Transitioning to Green Energy-Based Farm Mechanization through Agrivoltaics

Abstract

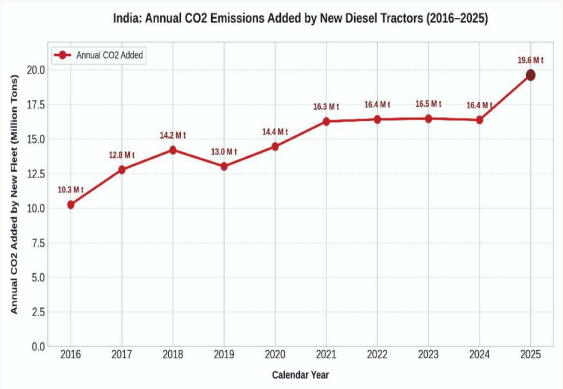
The transition toward green energy-based farm mechanization is a critical imperative for sustainable agriculture, driven by the dual pressures of climate change and rising fossil fuel costs. Agrivoltaics (Agri-PV) the strategic integration of solar energy generation and crop production offers a transformative pathway to **decarbonize farm operations** while optimizing land-use efficiency and **resource productivity.** By integrating clean energy into the agricultural value chain, Agri-PV facilitates a shift away from **diesel-dependent systems,** significantly lowering operational overheads, enhancing energy security, and fostering diversified income streams for smallholder farmers. Integrated Farm Mechanization Models drawing on field-level interventions by the BAIF Development Research Foundation across three states, the study illustrates a **"fully solar-powered farming ecosystem"** which utilises net-metering combined with battery storage to support the entire agricultural operations and value chain.

- **Pre-Sowing & Cultivation:** Land preparation via electric tractors and the use of energy-efficient poly house.
- **Precision Management:** Automatic drip and fertigation systems, high-pressure crop sprayers, and real-time data collection through solar-powered automatic weather stations.
- **Post-Harvest & Value Addition:** Inter-cropping operations, transport of agriculture produces, cooling systems, are potential areas in addition with solar dryers, decentralized processing units.
- **System Maintenance:** Semi-automated panel cleaning mechanisms to ensure peak energy generation efficiency.

Different Intervention with Agri PV	Solar + Battery Investment	Annual Saving	Payback period	Annual CO_2 Emission Reduction	Demonstrated at BAIF Rural Innovation Centre (BRIC) – Pune, Maharashtra
Agri PV with Cold Storage	₹10.33 lakh	₹2.7 lakh	3.8 years	14.35 tonnes Per year	
Agri PV with Poly Tunnel 10 kW	₹8.68 lakh	₹2.8 lakh	3.1 years	15 tonnes Per year	
Agri PV with EV Tractor	₹21.80 lakh	₹6.4 lakh	3.4 years	18 tonnes Per year	
Agri PV with Irrigation Pump	₹19.14 lakh	₹5.5 lakh	3.4 years	9 tonnes Per year	

Green jobs for 27 youth and women members

Emission Reduction 56.35 tonnes Per year



Ref. Tractor and Mechanization Association (TMA) - TMA Annual & Monthly Volume Reports.

Mon	EV Tota Cost (₹)	Diesel Total Cost (₹)	EV Saving (₹)	Diesel CO2 (kg)	Solar CO2 (kg)	CO2 Emission reduction (Kg)
Nov-25	11113	57785	46672	1571.82	47	1525
Dec-25	10271	53600	43329	1447.2	43	1404
Jan-26	11086	57650	46564	1567.8	47	1521
Feb-26	11221	58325	47104	1587.9	47	1541
Mar-26	11113	57785	46672	1571.82	47	1525
Apr-26	11710	60755	49045	1660.26	49	1611

Table: BAIF EV Tractor data

Annual Decarbonization Impact: Deploying an **EV tractor within an Agrivoltaics (Agri-PV) system** reduces carbon emissions by **18.25 tons of CO_2 per tractor per year** compared to conventional diesel operations.

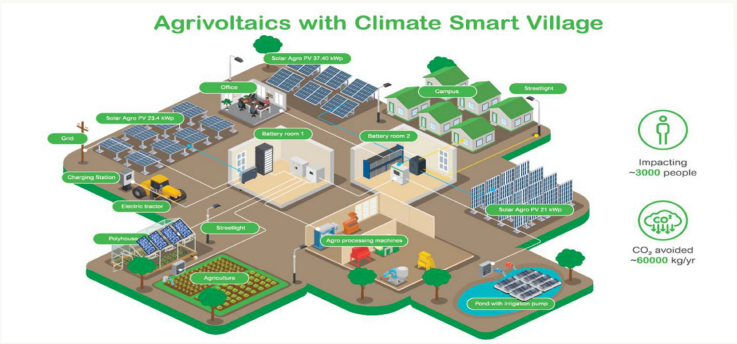
Decadal Climate Abatement Potential: If all domestic tractors sold in India between **2016 and 2025** had transitioned to an Agri-PV–powered EV ecosystem, the **cumulative CO_2 offset potential reaches 149.90 Million Tons Per annum in 2025.**











Successfully powers the complete agricultural value chain including farm mechanization, irrigation, and post-harvest processing while simultaneously supplying clean energy for community lighting and domestic drinking water schemes. Delivers reliable, decentralized clean energy benefiting over **750 households,** establishing a resilient rural infrastructure.

Environmental & Climate Impact: Achieves an immediate carbon reduction of **60 t CO_2e per year** at the village level, demonstrating the broader decadal potential to offset millions of tons of emissions when scaled across Indian farming communities.

The Agri-PV-enabled Climate Smart Village framework proved that green energy-based farm mechanization is both technically viable and economically transformative. Upscaling this model across Indian villages offers a sustainable blueprint to lower operational overheads, ensure energy security, build climate resilience, and accelerate India's transition toward net-zero agriculture

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