Proceedings of Bhavisya Entrepreneur 2025: National Symposium on Entrepreneurship Innovation
ISBN: **978-93-343-9865-6**

NSEI/2025/45

Waste-Energy Powered Smart Irrigation System

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Abstract- Agriculture is the only source of livelihood to farmers, but one of the major challenges they face is water scarcity. Surveys indicate that nearly 20 percent of agricultural land becomes unproductive due to a lack of adequate. To address this challenge, researchers proposed different irrigation schemes powered by renewable energy. The system integrates intelligent control with sustainability by utilizing energy generated from renewable resources, thereby reducing dependency on conventional power supply. A smart irrigation system generally uses sensors to monitor soil moisture, temperature, and other parameters, automating the water supply. This helps conserve water and energy, while also improving crop quality, maintaining soil health, and promoting a sustainable farming method. This paper provides a scheme for a smart irrigation system where energy from waste material is combined with solar energy to make irrigation systems more economical, eco-friendly, and suitable for rural farming communities.

Keywords- Smart Irrigation, Renewable Energy, Iot, Pumps, Waste To Energy

I. INTRODUCTION

Water scarcity and inefficient irrigation practices present a major threat to agricultural productivity worldwide. Smart irrigation, which combines sensors, control logic, and remote monitoring, provides a way to improve water usage efficiency while maintaining or increasing crop production (Singh et al., 2025; Das et al., 2025; Badar, Abeer, & Hashmi, 2025). Traditional irrigation systems usually depend on grid power or fossil fuels, which increases costs for farmers. At the same time, renewable energy sources such as solar photovoltaic, wind, biogas, and waste-to-energy enable off-grid irrigation solutions that are economical for rural areas with limited grid access. From the large amount of waste coming from industries, homes, and even fields, energy can be produced. If this unused energy could be captured and reused, it could offer a more affordable way to irrigation. This work proposes a smart irrigation scheme powered by renewable energy generated from waste, integrated with a solar energy system.

The remainder of this paper is organized as follows: Section II reviews related work on smart irrigation and waste energy utilization. Section III presents the proposed system architecture, methodology and results. Finally, Section IV concludes the paper with key insights and directions

ISBN: **978-93-343-9865-6**

for future research.

II. RELATED WORK

There are numerous papers on smart irrigation systems with renewable energy sources. Commonly used renewable sources are solar photovoltaic, wind, and biogas. In literature, solar power is used as a renewable energy source in many studies (Sudharshan et al., 2019; Nasiakou et al., 2016; Al-Ali et al., 2019). For instance, Sudharshan et al. (2019) proposed a fuzzy logic-based smart irrigation system where solar power is used as a renewable energy source. This irrigation system is embedded with IoT, where different sensors are used to monitor the different components of agriculture. This irrigation system used approximately 51.7% of the water used by the normal irrigation method. That is, nearly a 48.3% savings in water. This system conserves water while being economically viable and less dependent on grid power. Similarly, Nasiakou et al. (2016) implemented a solar energy-based smart irrigation system. To increase the efficiency of energy production, in this literature, authors used a solar-tracking setup using lightdependent resistors (LDRs).

It is shown in the paper that smart irrigation saved a considerable amount of water compared to manual irrigation. ted Al-Ali et al. (2019) also presented a smart irrigation system that is supported by solar energy and controlled via the Internet of Things (IoT). It uses a solar panel to supply power, along with supporting batteries, so the system can operate off-grid or when main power is not available. Whereas [9] proposed a hybrid renewable energy system in which solar and wind energy are both used with the aim of reducing dependence on grid electricity for agriculture. Ghosh et al. (2023) proposed a hybrid renewable energy system combining solar photovoltaic panels and wind turbines to power drip irrigation pumps. Again, in the last few decades, waste has been effectively used to generate electricity (Beyene et al., 2018). Hence, if this energy can be integrated with other renewable technologies, it can be used efficiently for waste-powered smart irrigation systems. To the best of our knowledge, there are no such studies that use waste energy for irrigation.

III. SMART IRRIGATION WITH WASTE ENERGY

The block diagram in fig. 1 shows a smart irrigation system using both solar energy and waste-to-energy. The primary source of energy is generated by converting waste into electricity. Also, a solar panel is used to meet the energy requirement during periods of shortage. The scheme also uses a battery, which stores the energy so that water can be pumped even when there is no sunlight or waste input. The inverter is used to convert the stored power in the battery into a usable form, which runs the water pump to deliver water to the fields. A soil moisture sensor is connected to the controller. Based on the set value, the controller decides when and how much water the crops need, and then automatically switches the pump on or off. The water is delivered through irrigation lines, such as drip or sprinkler systems, ensuring efficient use. By combining renewable energy with smart monitoring, this system reduces dependence on grid electricity, saves water, and supports eco-friendly farming.

In our previous work, the procedure of waste-to-energy generation was discussed in detail (Maity et al.,

ISBN: **978-93-343-9865-6**

2025). Fig. 2 shows the waste-to-energy production block diagram. According to this, the following calculation has been made for the energy requirement for irrigation:

According to (Maity et al., 2025), the amount of waste required to operate a pump with a power requirement of 6 Wh per hour:

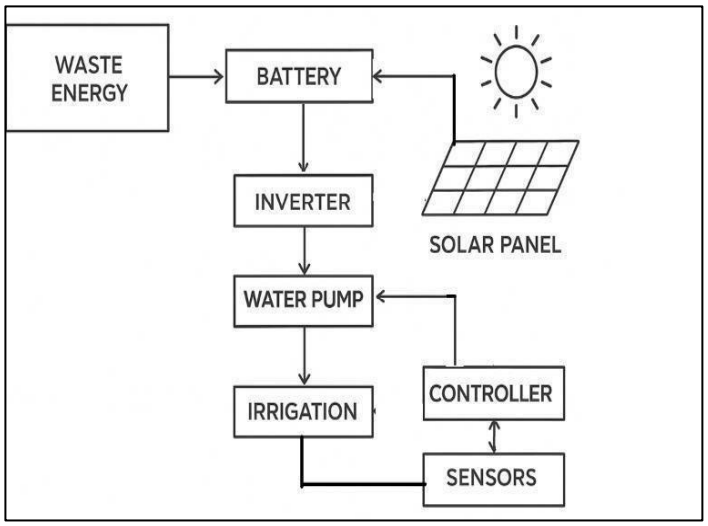
Step 1 – Energy from Waste

It is observed that 320 g of waste produces approximately 1.5 Ah of charge at 6 V . This corresponds to:

$E = 1.5\ Ah \times 6\ V = 9\ Wh$

Thus, 320 g → 9 Wh

⇒ 1 kg → 28.1 Wh



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Fig.1: Block diagram of the proposed scheme

Therefore, 1 kg of waste produces approximately 28 Wh of usable energy. Step 2 – Waste required for 1 hour operation Pump requirement = 6 Wh per hour.

Waste required = (6 ÷ 28) = 0.214 kg ≈ 214 g

Hence, to run the pump for 1 hour, about 214 g of waste is required.

Step 3 – Waste required for 100 hours (1 acre irrigation)

For irrigating 1 acre of field, a pump is assumed to run for 100 hours.

Energy needed = 100 × 6 Wh = 600 Wh

Waste required = (600 ÷ 28) = 21.43 kg ≈ 22 kg

Thus, 22 kg of waste is sufficient to irrigate 1 acre of field once, as per our assumption.

Table I: Waste Requirement vs Pump Running Hours

Pump Running Hours	Pump Energy Demand (Wh)	Waste Required (kg)

ISBN: 978-93-343-9865-6

1 hr	6 Wh	0.21 kg
10 hrs.	60 Wh	2.1 kg
25 hrs.	150 Wh	5.4 kg
50 hrs.	300 Wh	10.7 kg
75 hrs.	450 Wh	16.1 kg
100 hrs.	600 Wh	21.4 kg ≈ 22 kg

Table I provides details on the amount of energy required by a pump for irrigation and the corresponding amount of waste required to fulfil that.

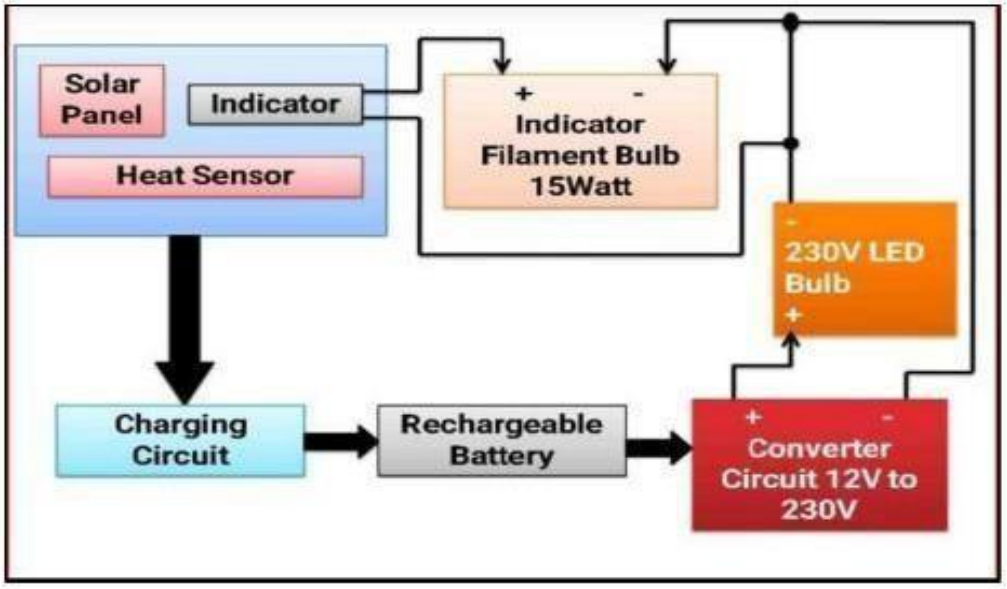


Fig 2. Block diagram of waste-to-energy generation (Maity et al., 2025)

IV. CONCLUSION

The study shows that agricultural or municipal waste can serve as the main energy source for irrigation, with solar PV acting as a reliable backup. One of the main challenges is ensuring a steady supply of waste every day. However, even small towns generate several tons of municipal solid waste (MSW) daily, and with support from local municipalities and farmer cooperatives, farms can access a consistent flow of sorted plastic and organic waste. This approach not only powers irrigation but also contributes to circular economy practices by turning waste into a resource. For larger-scale irrigation systems, improvements in combustion design, heat recovery, and energy conversion efficiency are still needed. A combined waste-to-energy and solar setup appears to be the most practical and eco-friendly way forward for sustainable irrigation. However, the future dimension of this work may consider the integration of automatic waste segregation and sorting for better combustion and energy yield. Also, the integration of artificial intelligence and machine learning can enhance decision-making for energy management and self-schedule the irrigation process based on the weather forecast.

ISBN: **978-93-343-9865-6**

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