

EEEC136 SOLAR ENERGY TECHNOLOGY

IOT ENABLED PAPER WASTE TO ELECTRICITY GENERATION INTEGRATED WITH SOLAR SYSTEM

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report “**IOT ENABLED PAPER WASTE TO ELECTRICITY GENERATION INTEGRATED WITH SOLAR SYSTEM**” is the bonafide work of “**AGALYA S (927623BEE006), HARINI M (927623BEE031), KARNIKA D (927623BEE039), MONIKKA K (927623BEE056)**” who carried out the project work during the academic year 2025-2026 under my supervision.

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This Project Work EEC1341 Solar Energy Technology report has been submitted for the Vth Semester Project viva voce Examination held on _____

INTERNAL EXAMINER

EXTERNAL EXAMINER

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To emerge as a leader among the top institutions in the field of technical education

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PEO1: Graduates will have flourishing career in the core areas of Electrical Engineering and allied disciplines.

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After the successful completion of the B.E. Electrical and Electronics Engineering degree Program, the students will be able to:

- **PO1 Engineering knowledge:** Apply knowledge of mathematics, natural science, computing, engineering fundamentals, and an engineering specialization to develop solutions to complex engineering problems.
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- **PO3 Design/development of solutions:** Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required.

- **PO4 Conduct investigations of complex problems:** Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions.
- **PO5 Engineering Tool Usage:** Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling recognizing their limitations to solve complex engineering problems.
- **PO6 The Engineer and The World:** Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment.
- **PO7 Ethics:** Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws.
- **PO8 Individual and Collaborative Team work:** Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
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- **PO11 Life-long learning:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change.

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The following are the Program Specific Outcomes of Engineering Students:

- **PSO1:** Apply the basic concepts of mathematics and science to analyze and design circuits, controls, Electrical machines and drives to solve complex problems.
- **PSO2:** Apply relevant models, resources and emerging tools and techniques to provide solutions to power and energy related issues & challenges.
- **PSO3:** Design, Develop and implement methods and concepts to facilitate solutions for electrical and electronics engineering-related real-world problems.

Abstract	POs Mapping
Waste-to-Energy, Hybrid Energy System, Solar Power, IoT Monitoring, Sustainable Electricity, Paper Waste Management.	PO1, PO2, PO3, PO5, PO6,PO11, PSO2, PSO3

SDG Goal		Mapping Justification
SDG 7	Affordable and Clean Energy	The project produces clean electricity using solar and waste-to-energy methods. This directly supports sustainable and affordable energy.

ABSTRACT

The amount of waste paper is increasing day by day. Besides that, there is a huge need for sustainable and eco-friendly Electricity solutions. This project provides a good solution. For this problem. This project will convert the waste paper into a useful energy resource, such as electricity. The system works by the heat produced by the burning of the waste paper and also by the solar panel, which uses the sunlight to give a more efficient way of producing electricity. Combining the solar and the waste-to-energy plant will provide a continuous power supply to the load. In IoT, it plays an important role in: real-time monitoring and controlling the system by connecting the passive elements like sensors, microcontroller and OLED to display the measured parameters. Still, users can monitor the system in real time, through laptops or mobile devices. This system not only gives electricity but also reduces the waste paper to meet the eco-friendly environment with a green future. The project, taken together, explains in detail the creative way to meet the demand of today's electricity needs by converting the paper into a useful energy source. Additionally, it the hybrid energy system reduces environmental pollution by reducing paper waste and lowering dependency on non renewable energy sources. This project will not focus only on efficient energy production but also on contributing to the environment by reducing paper waste. In general, it presents an excellent way of meeting modern-day electricity needs. All while promoting a future.

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LIST OF ABBREVIATIONS

S.No	ABBREVIATION	EXPANSION
1.	IoT	Internet of Things
2.	OLED	Organic Light Emitting Diode
3.	ESP 32	Espressif Systems 32 (Wi-Fi Module)
4.	BMS	Battery Management System
5.	DC	Direct Current
6.	AC	Alternating Current
7.	BMS	Battery Management System
8.	Li-ion	Lithium-ion (Battery)
9.	PV	Photovoltaic
10.	Wi-Fi	Wireless Fidelity
11.	NO _x	Nitrogen Oxides
12.	AI	Artificial Intelligence

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The rapid rise in paper usage in homes, offices, schools, and commercial institutions has resulted in a significant increase in discarded paper waste, which often ends up in landfills or is openly burned, causing air pollution, soil contamination, and unnecessary waste of a potentially valuable resource. Traditional disposal methods treat paper waste as useless material, ignoring the fact that it contains stored chemical energy that can be converted into heat and electricity. With the growing global demand for clean and renewable energy, it has become important to explore innovative ways of turning everyday waste into useful power sources. To address this challenge, the project titled “IoT-Enabled Paper Waste to Electricity Generation Integrated with Solar System” presents a hybrid model that combines waste-to-energy conversion, solar power generation, and IoT-based monitoring into a single smart-energy solution. The system uses discarded paper as the primary fuel, where the combustion process produces heat that is converted into electrical output. This output is supported by solar energy through a solar panel and charging circuitry, ensuring uninterrupted generation even when paper waste is limited. Key components such as the solar charging module, battery management system (BMS), voltage and temperature sensors, and ESP32 microcontroller work together to maintain stable energy production. The ESP32 also connects to the Blynk IoT platform, allowing users to remotely monitor voltage, battery health, temperature levels, and system status in real time through a smartphone or laptop. An OLED display is included for on-device visualization, while a DC servo motor enables controlled movement and automation within the setup. The integration of IoT ensures safety by preventing overheating and battery overcharging, while solar energy reduces dependency on conventional power sources. Overall, this project

demonstrates how combining renewable energy, digital monitoring, and smart automation can create an efficient and environmentally friendly electricity generation system. It also shows how simple household waste like paper can be transformed into usable power for small loads, promoting sustainability, reducing pollution, encouraging recycling, and supporting future advancements in green energy and smart-grid technologies.

1.2 PROBLEM STATEMENT

Paper waste is one of the largest contributors to municipal solid waste across the world, generated in huge quantities from households, offices, schools, printing shops, and packaging industries, and its improper disposal has become a major environmental challenge due to slow decomposition, landfill accumulation, and the release of greenhouse gases. Recognizing the urgent need for sustainable solutions, researchers have explored biological waste-to-energy methods capable of converting paper waste into usable forms of energy through natural microbial processes. The existing research paper reviewed in this study focuses on a traditional, non-IoT-based approach that converts paper waste into electricity using a combination of anaerobic digestion and microbial fuel cell (MFC) technology. In this work, the authors highlight that paper waste, due to its high cellulose and organic content, acts as an excellent substrate for anaerobic bacteria which break down the fibers in the absence of oxygen, producing biogas primarily composed of methane and carbon dioxide. The paper describes a manually operated anaerobic digester setup in which shredded and pre-soaked paper waste is mixed with cow dung as an inoculum, sealed inside a digestion drum, and allowed to undergo biological decomposition for several days without any digital sensing or automated monitoring. The biogas generated from this process is collected in a simple gas-holder and supplied to a miniature generator, where the methane-rich gas is used as fuel to produce electrical energy, while all voltage, pressure, and

performance readings are taken manually using basic laboratory tools such as multimeters and pressure meters. In addition to biogas-based electricity generation, the study integrates a microbial fuel cell system that utilizes the partially digested slurry as the organic feed for electroactive bacteria, which release electrons during metabolic activity, thereby producing low-voltage energy through a simple two-chamber MFC arrangement. The MFC setup, like the digester, operates completely without IoT devices, with all observations recorded manually, demonstrating that paper waste can continue producing energy even after initial digestion. The introduction of the existing paper emphasizes the scientific potential of these biological methods, noting that paper waste contains cellulose and hemicellulose that can be efficiently degraded under controlled anaerobic and electrochemical conditions. However, it also highlights the limitations of non-automated systems, such as the inability to control temperature, pH, retention time, and microbial activity accurately, as well as the lack of real-time data needed to maintain optimal process conditions. The study stresses that although the manual system is simple, affordable, and suitable for basic laboratory environments or rural areas, it requires continuous human supervision, suffers from fluctuating performance, and cannot be scaled effectively without modern monitoring tools. This makes it clear that traditional paper-waste-to-energy approaches, while scientifically effective, lack technological enhancement, automation, and reliability. Therefore, the existing paper provides a strong foundation and justification for the development of an improved IoT-enabled system—such as the one proposed in this project—which would integrate sensors, controllers, and real-time monitoring to overcome current limitations, optimize process efficiency, improve safety, and ensure continuous data-driven operation, making the conversion of paper waste into electricity far more effective and sustainable.

1.3 OBJECTIVE OVERVIEW

The objective of the project “IoT Enabled Paper Waste to Electricity Generation Integrated with Solar System” is to design, develop, and demonstrate a highly sustainable, intelligent, and hybrid energy-generation framework that transforms everyday paper waste into a reliable source of electrical power while simultaneously utilizing solar energy to create a continuous, stable, and eco-friendly power supply for small-scale and decentralized applications. This project aims to address multiple real-world challenges—such as the increasing generation of solid waste, the rising cost of conventional electricity, the global push toward renewable energy adoption, and the urgent need for smart automated energy infrastructures—by introducing an innovative solution that merges waste-to-energy technology with solar harvesting and IoT-driven monitoring. The system focuses on converting paper waste into energy through an optimized thermal, pyrolysis, or gasification-based process that ensures maximum energy extraction, reduced emissions, and minimal residue, thereby turning low-value, discarded material into a productive energy asset. In parallel, the solar subsystem captures clean and renewable power from sunlight, ensuring that energy production continues even when waste availability is inconsistent, thus creating a balanced and uninterrupted dual-energy pathway. The integration of IoT forms the intelligence layer of the project, where sensors, microcontrollers, and cloud platforms work together to monitor critical system variables such as combustion temperature, gas output rate, solar irradiance, photovoltaic efficiency, battery charge status, system voltage/current levels, environmental conditions, and operational safety metrics. This IoT-driven connectivity enables real-time data visualization, remote control, automated adjustments, predictive maintenance alerts, system optimization, and performance analytics, ultimately transforming the hybrid energy unit into a smart, self-regulating, and user-friendly system that can be accessed from anywhere. The project also aims to promote circular economy practices by encouraging resource recovery, reducing the burden on landfills, lowering greenhouse gas emissions, and minimizing dependency

on fossil fuels. Moreover, the objective includes creating a scalable, low-cost, compact, and easily deployable model that can be implemented in rural areas, academic institutions, offices, homes, and community-level microgrids where clean energy solutions are needed. By combining waste conversion, renewable solar power, and modern IoT automation, the project ultimately strives to present a futuristic green-energy solution that not only contributes to environmental protection and energy conservation but also paves the way for smarter, data-driven energy systems capable of supporting sustainable development goals and long-term environmental resilience.

1.4 SCOPE OF THE PROJECT

The scope of this project extends across the complete conceptualization, design, development, integration, and evaluation of an intelligent hybrid energy-generation system that utilizes paper waste as a primary input for electricity production while simultaneously incorporating solar energy to ensure stable and eco-friendly power generation under varying operating conditions. It covers the detailed investigation of different paper waste conversion techniques—such as controlled combustion, gasification, or pyrolysis—to determine the most efficient and environmentally safe method for extracting usable heat energy, which is then converted into electrical output using thermoelectric modules, micro-generators, or steam-based mechanisms. Alongside this, the project includes the installation and optimization of a solar photovoltaic arrangement capable of delivering supplementary or backup power, particularly in scenarios where waste input is low, energy demand increases, or continuous operation is required. The scope also encompasses the full integration of Internet of Things (IoT) technologies to elevate the system from a basic hybrid model to an advanced smart-energy platform capable of real-time tracking, automated control, predictive diagnostics, and remote observation through sensors, microcontrollers, wireless communication modules, and cloud-based dashboards. This

IoT-enabled monitoring will collect and process critical data such as combustion temperature, exhaust characteristics, solar intensity, panel efficiency, system voltage and current, battery charge level, operational cycles, energy output patterns, and environmental conditions, enabling data-driven optimization and early detection of system abnormalities. Furthermore, the project covers the development of intelligent control algorithms that manage automatic switching between the solar module and paper-waste module based on input availability, efficiency levels, and power demand, ensuring seamless hybrid operation with minimal energy loss. The scope includes prototyping, material selection, fabrication of the structural frame, integration of safety mechanisms, installation of sensors, and implementation of energy-storage components like rechargeable batteries or supercapacitors. Performance testing, efficiency analysis, environmental impact assessment, and reliability evaluation under different load conditions and waste-input patterns also form a major part of the scope. In addition, the project extends into studying the societal and economic benefits of converting everyday paper waste into clean energy—supporting circular economy practices, reducing landfill pressures, lowering carbon emissions, and providing affordable decentralized power solutions for rural communities, households, academic institutions, and small-scale industries. It also involves benchmarking the proposed model against existing waste-to-energy and solar-only systems, identifying possible limitations, and outlining future improvements such as AI-based monitoring, improved waste preprocessing units, enhancement of energy-storage capacity, and expansion into multi-waste energy conversion, thereby making the project comprehensive, scalable, environmentally impactful, and aligned with modern sustainability and smart automation trends.

1.5 ADVANTAGES

The advantages of this IoT-enabled paper waste to electricity generation system integrated with a solar subsystem are extensive, spanning environmental, economic, technological, and practical benefits that make the project highly impactful and future-ready. One major advantage is the significant reduction of paper waste that would otherwise accumulate in landfills, decompose, and release harmful greenhouse gases; instead, the system converts this abundant, low-cost waste into productive electrical energy, promoting a cleaner and healthier environment. By combining waste-to-energy conversion with solar power harvesting, the system ensures a continuous and reliable supply of electricity even during periods of low waste availability, making it more stable and dependable than single-source energy systems. The hybrid model improves overall energy efficiency, maximizes resource utilization, and reduces dependence on non-renewable fuels or costly grid electricity, leading to substantial long-term savings and enhanced sustainability. A key advantage is the integration of IoT intelligence, which brings modern automation and smart monitoring capabilities to the system; real-time data tracking on temperature, voltage, current, energy production, system health, and waste input allows users to remotely supervise and control the entire operation with high precision, improving safety, reducing manual effort, and preventing unexpected failures through predictive maintenance. The system's ability to automatically switch between solar and waste-based energy sources ensures seamless operation and optimal power generation under varying conditions, making it suitable for rural areas, off-grid communities, educational institutions, and small industries where consistent power availability is essential. Additionally, the project supports circular economy principles by transforming discarded paper into a valuable energy resource, lowering pollution, and promoting responsible waste reuse. Its modular and scalable design allows easy expansion based on energy demand, while its low operating cost and renewable input materials make it economically feasible for both small-scale and community-level applications. The system also contributes to

reducing carbon emissions by replacing fossil-fuel-based power with clean energy alternatives, thereby supporting global sustainability goals. Moreover, the simplicity of the design, combined with the advanced IoT framework, makes the system user-friendly, easy to maintain, and adaptable for future enhancements such as AI-based optimization, improved storage solutions, and multi-waste energy conversion capabilities. Overall, the combination of environmental protection, cost savings, renewable energy utilization, smart automation, operational reliability, and wide applicability makes this hybrid IoT-enabled waste-to-electricity and solar energy system a highly beneficial, impactful, and forward-thinking solution.

CHAPTER 2

LITERATURE REVIEW

PAPER TITLE: Transforming Paper Dust into Electricity and Biochar via Gasification

AUTHORS: A. Halba et al.

YEAR: 2025

JOURNAL: Fuel Processing / Energy Journal

DESCRIPTION:

This paper presents a sustainable method for converting waste paper dust into useful energy through gasification, offering an eco-friendly alternative to landfilling and open burning that contribute to pollution and greenhouse gas emissions. In the proposed system, paper dust is heated at high temperatures in a low-oxygen environment, producing syngas for electricity generation and biochar for agricultural and environmental applications. Because paper dust contains high cellulose, it serves as an excellent feedstock, giving stable syngas output and allowing continuous, predictable power generation suitable for industries, decentralized grids, and rural areas. The biochar produced is carbon-rich, porous, and valuable for improving soil fertility, supporting carbon sequestration, and acting as a filtration material, making the overall process efficient and aligned with circular-economy principles. The study also notes challenges such as variations in dust composition due to inks, coatings, and adhesives that may affect system efficiency and gas purity. To overcome this, the authors recommend further research on pre-processing, emission control, and real-time gas monitoring, along with automated controls to optimize temperature and airflow inside the gasifier. Overall, the study concludes that gasifying paper dust into electricity and biochar is a practical, low-cost, and environmentally friendly solution with strong potential for industrial-scale adoption, especially in regions with high paper waste generation. It encourages future advancements to make the technology even more efficient, automated.

PAPER TITLE: Energy Recovery from Waste Paper and Deinking Sludge to Support the Demand of the Paper Industry: A Numerical Analysis

AUTHORS: S. Di Fraia and M. R. Uddin

YEAR: 2022

JOURNAL: Sustainability, vol.14, no.8, p.4669

DESCRIPTION:

This paper presents a numerical analysis on converting waste paper and deinking sludge—major byproducts of paper manufacturing and recycling—into usable energy to meet the industry’s rising power needs. Since huge amounts of these wastes are generated every year and traditional disposal methods increase pollution and operating costs, the authors examine energy recovery using combustion, gasification, and pyrolysis. Their simulations evaluate how moisture content, feedstock composition, and thermal conditions influence energy output and system efficiency. Results show that waste paper has high calorific value and can produce substantial energy under optimized settings, while deinking sludge, though limited by high moisture, can still contribute effectively when pretreated or blended with other wastes. The study highlights that converting these materials into energy reduces dependence on external fuels, lowers emissions, cuts disposal costs, and supports circular economy principles. The authors also note challenges such as variations in sludge quality, preprocessing needs, emission concerns, and the requirement for proper pollution-control systems. They recommend further research to improve conversion efficiency, optimize reactor design, and evaluate long-term sustainability. Overall, the paper concludes that energy recovery from waste paper and deinking sludge is a feasible, economical, and environmentally beneficial approach for achieving cleaner and more sustainable paper industry operations.

PAPER TITLE: A Review Paper on Electricity Generation by Using Waste Materials

AUTHORS: S. D. Mulani, N. P. Adate, V. R. Sargar, and P. B. Yadav

YEAR: 2024

JOURNAL: International Journal of Research Publication and Reviews, vol. 5, no. 11, pp.7720–7724

DESCRIPTION:

This review paper outlines key methods for generating electricity from waste, stressing the need for sustainable waste management as global waste levels rise due to industrialization and population growth. Since landfilling and open burning cause severe pollution, the authors examine waste-to-energy (WTE) technologies that convert municipal, agricultural, industrial, biomass, paper, and plastic wastes into usable power. They describe thermal processes such as incineration, pyrolysis, and gasification, which break waste into heat, syngas, or bio-oil for electricity generation, and biological processes like anaerobic digestion that produce biogas from organic materials. The paper highlights that many waste types especially plastics and biomass have high calorific value and can generate significant energy when processed properly. Using waste for electricity reduces landfill use, cuts fossil-fuel dependence, and supports circular-economy practices. The authors also discuss challenges including inconsistent waste composition, high setup cost, emissions from thermal treatments, and the need for efficient segregation and pollution-control systems. They conclude that WTE is a practical and eco-friendly solution for managing waste while producing clean energy, and recommend further research to improve conversion efficiency, monitoring systems, and cost-effective technologies suitable for wider adoption.

PAPER TITLE: Generation of Electricity from Waste Papers and Plastic

AUTHORS: F. Tamboli, M. Shubham, O. Shelke, and S. Borshe

YEAR: 2024

JOURNAL: International Scientific Journal of Engineering and Management, vol. 3, no.3,pp.1–9,doi:10.55041/ISJEM01459

DESCRIPTION:

This paper presents a study on generating electricity from waste paper and plastic by converting these widely discarded materials into useful energy through suitable waste-to-energy technologies. Since improper disposal of paper and plastic—especially landfilling and open burning—causes soil pollution, water contamination, and harmful emissions, the authors explore thermal conversion methods such as incineration, gasification, and pyrolysis. Incineration burns the waste to produce steam for electricity generation, gasification heats it in low oxygen to produce syngas for engines or turbines, and pyrolysis decomposes it without oxygen to produce pyro-oil, gas, and char. The study shows that paper, with its cellulose content, and plastics like polyethylene and polypropylene, with their high calorific value, are excellent feedstocks for energy production. Experimental results indicate that a controlled mix of paper and plastic ensures stable energy output and better conversion efficiency. The paper also highlights the importance of waste segregation, shredding, drying, and maintaining proper temperature and airflow during thermal processing. It notes that modern emission control systems can significantly reduce pollutants like CO₂, NO_x, and dioxins, making waste-to-energy a safer alternative to conventional disposal. The authors acknowledge challenges such as variations in waste composition, different plastic types, equipment costs, and maintenance requirements, but emphasize that with proper pollution-control technology these issues can be managed. Overall, the study concludes that electricity generation from waste paper and plastic is a practical, economical, and environmentally friendly solution that reduces landfill burden, supports clean energy goals, and aligns with circular economy principal.

PAPER TITLE: Performance Analysis of a Solar-Aided Waste-to-Energy Plant

AUTHORS: H. Chen et al.

YEAR: 2021

JOURNAL: Energy, ScienceDirect

DESCRIPTION:

This paper analyzes the performance of a solar-aided waste-to-energy (WTE) plant, focusing on how adding solar thermal energy can improve the overall efficiency and sustainability of waste-based power generation. The authors explain that conventional WTE plants depend entirely on burning municipal solid waste to produce heat for steam generation, but the process often faces limitations such as inconsistent waste quality, fluctuating heat output and higher emissions. To overcome these limitations, the study proposes integrating solar collectors into the system to supply additional thermal energy to the boiler. This solar heat increases the steam temperature and pressure, which improves turbine performance and leads to higher electricity production. The simulation results show that the hybrid plant performs better than a normal WTE plant, producing more stable power even when the calorific value of waste varies. The authors also highlight that solar support reduces dependence on waste combustion alone, which helps lower carbon emissions and makes the system more environmentally friendly. The paper discusses the design considerations needed for such integration, including selecting the right type of solar collectors, designing heat exchangers and controlling the heat flow between the solar and waste systems. Although the hybrid model shows strong advantages, the authors note challenges such as high installation costs, the need for large space for solar panels and variations in sunlight due to weather. They suggest that using thermal energy storage could help maintain continuous operation even during low-sun periods. Overall, the study concludes that solar-aided WTE plants can significantly improve energy efficiency, reduce emissions and support sustainable electricity production, especially in regions with high solar potential.

CHAPTER 3

EXISTING SYSTEM

3.1 INTRODUCTION

Paper waste is one of the largest contributors to municipal solid waste across the world, generated in huge quantities from households, offices, schools, printing shops, and packaging industries, and its improper disposal has become a major environmental challenge due to slow decomposition, landfill accumulation, and the release of greenhouse gases. Recognizing the urgent need for sustainable solutions, researchers have explored biological waste-to-energy methods capable of converting paper waste into usable forms of energy through natural microbial processes. The existing research paper reviewed in this study focuses on a traditional, non-IoT-based approach that converts paper waste into electricity using a combination of anaerobic digestion and microbial fuel cell (MFC) technology. In this work, the authors highlight that paper waste, due to its high cellulose and organic content, acts as an excellent substrate for anaerobic bacteria which break down the fibers in the absence of oxygen, producing biogas primarily composed of methane and carbon dioxide. The paper describes a manually operated anaerobic digester setup in which shredded and pre-soaked paper waste is mixed with cow dung as an inoculum, sealed inside a digestion drum, and allowed to undergo biological decomposition for several days without any digital sensing or automated monitoring. The biogas generated from this process is collected in a simple gas-holder and supplied to a miniature generator, where the methane-rich gas is used as fuel to produce electrical energy, while all voltage, pressure, and performance readings are taken manually using basic laboratory tools such as multimeters and pressure meters. In addition to biogas-based electricity generation, the study integrates a microbial fuel cell system that utilizes the partially digested slurry as the organic feed for electroactive bacteria, which release electrons during metabolic activity, thereby producing low-voltage energy through a simple two-chamber MFC arrangement.

The MFC setup, like the digester, operates completely without IoT devices, with all observations recorded manually, demonstrating that paper waste can continue producing energy even after initial digestion. The introduction of the existing paper emphasizes the scientific potential of these biological methods, noting that paper waste contains cellulose and hemicellulose that can be efficiently degraded under controlled anaerobic and electrochemical conditions. However, it also highlights the limitations of non-automated systems, such as the inability to control temperature, pH, retention time, and microbial activity accurately, as well as the lack of real-time data needed to maintain optimal process conditions. The study stresses that although the manual system is simple, affordable, and suitable for basic laboratory environments or rural areas, it requires continuous human supervision, suffers from fluctuating performance, and cannot be scaled effectively without modern monitoring tools. This makes it clear that traditional paper-waste-to-energy approaches, while scientifically effective, lack technological enhancement, automation, and reliability. Therefore, the existing paper provides a strong foundation and justification for the development of an improved IoT-enabled system—such as the one proposed in this project—which would integrate sensors, controllers, and real-time monitoring to overcome current limitations, optimize process efficiency, improve safety, and ensure continuous data-driven operation, making the conversion of paper waste into electricity far more effective and sustainable.

3.2 BLOCK DIAGRAM

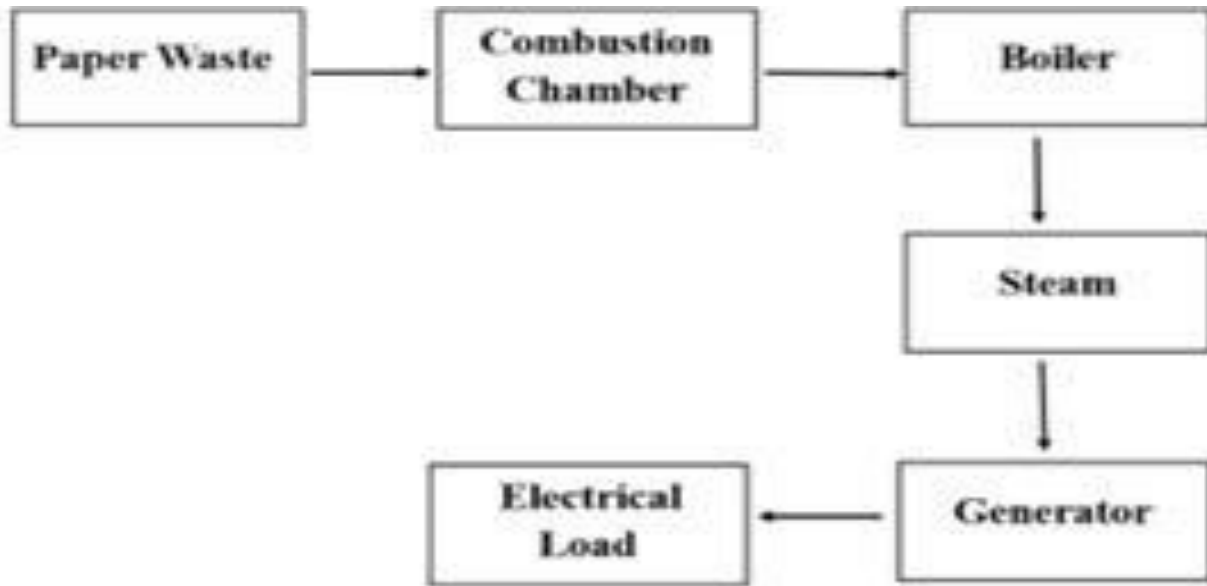


Fig.3.1 block diagram of existing method

3.3 WORKING OF EXISTING METHOD

The working of the traditional paper-waste-to-electricity generation system integrated with a solar power unit, without any IoT or digital monitoring, follows a fully manual and conventional process in which the transformation of biodegradable paper waste into usable electrical energy is achieved through mechanical preparation, thermal conversion, and electromechanical energy generation. In the beginning, paper waste is manually collected from schools, offices, households, and industries, and then sorted to remove non-combustible materials like plastics, staples, metal pieces, and laminated sheets to ensure clean biomass input for efficient combustion. The sorted paper is then shredded using a mechanical cutter to decrease the size of the paper particles, increasing surface area and enhancing the combustion rate. After shredding, the waste is dried by natural sun-drying or mechanical heating to remove moisture, as wet paper burns poorly and reduces the thermal

output. Once the paper achieves the ideal dryness, it is fed into a manually operated biomass combustion chamber or a small-scale gasifier, where it undergoes pyrolysis and partial oxidation. During this stage, the paper decomposes due to heat and releases combustible gases such as hydrogen, methane, and carbon monoxide, along with heat energy. This produced heat is used to convert water into steam through a compact boiler arrangement connected to the combustion unit. The high-pressure steam is routed through a small turbine, steam engine, or rotary mechanism, where the kinetic energy of the high-velocity steam rotates the turbine blades. The turbine shaft is directly coupled with a mini electrical generator or alternator, and the rotation of the shaft induces electromagnetic induction, producing AC or DC power depending on the generator type. The generated electricity is then passed through a simple charge controller or rectifier–regulator circuit to ensure stable voltage levels before being stored in a battery or directly used to power small loads such as lights, fans, or low-power appliances. In parallel with this biomass-based generation system, a solar photovoltaic (PV) panel is installed to provide an additional renewable energy source. Solar energy captured by the PV panels is converted into DC electricity and stored in the battery using a basic solar charge controller. The integration of solar ensures that electricity is available even when the biomass system is not actively operating or when paper waste availability is inconsistent. The coordination between the two energy sources is typically manual, where an operator checks the battery status, decides when to use solar or biomass energy, and physically switches between sources if needed. In the absence of IoT, key parameters such as combustion temperature, steam pressure, turbine rotation speed, heat level, and battery charging are observed manually using analog gauges, physical meters, or simple mechanical indicators. The efficiency of the system depends heavily on manual supervision—operators must maintain the right airflow for combustion, regulate fuel feeding rate, periodically check the boiler water level, and ensure that the turbine and generator components function smoothly without overheating. Maintenance also becomes entirely manual, requiring regular cleaning of ash residues, lubrication of rotating parts, inspection of boiler tubes for scaling, and checking electrical wiring for faults. Despite being low-tech

compared to modern IoT-based systems, this existing model is highly useful in rural and semi-urban areas because it operates with simple components, requires no internet connectivity, has low installation cost, and can be constructed using basic engineering principles. It demonstrates how paper waste, a commonly discarded material, can be converted into energy through a self-sustaining cycle involving shredding, drying, combustion, steam production, turbine rotation, and electricity generation. The addition of a basic solar system ensures hybrid power generation, making the setup more reliable and suitable for locations with frequent power shortages. Overall, the working of this existing non-IoT system relies on direct human supervision and mechanical control, maintaining a balance between biomass-based energy production and solar energy harvesting, thus offering a practical small-scale renewable energy solution without any advanced automation or monitoring technologies.

CHAPTER 4

PROPOSED SYSTEM

4.1 INTRODUCTION

IoT-enabled paper waste-to-electricity generation system provides a complete visual representation of how various components work together to convert paper waste into usable electrical energy while ensuring continuous monitoring and control. The entire system is designed to utilize two main energy sources—thermal energy generated from burning paper waste and renewable solar energy—both of which contribute to the production of clean power. At the core of this setup is the ESP32 microcontroller, which acts as the central processing and communication unit, linking all sensors, energy inputs, and output modules. The block diagram helps in understanding the logical flow of energy conversion, data acquisition, and smart control within the proposed solution. The process begins with paper waste being burned inside a controlled chamber to generate thermal energy. This heat is then directed to a specialized thermal or thermoelectric conversion panel, which transforms the heat into electrical power. As paper waste supply might not always be consistent, solar panels are integrated into the system to provide a stable auxiliary energy source. The block diagram shows how both these energy sources are routed through monitoring components before reaching the load. Voltage sensors are placed at key points to measure the voltage produced by both the waste-to-energy unit and the solar panel. This continuous sensing ensures that the system functions within safe and efficient limits by providing real-time readings to the ESP32. In addition to voltage monitoring, temperature sensors such as the DS18B20 are included to track the heat levels around the system. This is crucial because excessive heat may damage internal components or lead to unsafe operating conditions. The block diagram highlights how temperature data is fed to the ESP32, allowing it to take protective actions when needed. An OLED display is also connected to the ESP32 to present immediate information such as temperature, voltage, and power output directly on the device, enabling quick verification without needing additional tools.

A key feature represented in the block diagram is the relay module, which functions as an intelligent switch controlled by the ESP32. Based on voltage levels or preset thresholds, the relay automatically switches between solar energy and paper-waste-generated energy, ensuring smooth and uninterrupted power supply to the load. This prevents overload, optimizes energy usage, and enhances system performance. The load, typically a small motor, LED strip, or any low-power device, is placed at the output end, demonstrating the practical use of the generated energy. The block diagram also emphasizes the role of IoT integration in this project. The ESP32 communicates with the Blynk cloud platform via Wi-Fi, sending real-time sensor values to a mobile dashboard. This allows users to remotely monitor voltage, temperature, energy production rate, and system status. Notifications and alerts can be generated when abnormal conditions are detected. Thus, the block diagram not only illustrates the energy conversion pathway but also shows how smart monitoring, automation, and renewable integration come together to create an efficient and sustainable waste-to-energy system.

4.2 BLOCK DIAGRAM

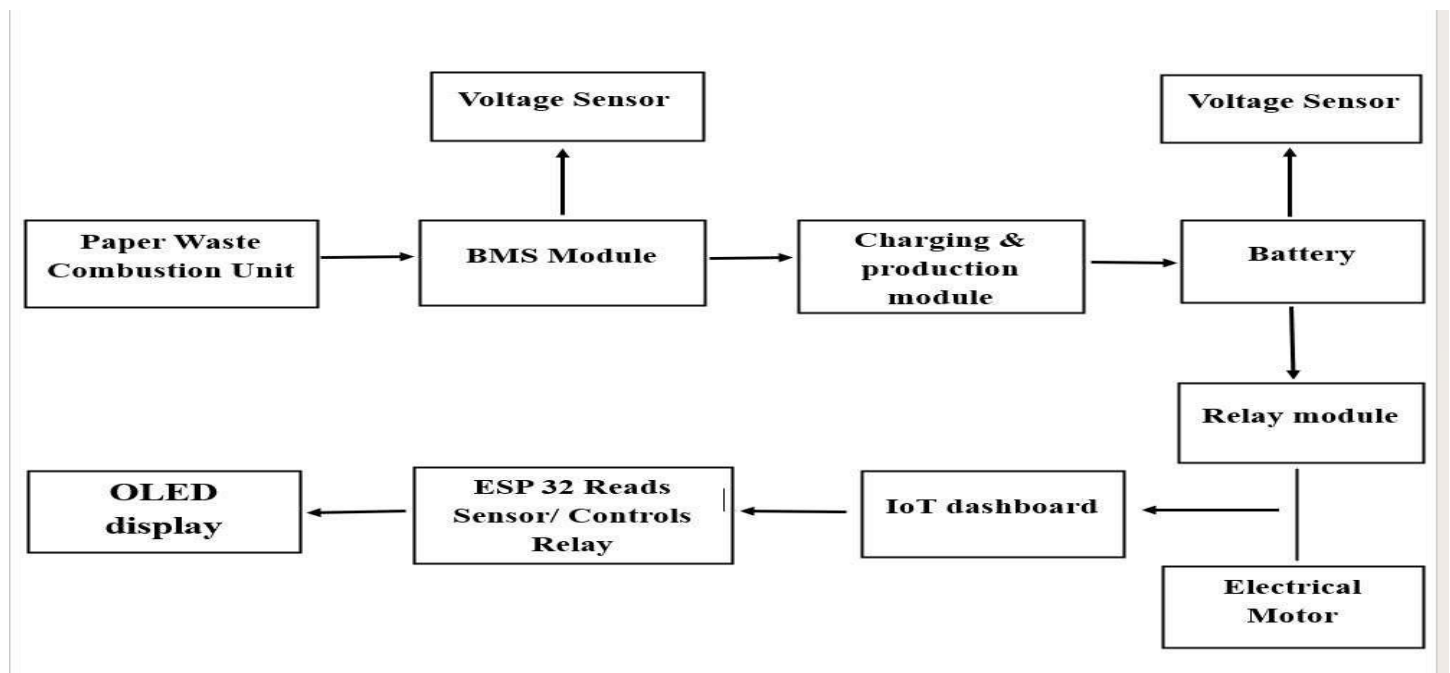


Fig.4.1 block diagram of proposed diagram

4.3 WORKING OF THE BLOCK DIAGRAM

1.Paper Waste Heat Source:

Paper waste is burned inside the chamber, producing heat energy.

2. Solar Panel Input:

The solar panel adds extra power to support the load and provides energy when paper waste is unavailable.

3. Voltage Sensor:

Voltage from both sources is measured to monitor power levels and ensure correct switching between solar and waste energy.

4. Temperature Sensor :

It monitors system temperature to prevent overheating during operation.

5. ESP32 Controller:

The ESP32 collects all sensor data and controls the relay module.

It also sends real-time temperature, voltage, and power values to the IoT dashboard.

6. Relay Module:

The relay switches between solar power and waste-generated electricity based on voltage levels and system conditions.

7. OLED Display:

Shows real-time readings such as voltage, temperature, and power output locally on the device.

8. IoT Dashboard (Blynk):

Users can view live data, receive alerts, and monitor system performance remotely using the Blynk app.

9. Output Load:

The generated electricity powers small loads such as motors or LEDs, showing the system's working.

CHAPTER 5

HARDWARE IMPLEMENTATION

5.1 IMPLEMENTATION OF HARDWARE

Paper waste is one of the most common forms of solid waste generated in households, schools, offices, and industries. Improper disposal of this waste leads to environmental pollution and loss of valuable energy. To utilize this waste effectively, this project proposes an IoT-enabled paper waste-to-electricity generation system integrated with a solar energy module. The system converts paper waste into heat energy through controlled burning, and this heat is used for hybrid energy production along with solar power. An ESP32 microcontroller continuously monitors key parameters such as solar voltage, battery voltage, and temperature, and updates the readings to the Blynk IoT platform for remote monitoring. By combining waste-to-energy generation with renewable solar power, the system ensures continuous, eco-friendly, and reliable energy production suitable for smart homes and green technology applications. To store the generated energy, a Li-ion battery is integrated into the system, supported by a Battery Management System (BMS) for over-charge, over-discharge, and short-circuit protection. A charging module (TP4056/LM2596) regulates the input from the solar panel and ensures safe charging of the battery. The system also includes a paper-waste combustion unit, designed to burn paper safely and supply additional thermal energy that enhances solar panel performance. A relay module is connected to control a DC motor, demonstrating the use of the generated electricity in powering small loads. Together, these hardware components form a compact, efficient, and IoT-enabled hybrid energy generation system that demonstrates the conversion of paper waste and solar energy into usable electrical power.

5.2 Description of Hardware Components

1. Paper Waste Burning Chamber

Designed to burn paper waste in a controlled environment.

Generates heat energy required for electricity production.

Ensures safe combustion and prevents excessive smoke spread.

2. BMS Module

Converts the heat from the burning chamber into electrical energy.

Works based on temperature difference across the module.

Acts as the main energy conversion unit in the waste-to-electricity process.

3. Solar Panel

Provides an additional renewable energy source.

Generates voltage during daylight to support the system.

Helps maintain battery charge even when no waste is burned.

4. Battery

Stores energy from both the solar panel and the heat-conversion module.

Supplies power to sensors, microcontroller, display, and motors.

Ensures continuous operation during low sunlight or no burning.

5. Charging Module

Manages charging from two sources: solar and waste-generated power.

Protects the battery from overcharging and voltage fluctuations.

Ensures stable output for all connected components.

6. Voltage Sensor

Measures solar voltage, battery voltage, and output voltage.

Helps monitor the power generation pattern.

Sends continuous readings to ESP32 for IoT display.

7. Temperature Sensor

Measures the burning chamber temperature.

Provides safety by preventing overheating or unsafe combustion levels.

Data is shown on OLED and also uploaded to Blynk IoT.

8. ESP32 Wi-Fi Module

Central microcontroller of the system.

Collects sensor data and uploads it to the Blynk IoT dashboard.

Enables real-time monitoring of solar voltage, battery voltage, and temperature.

9. OLED Display

Shows real-time system values such as voltage and temperature.

Helps with local on-site monitoring and troubleshooting.

Useful during testing and demonstration.

10. DC Servo Motor

Helps control airflow inside the burning chamber (if included).

Supports stable combustion and heat control.

Ensures efficient burning of paper waste.

11. Blynk IoT Platform

Displays solar voltage, battery voltage, and system temperature.

Enables remote monitoring from mobile devices.

Makes the system smart, user-friendly, and interactive.

CHAPTER 6

RESULT AND DISCUSSION

6.1 IMAGES OF THE SOFTWARE & HARDWARE

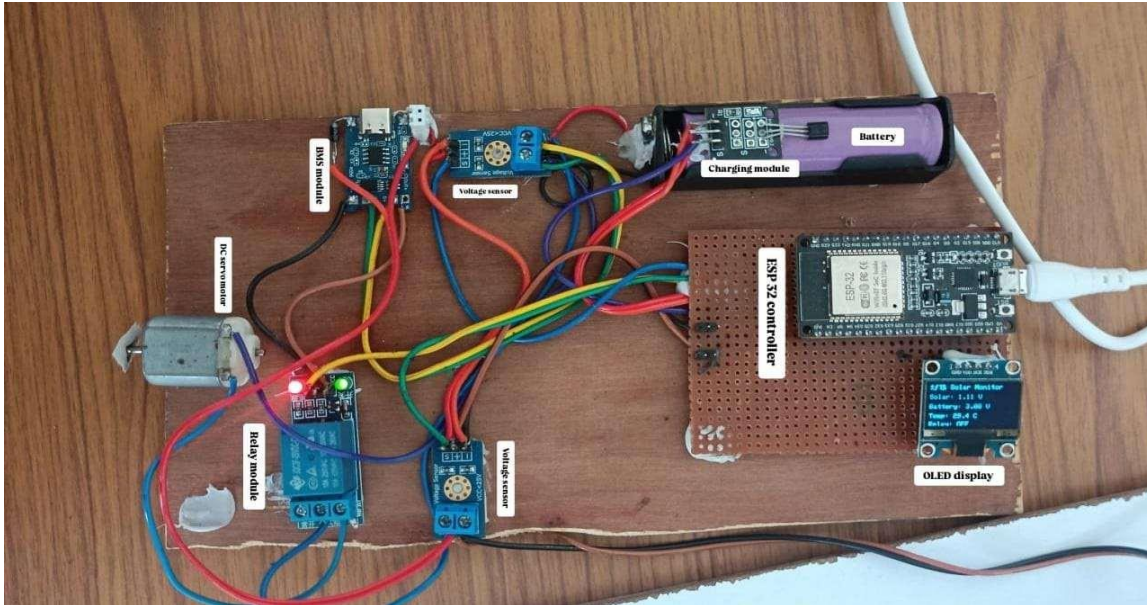


Figure: 6.1 Output show in OLED display

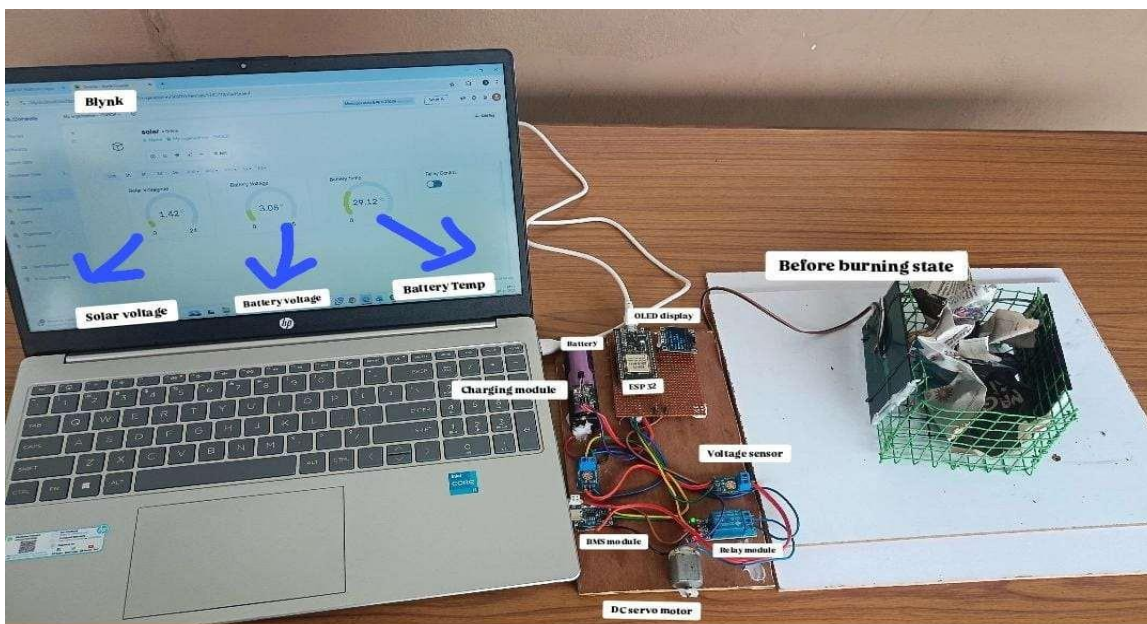


Figure: 6.2 Before burning the waste paper

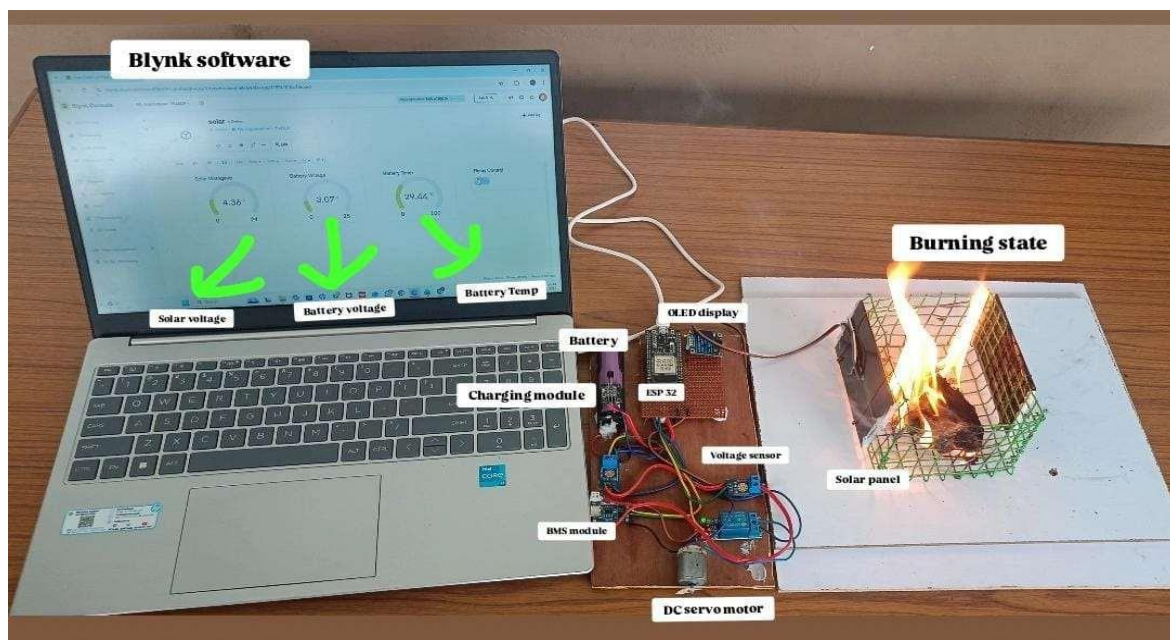


Figure: 6.3 While burning the paper waste

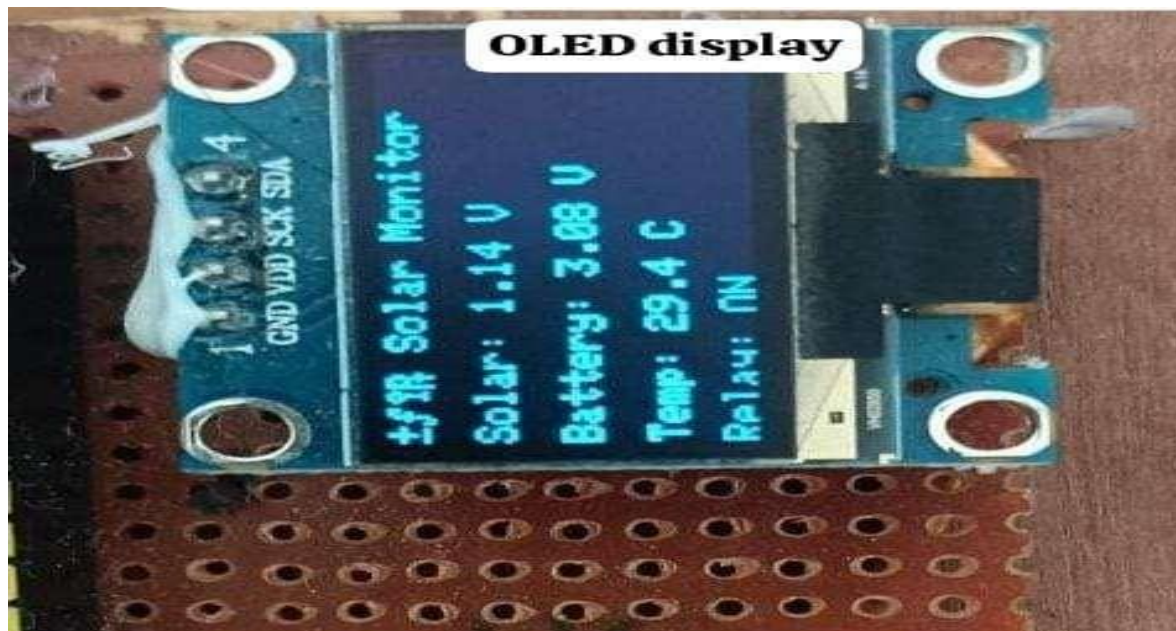


Figure: 6.4 OLED display

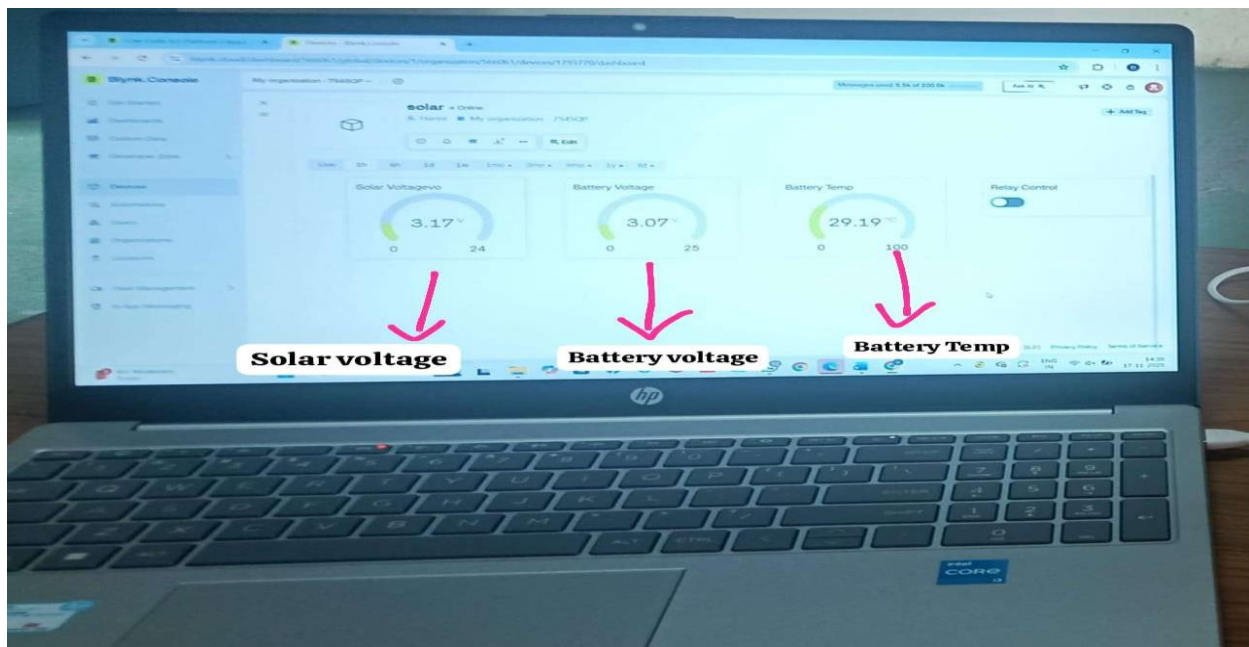


Figure: 6.7 Output in BLYNK IoT software

6.2 DISCUSSION

- First, place the main prototype board/zero-PCB on the base panel to mount all electronic components securely.
- Fix the ESP32 microcontroller on the board and connect it using jumper wires for data processing and IoT communication.
- Connect the voltage sensor modules to measure the solar panel output and the battery charging voltage.
- Mount the paper-waste combustion chamber safely on the right side of the base platform.
- Fix the solar panel on the side of the combustion unit so that it can utilize both ambient light and heat-assisted radiation.
- Connect the solar panel output to the charging module (TP4056/LM2596) for regulated charging of the Li-ion battery.
- Attach the BMS module to protect the battery from over-voltage, over-current, and deep discharging.
- Place the Li-ion battery on the board and connect it to the charging module for energy storage.

- Interface the relay module with the ESP32 to switch the DC motor or load using the generated electricity.
- Fix the DC motor to demonstrate the utilisation of stored/generated power.
- Connect the OLED display to the ESP32 to show live readings such as solar voltage, battery voltage, and temperature.
- Connect the ESP32 to the Blynk IoT platform using Wi-Fi for real-time monitoring of system parameters.
- Ensure all wiring between the voltage sensors, battery, ESP32, and charging units is secured and insulated.
- Finally, power the prototype; the IoT monitoring interface activates automatically, and the combustion-plus-solar hybrid energy system begins operating.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

The experimental setup successfully proved the working of the IoT-enabled paper waste-to-electricity generation system integrated with solar energy. When paper waste was burned inside the mesh chamber, sufficient heat energy was produced, contributing to the electrical output, while the solar panel simultaneously generated additional voltage, making the system function as a hybrid renewable energy model. The voltage sensor accurately detected the generated power, and the ESP32 processed and transmitted this data smoothly to the Blynk IoT platform. The real-time values such as solar voltage, battery voltage, and battery temperature were clearly displayed on the dashboard, confirming stable IoT connectivity and effective remote monitoring. The OLED display on the hardware also presented local readings, ensuring dual-mode monitoring. The battery stored the generated electricity efficiently under the control of the charging module and BMS, preventing overvoltage and maintaining safe operation. The DC servo motor used as the load operated successfully, demonstrating that the energy produced can be used to power small electrical devices. Overall, the results confirm that the system can generate usable electricity from burning paper waste, supplement it with solar power, store it safely, and monitor all parameters in real time through IoT. This validates the feasibility of combining waste-to-energy conversion, renewable sources, and smart monitoring to create a practical, sustainable, and intelligent power generation model.

7.2 FUTURE SCOPE

This project can be expanded in several ways to improve performance, reliability, and real-world application. Advanced thermoelectric materials and optimized combustion systems can significantly increase the energy conversion efficiency. The IoT dashboard can be upgraded using AI and data analytics to predict energy generation, detect faults

automatically, and improve power management. Larger solar modules and battery storage can also be integrated to support higher loads and ensure uninterrupted power supply even when waste availability is low. The system can be scaled to community-level waste management centers, educational institutions, or small industries where paper waste is abundant. Additionally, integrating mobile applications, cloud-based reporting, and automated waste-feeding mechanisms can transform this model into a fully intelligent waste-to-energy micro-generation plant. These improvements can help the project evolve into a commercially viable and eco-sustainable energy solution.

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