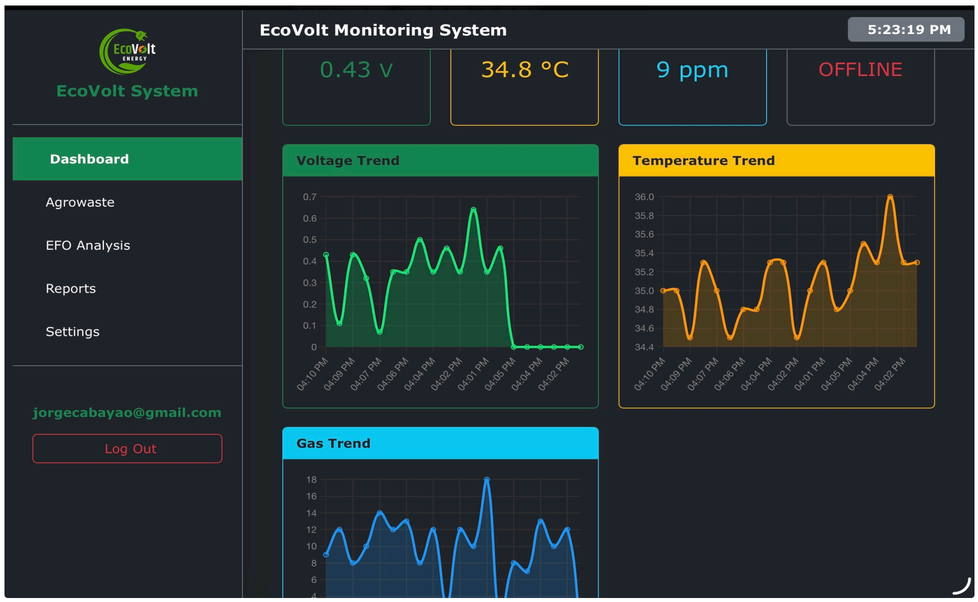


Figure 13. Dashboard

Figure 13 shows the EcoVolt Monitoring System dashboard, which provides real-time display of voltage, temperature, gas levels, and system status. It includes graphical trends for easy monitoring and a side navigation menu for quick access to system features, enabling efficient and user-friendly system management.

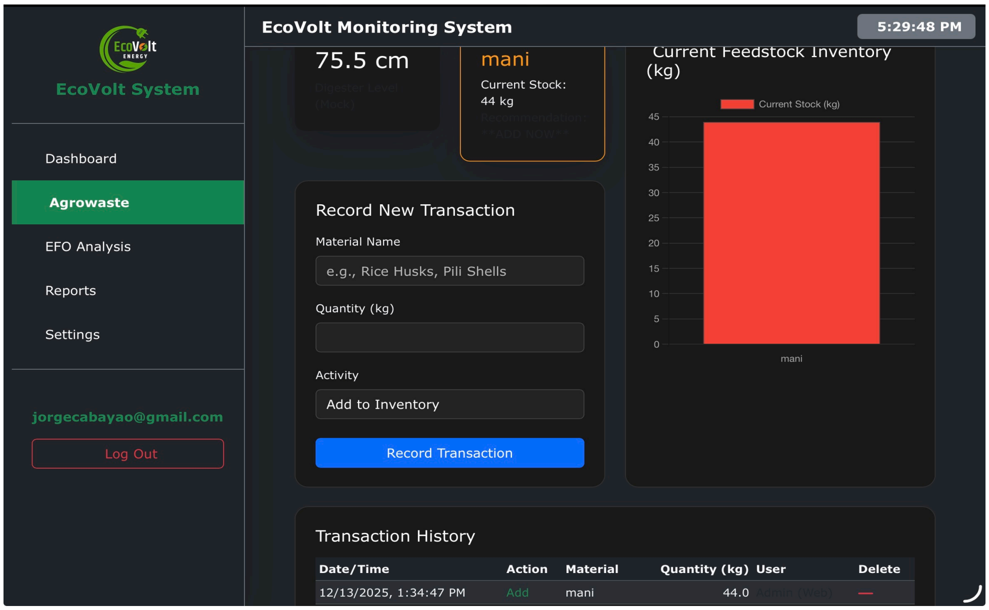


Figure 14. Agrowaste Management

The figure shows the Agrowaste page of the EcoVolt Monitoring System, which allows users to record agrowaste transactions, monitor current feedstock inventory, and view transaction history, supporting efficient and organized inventory management.

Figure 15. EFO Analysis & Optimization

The figure shows the EFO Analysis page of the EcoVolt Monitoring System, providing real-time system status, key operational readings, and visual trends for power, temperature, gas levels, and feedstock composition to support effective monitoring.

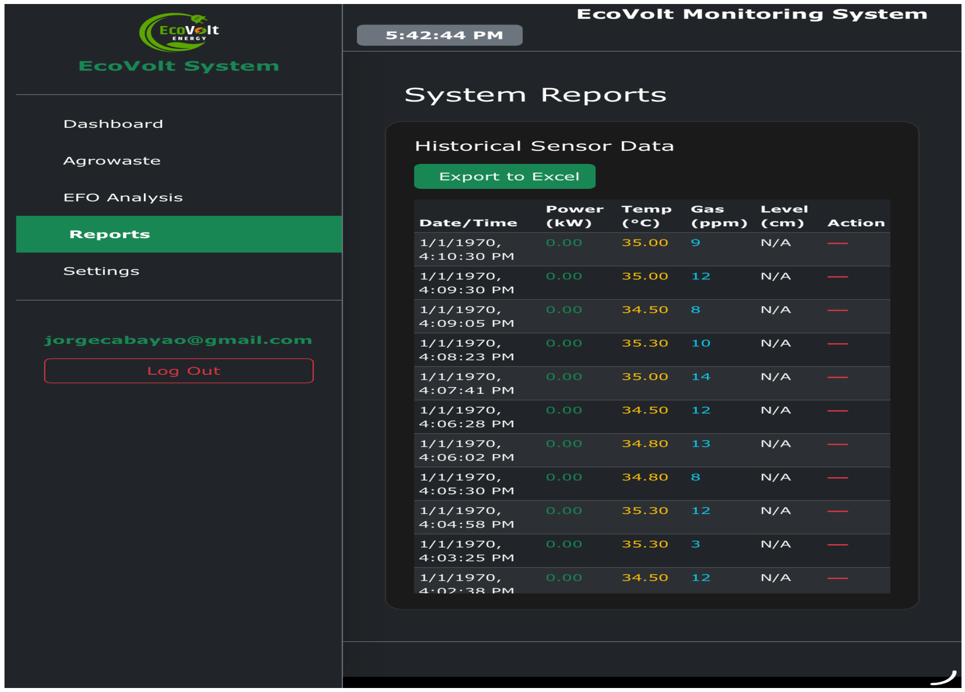


Figure 16. System Reports

The figure presents the Reports page of the EcoVolt Monitoring System, which displays historical sensor data in a structured table format. It shows recorded values for power output, temperature, gas level, and level measurements with corresponding date and time entries. An Export to Excel feature is included, allowing users to download and analyze system data for reporting and performance evaluation.

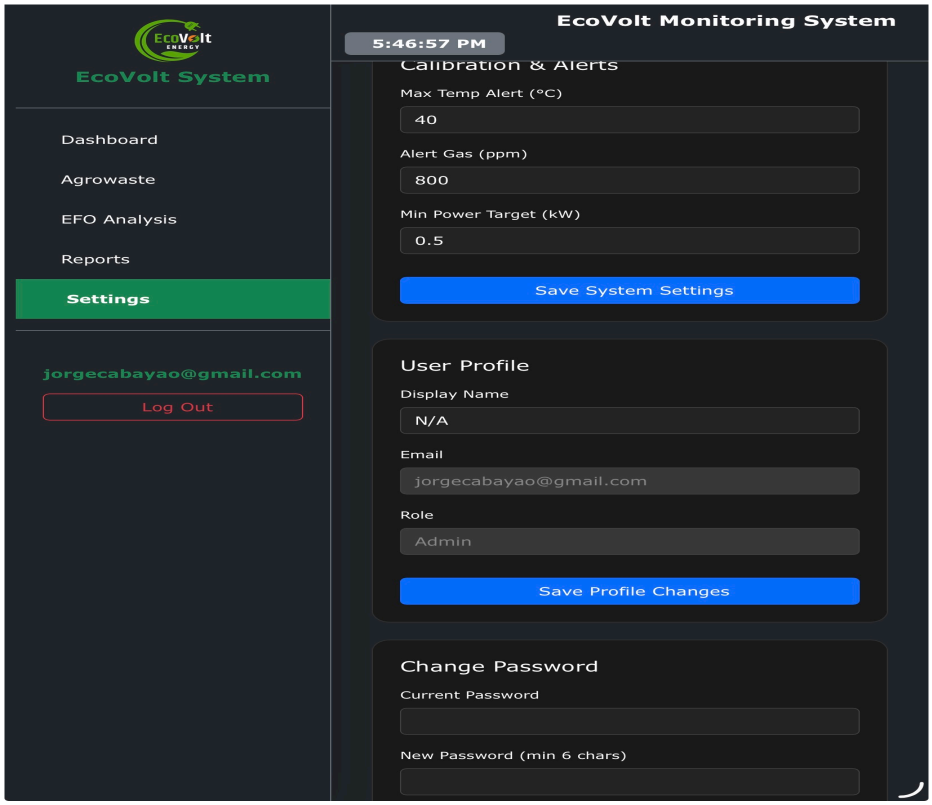


Figure 17. System Reports

The figure shows the Settings page of the EcoVolt Monitoring System, where administrators can configure system calibration and alert thresholds, manage their user profile, and change account passwords. This page ensures secure access and allows authorized users to customize system parameters and account settings efficiently.

Evaluation of the Systems

This chapter presents the analysis and evaluation of EcoVolt. The criteria used to evaluate the system include functional sustainability, performance efficiency, usability, reliability, security, flexibility, maintainability, and portability. These criteria serve as the basis for determining the effectiveness of the system and identifying areas for future improvement and enhancement.

Table 8. Functional Sustainability of the System

Table 8 presents the mean scores and verbal interpretations of EcoVolt in terms of functional sustainability. The results indicate that the system effectively supports its intended functions while promoting sustainable and energy-efficient operations. EcoVolt demonstrates the ability to optimize power usage, monitor energy consumption accurately, and support environmentally responsible practices.

The respondents rated EcoVolt with a high level of functional sustainability, suggesting that the system consistently performs its core functions while contributing to long-term sustainability goals. This implies that EcoVolt is capable of adapting to energy demands, minimizing resource waste, and maintaining operational efficiency over time.

Overall, the evaluation confirms that EcoVolt meets the required standards for functional sustainability and can serve as a reliable and sustainable solution for energy monitoring and management.

Functional Sustainability	Mean	Rank	Verbal Interpretation
1.The functions required for the system are implemented.	3.30	2	Strongly Agree
2. The functional ccuracy is provided.	3.27	3	Strongly Agree
3.The system facilitates the accomplishment of specified tasks and objectives	3.40	1	Strongly Agree
Overall Mean	3.33		**Strongly Agree**

The table results show it would signify a positive perception concerning the system's functional sustainability. The highest rank with a mean score of 3.40, indicates that users find the system particularly reliable in accomplishing specified tasks and objectives. The lowest rank with a mean score of 3.27 although the users agree that the system runs without errors, the lower score may suggest room for improvement. With an overall mean of 3.33, respondents strongly agreed that the system runs without any error interruption and functions accordingly.

Table 9. Performance Efficiency of the System

Table shows the mean and verbal interpretation of the proposed system in terms of performance efficiency.

Performance Efficiency	**Mean**	**Rank**	**Verbal Interpretation**
1.The system provides a good response.	**3.63**	**1**	**Strongly Agree**
2.The system displays the level efficiency.	**3.46**	**3**	**Strongly Agree**
3. The system has the capability display result.	**3.46**	**2**	**Strongly Agree**
Overall Mean		**3.52**	**Strongly Agree**

The table shows the overall performance of the system in terms of performance efficiency. The highest rank with a mean score 3.63, this reflects that respondent strongly agreed that the system has capability to display results and provide good responses. While the lowest rank with a mean score 3.46, respondents agreed that the system allows interaction between admin and staffs. With an overall average score of 3.52, respondents strongly agreed that the system effectively meets their expectations and needs in terms of performance efficiency.

Table 10. Usability of the System

Table shows the mean and verbal interpretation of the proposed system

in terms of usability.

Usability	Mean	Rank	Verbal Interpretation
1.The system meets the needs of the target users.	**3.46**	**2**	**Strongly Agree**
2.The system is easy to understand, operated, and control by the end users.	**3.41**	**3**	**Strongly Agree**
3.The system user interface is pleasing and satisfies user interaction.	**3.47**	**1**	**Strongly Agree**
Overall Mean	**3.45**		**Strongly Agree**

This table shows the results of the evaluation regarding the usability of the system. The highest rank mean score 3.47 indicates that the system is easy to understand and operate which is highly appreciated by users. The user’s also find the user interface of the system pleasing to the eyes. On the other hand, the lowest rank mean score 3.41, users agree that the system is fulfilling, and may suggest that the overall experience, while adequate, lacks certain elements that could make it exceptional or widely recommendable. The overall rank mean score 3.45, reflects a positive perception of the system's usability, with users finding it easy to use and effective in fulfilling its intended purpose.

Table 11. Reliability of the System

Table shows the mean and verbal interpretation of the proposed system in terms of reliability.

Reliability	**Mean**	Rank	Verbal Interpretation
1.The system works properly.	3.26	2	Strongly Agree
The system facilitates recovery procedure in the	3.01	3	Agree
The system generates accurate and relevant information.	3.40	1	Strongly Agree
Overall Mean	3.22		Agree

This table shows the results of the evaluation regarding the reliability of the system. The highest rank mean score of 3.40 indicates that users strongly agree the system generates accurate and relevant information, which they find highly dependable. The lowest rank mean score of 3.01 reflects that users agree the system has a recovery procedure in place in case of failure, though it suggests there may be room for improvement in how quickly or smoothly it recovers. The overall mean score of 3.22 reflects a generally positive view of the system's reliability, with users finding it stable and effective, but with some areas, particularly recovery, that could be enhanced to improve overall Performance.

Table 12. Security of the System

Table shows the mean and verbal interpretation of the proposed system in terms of security.

Security	Mean	Rank	Verbal Interpretation
The system can be accessed only by the authorized user.	3.46	1	Strongly Agree
The system is secured and protected in terms of data transmission.	3.34	3	Strongly Agree
The system provides unique account to each end users	3.36	2	Strongly Agree
Overall Mean	3.40		Strongly Agree

This table shows the results of the evaluation regarding the security of the system. The highest mean score of 3.46 indicates that users strongly agree the system is accessible only to authorized users. The system's protection of data transmission scored 3.34, showing strong agreement that it is secure. The mean score of 3.37 for providing unique accounts to each user also reflects strong agreement. With an overall mean score of 3.40, users generally view the system as secure, with effective access control and data protection.

Table 13. Flexibility of the System

Table shows the mean and verbal interpretation of the proposed system in terms of flexibility.

Flexibility	Mean	Rank	Verbal Interpretation
The system is easy to install and maintain.	3.63	1	Strongly Agree
The system can be modified and improve, correct or adapt it to the changes in environment, and in requirements.	3.32	3	Strongly Agree
The system can be successfully installed and/or uninstalled in a specified environment.	3.51	2	Strongly Agree
Overall Mean	3.52		Strongly Agree

Implementation Results

The implementation of EcoVolt has significantly contributed to the modernization of energy management through the application of sustainable and intelligent technology. Designed to convert agricultural waste into usable electricity, the system integrates sensor-based monitoring, artificial intelligence, and a cloud-connected platform to optimize energy production and system performance. EcoVolt utilizes biomass processing units equipped with sensors to capture real-time operational data such as temperature, gas output, and energy generation, enabling continuous monitoring and data-driven control.

During the initial deployment, the system components—including sensors, microcontrollers, and the energy conversion unit—were installed and integrated with the cloud-based platform. This setup allowed real-time transmission of system data to a centralized dashboard that can be accessed using any compatible device. Through this interface, authorized users can remotely monitor energy output, system status, and performance metrics without the need for manual inspection. Despite minor challenges encountered during hardware assembly and casing design, the system was successfully deployed and became fully operational within a short period.

The results of the EcoVolt implementation were highly promising. Throughout the trial period, the system demonstrated improved energy efficiency through accurate real-time monitoring and AI-driven optimization of the energy conversion process. By utilizing agricultural waste as a renewable energy source, EcoVolt reduced reliance on conventional energy systems while promoting sustainable waste management. User feedback indicated high levels of satisfaction, particularly in terms of system reliability, ease of access, and clarity of information presented on the monitoring platform.

Overall, EcoVolt has proven to be an innovative and effective solution for sustainable energy generation and management. Its successful implementation highlights its potential for wider adoption in rural and agricultural communities. Future enhancements may include advanced energy optimization techniques, predictive analytics for system maintenance, and the integration of additional sensors to further improve performance monitoring and environmental impact assessment. With its emphasis on efficiency, sustainability, and intelligent system control, EcoVolt presents a practical and environmentally responsible approach to modern energy management.

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