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Integrating Renewable Energy in Vegetable Farming: Reducing Carbon Footprints with Solar, Biogas and Wind

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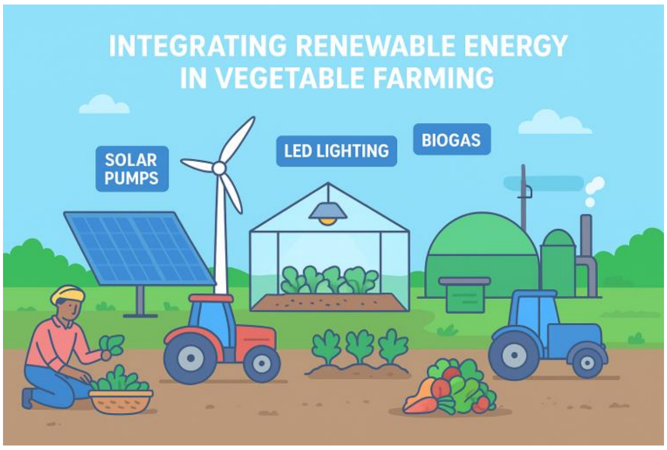
The vegetable sector is a crucial pillar of Indian agriculture, contributing to nutritional security and rural livelihoods. India produces more than 215 million tonnes of vegetables annually, accounting for around 15% of global production (FAO, 2023). However, conventional farming practices in vegetables are energy-intensive due to frequent irrigation, fertilizer use, mechanization and reliance on fossil fuels for pumping and post-harvest processing (Patra et al., 2022). This results in significant greenhouse gas (GHG) emissions with protected cultivation systems often recording higher carbon footprints compared to field systems.

Renewable energy technologies, especially solar, wind and biogas, are being increasingly promoted as solutions to cut emissions while improving resource efficiency. Government initiatives such as the PM-KUSUM scheme have already enabled widespread adoption of solar irrigation pumps, while biogas and solar dryers are being piloted in vegetable clusters (ICAR, 2023). This article highlights the scope and benefits of integrating renewable energy in vegetable farming with a focus on solar pumps, solar dryers, LED lighting in polyhouses and biogas production from vegetable residues.



Solar Applications in Vegetable Farming

Solar Pumps

Solar-powered irrigation pumps are emerging as a sustainable alternative to diesel and electric pumps in vegetable farming. They help reduce dependency on fossil fuels, cut irrigation costs and provide assured water supply for crops such as tomato, brinjal and okra (Kumar et al., 2021). Studies suggest that solar pumps can save up to 1.5–2 tonnes CO_2-equivalent per pump annually, making them an effective climate-smart technology (Gupta et al., 2023).

Solar irrigation pump setup in vegetable farm under Indian scheme

Solar Dryers

Post-harvest losses in vegetables in India are estimated at 20–25%, mainly due to poor storage and drying facilities (Sharma et al., 2022). Solar dryers provide an eco-friendly way of dehydrating surplus produce like onions, chilies and leafy greens, reducing wastage and enhancing shelf life. Compared to traditional sun drying, solar dryers ensure hygienic drying in less time, improve product quality and save energy costs (Verma et al., 2021). Their adoption not only curbs carbon emissions but also adds value through dried products in local and export markets.

Table 1. Comparison of Diesel vs. Solar Irrigation

Parameters	Diesel Pump	Solar Pump
Installation Cost (₹)	45,000	1,20,000
Annual Operating Cost (₹)	50,000	5,000
CO_2 Emission (tonnes/year)	2.1	0.3
Lifespan (years)	7	15

LED Lighting in Polyhouses

Protected cultivation is rapidly expanding in India, covering over 70,000 hectares under polyhouses and net houses (NHB, 2023). However, conventional lighting and heating in polyhouses are energy-intensive. The use of energy-efficient

LED lights enables longer photoperiods for crops like cucumber, capsicum and lettuce, resulting in higher productivity and improved quality (Rao et al., 2022). LEDs consume up to 60% less energy than traditional lamps and can be powered by solar panels, further reducing the carbon footprint of protected vegetable production (Choudhury et al., 2023).

Table 2. Reduction in Post-Harvest Losses by Solar Dryers

Vegetables	Traditional Loss (%)	With Solar Dryer Loss (%)
Onion	25	10
Tomato	20	8
Chili	22	9
Leafy Greens	30	12

Large scale greenhouse LED lighting layout

Biogas from Vegetable Residues

India generates over 50 million tonnes of vegetable waste annually, much of which is either dumped or left to rot, releasing methane into the atmosphere (FAO, 2023). Biogas technology provides a circular solution by converting this waste into renewable energy and nutrient-rich slurry. Vegetable market waste such as cabbage leaves, tomato rejects and pea shells can be fed into biogas digesters to produce methane for cooking and electricity (Singh et al., 2021). The slurry by-product serves as an organic fertilizer, reducing dependence on chemical inputs. Studies show that adopting biogas plants in vegetable clusters can reduce methane emissions by 30–40% while meeting household energy needs (Das et al., 2022).

Wind Energy and Hybrid Models

Wind power, though less explored in vegetable farming compared to solar, has great potential in coastal and plateau regions of India. Small-scale wind turbines can supplement farm energy requirements for irrigation, cold storage and greenhouse operations (Mishra et al., 2020). Integrating wind with solar systems ensures a hybrid energy model, providing round-the-clock power availability. This hybrid approach minimizes reliance on grid electricity and diesel, thereby lowering the farm's carbon footprint and improving long-term sustainability.

Benefits and Carbon Footprint Reduction

Integrating renewable energy into vegetable farming offers multiple environmental and socio-economic benefits. It reduces greenhouse gas emissions by displacing fossil fuels, enhances energy security and brings down production costs. For example, replacing a 5 HP diesel pump with a solar pump can save around ₹50,000 annually in fuel costs while avoiding significant CO_2 emissions (Gupta et al., 2023). Similarly, solar dryers and LED lights enhance quality and shelf life of produce, thus improving farmer income. Biogas plants transform waste into valuable energy and organic manure, creating a circular economy model. Together, these interventions make vegetable farming more resilient, climate-friendly and sustainable (Patra et al., 2022).

Indian Success Stories

Maharashtra: Farmer groups in Nashik have adopted solar-powered cold storages for onions and tomatoes, reducing spoilage by 30% and saving on diesel costs (Sharma et al., 2022).

Odisha: Pilot projects on solar dryers in tribal belts for leafy greens have increased women farmers' incomes by 25–30% (ICAR, 2023).

Gujarat: Large-scale use of solar pumps under PM-KUSUM has made vegetable irrigation independent of erratic electricity supply (Kumar et al., 2021).

Karnataka: Vegetable markets in Bengaluru are using biogas plants to process unsold residues into cooking fuel for canteens (Das et al., 2022).

Conclusion

Renewable energy integration in vegetable farming represents a transformative step toward achieving low-carbon agriculture. Solar pumps, solar dryers, LED-based protected cultivation and biogas plants not only reduce greenhouse gas emissions but also improve farm profitability and resilience. However, challenges such as high initial investment, lack of awareness and inadequate technical support remain. Policies must focus on financial incentives, capacity building and community-based renewable energy models to encourage adoption.

As India moves towards its net-zero carbon target by 2070, renewable energy-driven vegetable farming will play a vital role in achieving sustainable intensification, ensuring food security and protecting the environment (FAO, 2023; ICAR, 2023).

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